CHAPTER VII

ELECTRIC WATER HEATING.

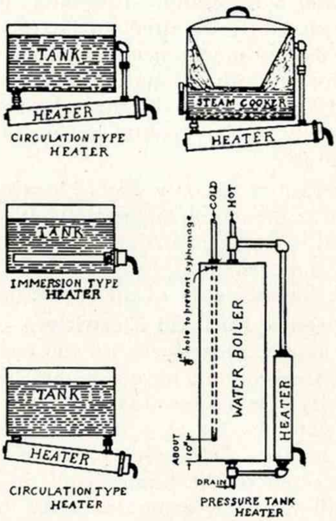
Hot Water a Necessity.—Enormous quantities of energy are constantly required for heating water. In the average home, more energy is used for heating water than for any other domestic purpose aside from that utilized in warming the air. In the industrial field, the operations that require hot water are almost without number.

For generations the only way of heating water has been by fuel combustion methods whereby chemical energy stored in fuel is transformed into heat energy, which is in turn taken up by the water in amounts varying with the efficiency of the apparatus employed.

Comparison of Fuel and Electricity.—As set forth in another chapter, most fuels, on the basis of actual cost of the two mediums, have a higher heating value than electricity. It is possible, however, to operate an electric water heater at a much higher efficiency than a fuel heater. If necessary, the electric heater may be immersed in the liquid itself, in which case practically all the heat generated must be imparted directly to the water. This is impossible with a fuel device which requires that external heat be applied. It is obvious that fuel heat generated on the outside of a tank must lose much useful energy through the chimney and the surrounding atmosphere.

Although it should not be understood that electricity for heating water can compete on a cost basis with the many cheap fuels that are available in most localities, it should be known that it is often possible to so design electrical installations that they will not be more expensive to operate than the less efficient fuel burning devices that are commonly used. This condition is especially true with the smaller installations.

In making comparisons between fuel and electric water heating methods, the many advantages of electric operation, aside from the cost, should be considered. Dirt, smoke, moisture, fumes, and excessive heat are obviated when the electric method is used. The dangers of fire and explosions are done away with. The care and attention required by fuel burning apparatus is eliminated and the only attention necessary is the turning on and off of the current. Some of the electric devices now being constructed are controlled automatically, and therefore demand no attention whatever.



Typical Methods for Heating Water.

Thermal Characteristics of Water.—No other known liquid or solid has as high a specific heat as water. In other words, water has a greater capacity for storing heat energy than an equal weight of any liquid or solid raised an equal number of degrees in temperature. Its capacity for storing heat may be considered analogous to that of a sponge for absorbing water.

After the boiling point of water is reached, steam begins to be generated and unless the water is heated under pressure, it no longer continues to store energy, but gives off the heat with the same rapidity it is taken up.

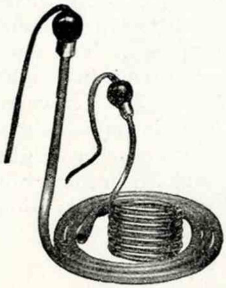
Water, like other liquids, is heated by convection currents set up within the substance itself. Very little of the heating is done by conduction between the individual particles of which it is composed. The convection currents are created by the difference in weight of hot and cold water. Whereas, at 32° F. water weighs 62.42 pounds per cubic foot, it only weighs 59.85 pounds at 212° F. It is this difference in weight that causes the top of a storage tank to become hot before the bottom, and which creates the circulation in the ordinary hot water heating system.

Cutler-Hammer Instantaneous Water Heater.

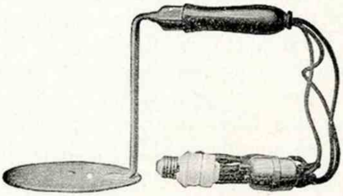
Electric Energy Required for Heating Water—Assuming the weight of water to be 8.3356 pounds per gallon it may be calculated that one kilowatt hour of electric energy will raise 409.33 gallons of water one degree F. or 4.0933 gallons 100° F. If a water heater of one kilowatt capacity be operated at 100 per cent efficiency it would accomplish the following results:

Raise	409.33	gal.	1° F.	in	1	hour	and	consume	1	kw.-hr.
Raise	8.19	gal.	50° F.	in	1	hour	and	consume	1	kw.-hr.
Raise	4.09	gal.	100° F.	in	1	hour	and	consume	1	kw.-hr.
Raise	9823.9	gal.	1° F.	in	24	hours	and	consume	24	kw.-hr.
Raise	196.48	gal.	50° F.	in	24	hours	and	consume	24	kw.-hr.
Raise	98.24	gal.	100° F.	in	24	hours	and	consume	24	kw.-hr.

For ordinary calculations, it is often convenient to remember that one kilowatt of capacity will raise about 100 gallons of water 100° F. in twenty-four hours.



Simplex Coil Type Immersion Heaters.



Westinghouse Disc Type Immersion Heater.

Utilizing Waste Energy.—The energy utilized in heating water is expended in two ways. A certain percentage is required to supply the losses of heat which take place on account of radiation, convection, and conduction from the heater, piping system, and storage tank. Energy, so expended, cannot be utilized in any other way and is entirely wasted. The balance of the heat energy generated may be called the useful energy, as it alone affords the user his supply of hot water. It is therefore apparent that every possible effort should be made to so design a water heating installation that the losses will be reduced to a minimum, and in that way utilize the waste energy. This purpose is usually accomplished by covering the pipes and tank with material of low heat conductivity—a process generally known as lagging.

Heat Losses.—Authorities vary in their estimates of heat losses from metallic surfaces, between 1.5 and 3 B.t.u. per square foot per Fahrenheit degree difference in temperature per hour. The loss is naturally greater from dark, rough radiator surfaces than from the brighter and smoother ones of galvanized iron tanks and pipes. For ordinary water heating calculations it has been found safe to figure a loss of 0.6 of a watt (approximately 2 B.t.u.) loss per square foot per Fahrenheit degree difference of temperature per hour.

The tremendous amount of heat that is lost from surfaces of exposed water tanks and piping systems is seldom appreciated. It may be assumed, for instance, that a 24 gallon tank of water having an exposed area of 14 square feet, is to be maintained at a temperature of 100° F. above that of the surrounding atmosphere. The energy that would be required to maintain such a temperature, provided no water was drawn off, would be approximately:

$$14 \times .6 \times 100 = 840 \text{ watts.}$$

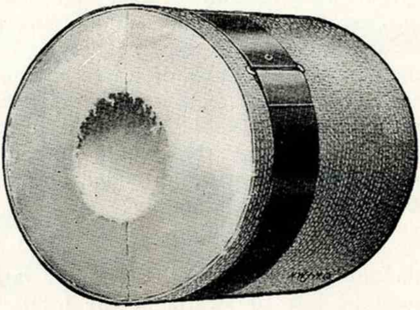
If this tank were heated with a one kilowatt heater there would be but 160 watts of the total capacity available for supplying hot water at the required temperature. In this instance, the energy produced by the 840 watts of the heater capacity would be lost and only 160 watts capacity utilized.

Efficient Lagging Essential.—Had this tank been covered with some form of lagging material of low heat conductivity, having an efficiency of say 85 per cent, the capacity required to maintain the desired temperature would have been:

$$14 \times .6 \times 100 \times 15\% = 126 \text{ watts.}$$

It is thus apparent that the energy produced by only 126 watts capacity could be lost, whereas, the remaining 874 watts capacity could be utilized for heating water to the required temperature. The operating efficiency of the unlagged tank installation would be 16 per cent, whereas it would be 87.4 per cent efficient when lagged in the manner assumed.

Table 1 indicates the number of gallons of water that can be delivered per day at a temperature 100° F. above that of the water supply and of the surrounding atmosphere with various installations. The figures are based on the use of seven different standard sized tanks and six different capacity heaters. The daily output is computed, first with the tanks unlagged, second with a 50 per cent efficient covering applied, and third with an 80 per cent efficient covering applied. Other losses than those from the surfaces of the tanks are not considered.



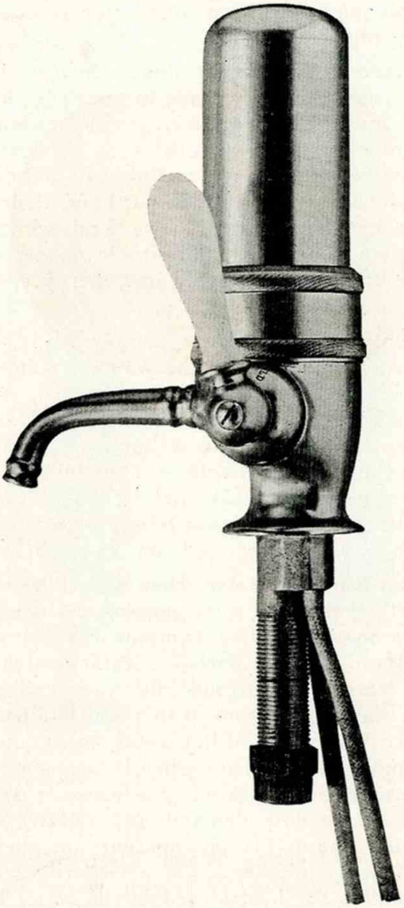
J. M. Magnesia Sectional Pipe Covering.

TABLE 1.

Gallons of Water per day—100° F. Temperature Rise.

Heater Capacity in Watts	Tank Dimensions and Capacities.							
	Gallons Capacity.	18	24	30	40	66	82	100
	Dimensions.......	12″x3′	21″x4′	12″x5′	14″x5′	18″x5′	20″x5′	22″x5′
	Area in Sq. Ft...	11	14	17.25	21.3	27	30.5	34
750	Unlagged	9	..	..	..	..	..	..
	Lagged 50% Eff.	42	33	23	11	..	..	..
	Lagged 80% Eff.	62	58	54	49	43	38	34
1000	Unlagged	34	16	..	..	..	..	..
	Lagged 50% Eff.	67	58	48	36	19	9	..
	Lagged 80% Eff.	88	83	79	74	68	63	59
1500	Unlagged	84	66	46	22	..	..	..
	Lagged 50% Eff.	117	108	98	86	69	58	48
	Lagged 80% Eff.	137	133	129	124	118	113	109
2000	Unlagged	...	116	97	72	38	17	..
	Lagged 50% Eff.	...	158	148	136	119	109	98
	Lagged 80% Eff.	...	183	179	174	168	163	159
3000	Unlagged	...	...	197	172	138	117	96
	Lagged 50% Eff.	...	...	248	236	219	209	198
	Lagged 80% Eff.	...	...	279	274	268	263	259
5000	Unlagged	...	...	...	372	338	317	296
	Lagged 50% Eff.	...	...	...	436	419	408	398
	Lagged 80% Eff.	...	...	...	474	468	463	459

Methods of Heating Water Electrically.—There are two general methods of heating water that have come into general use—the instantaneous method and the thermal storage method. The former makes use of special devices which heat the water as it passes from the faucet and which are not connected at other times. The latter method, as the name implies, is used



United Sales Hot Water Faucet.

for heating water and storing it for future use in a tank or reservoir.

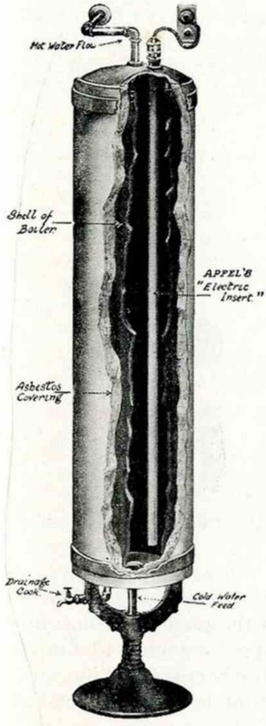
Two types of heating devices are commonly used with thermal storage systems—the immersion type, and the circulation type. The former is usually inserted in the tank, whereas the latter is connected with pipes outside the tank.

Instantaneous Water Heating.—Devices for this class of service are usually made to attach to the ordinary water faucet. They are convenient for many purposes where only small quantities of hot water are needed. As it is possible for one kilowatt to heat only about 4 gallons of water 100° F. per hour, their use is naturally somewhat limited. The load which they create is often considered undesirable on account of the high demand and relatively low energy consumption.

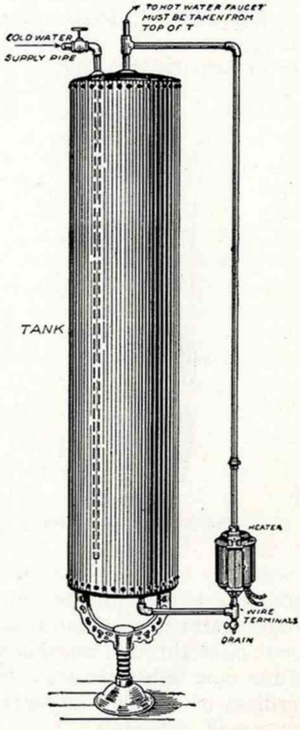
Instantaneous heaters are usually made with a resistance coil around which the water circulates, and which is connected when the faucet is opened. Another device, however, consists of a hollow cylinder and core of graphite. When the water flows around the core inside the cylinder it acts as a conductor and the flow of current set up causes heat to be generated in the water itself. In other words, the water is heated in the same way as in the common water rheostat.

Thermal Storage Water Heating.—The thermal storage method is more often employed than the instantaneous method. The equipment must consist of at least two essential parts—a water heater and a containing vessel for storing the water after it is heated. With an equipment of this kind the user may store up a large quantity of hot water slowly and draw it off as rapidly as he wishes when it becomes heated. The load created by this kind of a heater is desirable on account of its low demand and relatively high energy consumption. It is apparent, on the other hand, that such equipments are necessarily wasteful of energy unless the heat stored in the water is conserved.

Immersion Type Heaters.—The heating of water or other liquids is accomplished with these devices, by the insertion of resistance elements in them. Many types of immersion heaters have been developed. Some



Apfel Immersion Tank Heater.

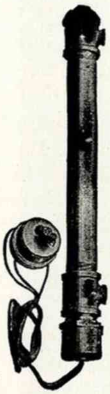


Coin Circulation Tank Heater.

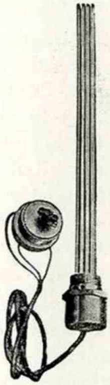
consist of open coils and others of hermetically sealed tubes. Some are constructed for use in open vessels, and others are provided with fittings for attaching them to closed tanks.

The essential advantage of this type of heater, for thermal storage water heating, is that the device must give off practically all its heat to the liquid. Energy can only be dissipated indirectly from the water and surface of the containing vessel or directly by conduction through the metallic fittings.

Circulation Type Heaters.—It is customary, though not essential, to mount a circulation type heater outside the tank or reservoir. A pipe leading



Westinghouse Circulation Heater.



Westinghouse Immersion Heater.

from the bottom of the containing vessel carries the colder water to the heater. As the water becomes hotter it rises through another pipe connected to the top of the containing vessel. This process continues, regardless of whether any pressure is applied, until all the water is heated.

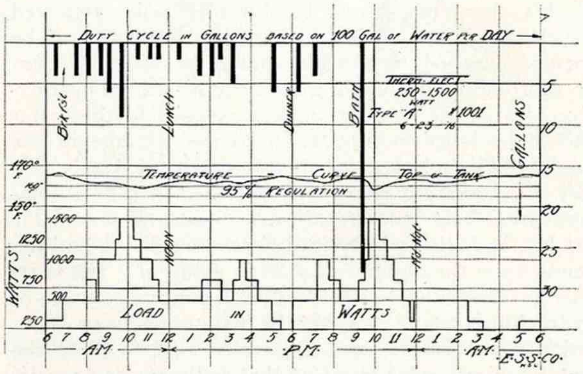
Circulation heaters are available in many styles, forms, and sizes. The Westinghouse heater consists essentially of a waterproof bayonet element, inserted in a metal casing, and designed so that the water circulates around the heating element inside the casing. The Simplex, General Electric, and many other types of circulation heaters, are made up of resistance wire wound around hollow tubes through which the water passes. The Coin Machine heater is of the induction type, and so designed that the passage of current through copper wires surrounding an iron core creates eddy currents in the iron and causes it to heat. The advantages of the induction type heater over the resistance types are its rugged construction and its capacity for running dry without burning out when the water supply is cut off. The present designs of induction heaters, however, create a relatively low power factor load, averaging about 80 per cent.

The attractive features about the circulation type heaters are the ease with which they may be attached to any tank or containing vessel, and the facility with which they may be removed for repairing or cleaning. The water, furthermore, is delivered to the top of the tank as it is heated and is soon ready for use even though only a portion of the tank may be heated when the water is wanted. The great disadvantage is the extra radiating surface the heaters and pipes present, and the additional, though relatively small, heat losses that must inevitably result.

Essential Features of a Water Heater.—A device of this character should be durable, easily removed for cleaning or repairing, and readily controlled. The surface exposed to the air should be of small area or thoroughly insulated from heat losses. The relative area of the heating surface exposed to the water should be large in proportion to the wattage of the heater. Air bubbles and deposits will inevitably collect if the heating element is operated at a high temperature. The amount of scale which forms inside the heater varies widely in different localities, and depends upon the amount of salts in solution. The scale may be chipped off or removed with a dilute solution of hydrochloric acid. In either the instantaneous or circulation type heaters, it is generally best to have the water passage quite large, so that sediment or deposits will not obstruct the flow. It is sometimes desirable to restrict the flow of water through a circulation heater in order that it may rise to a higher temperature as it passes. This may be done by making the passageway smaller or by mounting the heater somewhat higher than the bottom of the tank. Water heaters that create low demands and are required for long hour use are generally considered more desirable load builders than those constructed for high demands and short hour use.

Automatic Temperature Control Devices.—Where it is desirable to keep a supply of hot water available for use at any and all times or to maintain water at a certain temperature for various purposes, automatic temperature control devices have a wide field of application. Electrical apparatus lends itself particularly well to automatic control, but the possibilities it naturally affords are as yet little understood. Any device of this kind that will cut off the current supply immediately a certain predetermined temperature is attained will be a wonderful convenience, and a great economizer of energy. Its general application cannot but improve the diversity factor of central station loads.

Devices of this character should be simple, durable, easily repaired, and readily adjusted.



Performance Curves Therm Elect Water Heater.
Temperature and Load Regulation, 24 hrs.

Explanation of Temperatures and Load Regulation Curves of Therm-Elect 1500-watt Water Heater.

The above curves were plotted from observations taken on the 24-hour operation of a 1500-watt thermally-controlled Therm-Elect Immersion Heater installed in a standard 30-gallon kitchen boiler.

The heavy black lines extending from the top of the chart are a graphic representation of the hot water duty-cycle imposed upon the heating system in a household using 100 gallons of 116 degree F. water per day.

The length of each line is in proportion to the gallons of water drawn at the time indicated by its position; covering the day from the preparation of breakfast at 6:30 a. m. through the bathing period from 9 to 10 p. m.

The curve in the center of the chart indicates the temperature regulation of the water drawn from the tank, and represents a regulation of 95 per cent for the immersion heater.

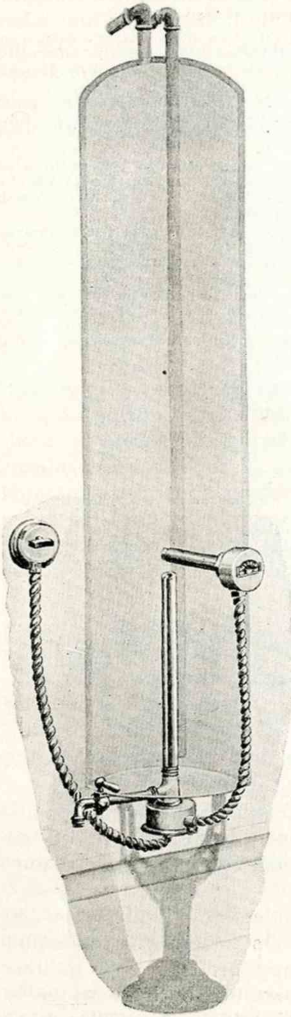
The load curve produced by the six-point thermal control is shown at the bottom of the page, with its peaks at 10 a. m., 3 p. m. and at 10 p. m., and its valleys at 6 a. m., 12 noon and 6 p. m., indicating the diversity which would be obtained with respect to a cooking load operating in combination with the thermally-controlled water-heater.

Automatic Time Control Devices.—Many companies are in position to supply energy during off peak hours at lower rates than during the period of maximum load. The building up of such loads by means of thermal storage water heating apparatus, operated with time control devices, has probably not been given the attention heretofore that it will receive in the future. The loads that could be created would prove enormous.

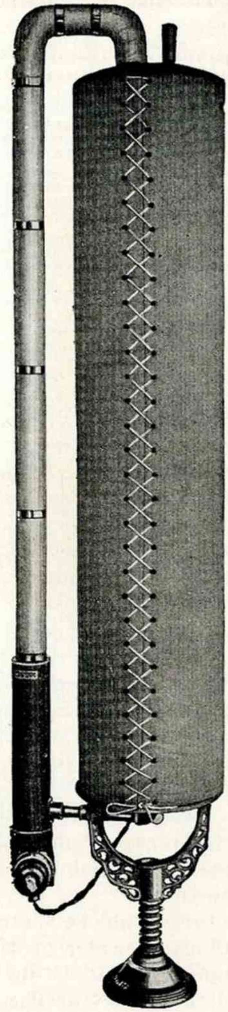
An equipment of this kind naturally requires larger water storage facilities than one that may be supplied with energy at any and all times. The additional storage necessary will depend on the number of hours during which the energy will not be available and upon the quantity and temperature of the water needed.

Average Hot Water Requirements.—Many individuals have little conception of the amount of hot water required for either domestic or commercial purposes.

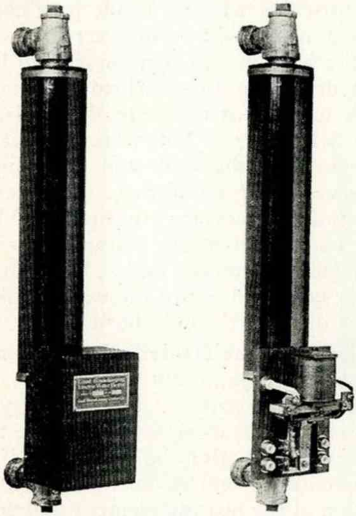
It should be clearly understood that when 30 gallons of water at 150° F. is mixed with an equal quantity at 50° F. the temperature of the 60 gallons will be 100° F. The temperature of bath water is usually about 98° F., whereas 120° F. is scalding temperature. It is therefore apparent that if a relatively



"Therm Elect" Immersion Heater and Thermostat.



Hughes Circulation Heater Applied to Tank small quantity of water is heated to a high temperature, it will afford a considerably larger amount when diluted with cold water for ordinary use. The hot water requirements of hotels, restaurants, barber shops,



Good Housekeeping Automatic Temperature Control Circulation Water Heater.

and other commercial users is generally underestimated, and it is advisable to give each proposed installation careful preliminary consideration.

Installation of Thermal Storage Water Heaters.

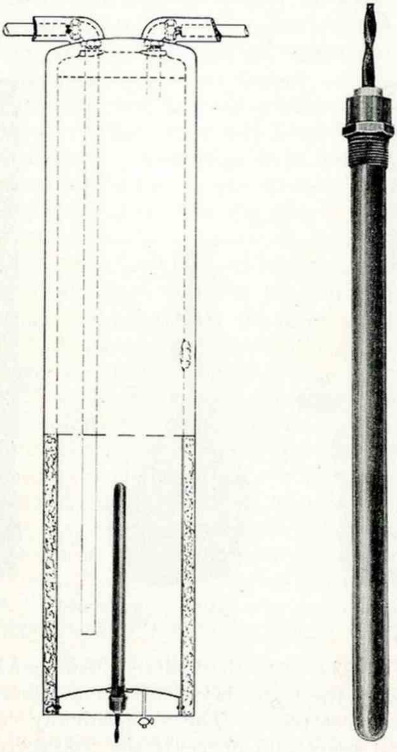
Correct Plumbing Essential.—The relative position of the tank and heater, the connections between the two, the size of tank and pipe used, the elimination of air pockets, and many other plumbing features are worthy of serious consideration when a thermal storage water heating system is installed.

The tank used with equipments operated under pressure should be mounted vertically to insure maximum difference in temperature between the top and bottom, to obviate mixing the hot and cold water when the supply is drawn off rapidly, and to create better circulation of water through the heater. Standard tanks are usually fitted with two taps at the top. The tap used for connecting the tank to a water main should be provided with an inside pipe connection so that the cold water will be delivered to within a few inches of the bottom. It is necessary to have a very small hole drilled in this vertical pipe near the top of the tank to prevent the water being drawn out by syphonage whenever a hot water faucet is located below the level of the tank and a possibility exists of the pressure being withdrawn. Instances of where this precaution is necessary are often found in country residences when the domestic water supply is furnished from a pressure or storage tank. It is obvious that if the water is syphoned out of the water tank the heater will become dry and possibly burn out.

Installation of the Heater.—Immersion type heaters are usually, though not necessarily, inserted in the bottom of the tank. Circulation type heaters should be installed as close to the storage tank as possible. Better circulation will obtain if they are mounted vertically, and in such a position that the lower portion of the heating element will not be higher than the bottom of the tank. Rapid circulation is not always desirable, however, as the water passing through may not take up enough heat to produce the desired difference in temperature between the top and bottom of the tank.

Pipe Connections.—Circulation type heaters should be connected with pipe unions to permit of their quick and easy removal for inspection, cleaning, or repairing. Unless an electric heater is of extremely large capacity in proportion to the size of the storage tank, its upper end should be connected either to the hot water outlet or to a special tap near the top of the tank, rather than to the standard side outlet usually provided. If the hot water coming from the heater is delivered at or near the top, rather than at the side, it will be found that the circulation will be better and that a quantity of hot water can be drawn from the tank much more quickly than otherwise.

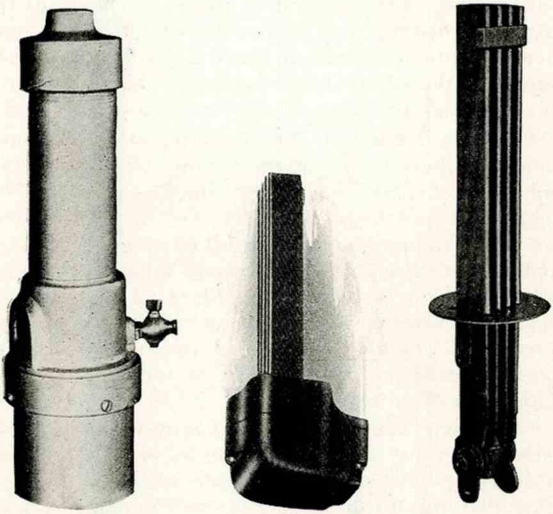
By-Passing.—The pipe connections at the top of the tank should be carefully arranged. The hot water distribution pipe should lead straight out of the tank, and the connection from the heater should connect to



Epco Immersion Heater showing Application to Tank.

it from the side as close to the tank as possible. If this precaution is not taken the water drawn out through the distribution pipes may come partially from the top of the tank and partially from the bottom on account of the rapid suction of cold water through the heater. The action produced is somewhat similar to that in an ordinary atomizer and is called by-passing. Some manufacturers recommend the use of special "non-by-pass tees" to entirely obviate this difficulty.

Air Pockets.—Unless the plumbing is properly done and the hot water distribution pipes are free from air pockets, unsatisfactory operation is likely to be



Cutler-Hammer Circulation and Immersion Type Heaters showing Form of Heating Elements.

charged to the electric heater. Air pockets are formed when the water is carried up and finally delivered at a lower point. The air gradually collects at the highest point and prevents the passage of water. The only relief from such a condition is the placing of an air cock at the highest point, or a rearrangement of the piping system.

Design of Distribution System.—The arrangement should be such that the storage tank will be situated as near as possible to the central point of distribution. Connections between the tank and faucets should be made by the shortest routes, and the pipes should not be larger than is absolutely necessary for satisfactory service. The longer and larger the pipes that are used, the greater will be the loss through radiation from their surfaces.

So-called "return systems," wherein hot water is allowed to circulate continuously from the top of the tank, through the distribution pipes, and back to the bottom of the tank, will be found to require much more energy for their operation than ordinary systems, on account of the constant heat losses that take place from the surface of the pipes.

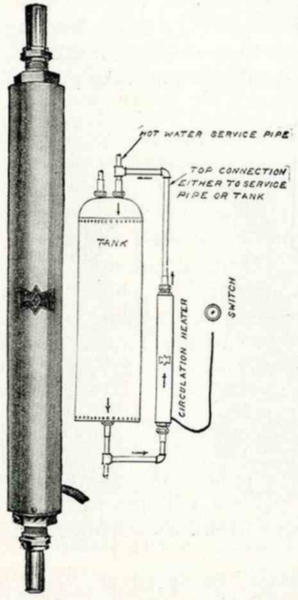
Storage Tank and Pipe Lagging.—As heretofore suggested the proper lagging of tanks and piping systems is often of as much importance as provision for adequate heater capacity. The kind of material employed should be carefully considered and the most approved methods of application adopted. Unless good lagging is used and properly applied, the operating efficiencies of the heating system may be greatly impaired. A few of the commonly known types of lagging materials are described and the methods of application outlined.

Keystone Tank Cover.—This form of lagging consists of a 3/8 in. layer of compressed hair felt having an asbestos lining, and a canvas cover. Experiments show that this form of lagging will prevent at least 50 per cent of the usual radiation losses from the sides of an exposed tank.

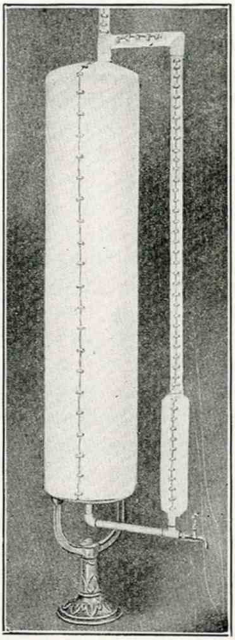
Keystone covers should be laced tightly. The upper edge of the cover should be allowed to project at least half an inch above the side edges of the tank. The top of the tank should then be covered with a half-inch layer of cement and pasted over with six-ounce drill.

Economy Tank Covers.—The Johns-Manville Economy tank covers are made up of 1 in. hair felt lined with asbestos and covered with a canvas jacket. They are designed to fit the standard water tanks. The top and sides are in one piece and may be laced tightly around the tank. A rope wrapped temporarily about the jacket will hold it in place and make the lacing much easier.

When the tank is exposed the canvas jacket should have a coat of sizing and be painted with two coats of cold water paint or lead and oil.



Simplex Heater and Standard Pipe Connections.



Economy Covering Applied to Tank and Pipes.

The manufacturers claim an efficiency for this form of lagging of from 85 per cent to 90 per cent. Although Economy covers cost about twice as much as Keystone covers the increased savings which they effect warrant their use.

Directions for Lacing Tank Covers.—Start lacing at the top of the cover. Tie the end of the lace to the right hand eyelet and thread it over to the opposite eyelet. Make two loops and then lace diagonally under the cover to the eyelet below the first and make two loops. Repeat the process until the last pair of eyelets is reached and then make three loops. Lace one of these loops back and tie it to the lace end by means of a bowknot beneath the cover.

Block Lagging.—Many forms of heat insulating blocks for lagging the larger sized tanks are available. One inch thickness is usually recommended for water tanks and the insulating efficiencies may be figured at from 80 per cent to 90 per cent depending upon the material used and the care with which it is applied. The blocks usually come in strips about 6 in. wide and 3 ft. long.

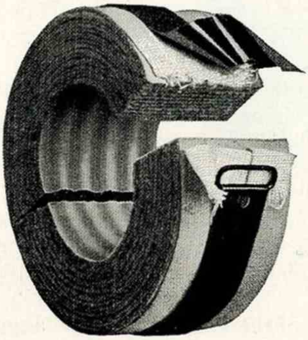
For lagging the sides of a small tank the blocks are usually cut in strips about 3 in. in width so that they will more nearly conform with the surface contour. These strips are then placed around and lengthwise of the tank and held in position temporarily with a small rope. The blocks are allowed to project about 1½ in. over each end of the tank to conform with the top and bottom lagging. Soft annealed wire (about No. 16 gauge) is then wound around the blocks and tightened up so as to hold them firmly in place. The blocks are then beaten down into shape with a wood paddle or mallet so that no air passages may be left between the covering and the tank.

Cement is then mixed with water to about the consistency of ordinary mortar and applied to the outside about ½ in. in thickness by means of a trowel. All cracks and crevices should be filled, and the surface made smooth and even. A six-ounce drill jacket is then pasted on the outside. Flour and water may be used for paste. The salvage edges of the drill should be torn off, before it is dipped in the paste, to prevent puckering.

The ends of the tank are usually lagged with small blocks wired in position (when possible), pounded down, coated with cement and a drill cover pasted on in a similar way to that suggested for the sides. When the tank is convex at the bottom or so mounted that the blocks cannot be placed in position, a coating of soft cement is put on the surface of the tank first. The blocks will then adhere to the outside while the next coating of cement is trowelled over them and the covering is put in place.

Pipe Lagging.—A large variety of coverings are available for lagging pipes and fittings. Sectional pipe covering which may be hinged over, pasted together by means of a lap in the canvas jacket, and held secure with brass bands, is most commonly used. It may be secured in thicknesses varying from ½ to 3 inches, but for water piping, 1 in. thickness is ample. It is usually made up in 3 ft. lengths. The savings in heat that may be effected by the careful lagging of pipes and fittings are enormous. Fifty feet of 1 in. pipe for instance, has approximately the same area as a thirty gallon tank, and filled with water at the same temperture, will radiate heat just as rapidly.

It is of the utmost importance that the pipe leading from the heater to the top of the tank should be lagged when water is heated by the circulation method. The water circulates constantly in this portion of the system as long as the heater is in service.

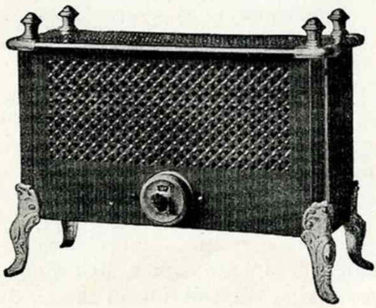


J. M. Asbestocel Sectional Pipe Covering.

CHAPTER VIII

ELECTRIC HEATING OF BUILDINGS.

Use and Advantages.—Were it possible to heat buildings with electricity at no greater cost than with combustion methods, it would be only a matter of time until they would all be heated electrically on account of the many superior advantages afforded. The present high cost of generating and distributing electric energy, however, precludes its universal application as a substitute for fuel heat. It is only in localities where fuel is very costly, or where electricity may be used for heating during off-peak seasons or off-peak hours, that extensive use may be made of it as an

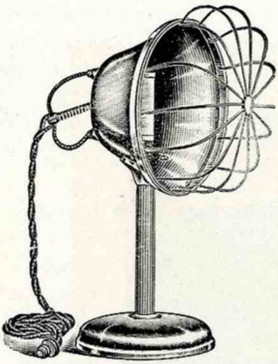


Westinghouse Convection Heater.

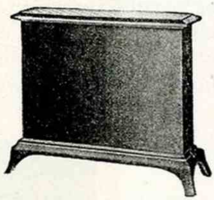
air heating medium. In some sections of the west, where water power is used extensively for irrigation pumping in the summer, it has been applied during the winter season to the heating of buildings with considerable success. The energy so used, which might otherwise be wasted, is turned into a useful by-product and sold at a low rate in competition with coal and other fuels, at the same time netting the central stations a small profit.

Some attention has also been given to the development of electric heating systems designed to make use of the great heat storage capacity of water, and so arranged as to heat large quantities of it during off-peak hours for use in warming buildings. Where conditions are favorable this method should find a wide application.

In a general way it may be stated that electric energy is too costly to compete with ordinary fuels, but where the cost of heating a building is a relatively unimportant item in comparison with the desire for



Majestic Radiant Heater.



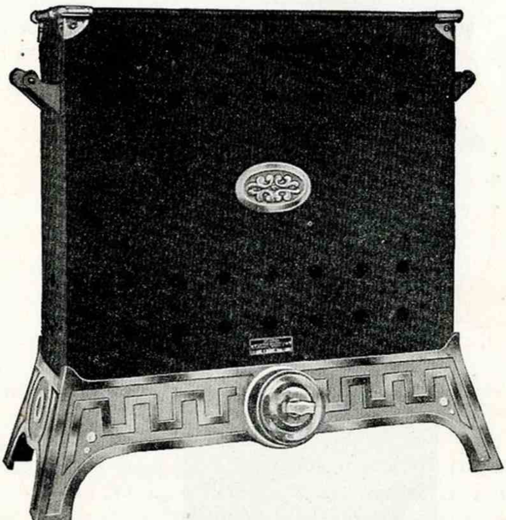
General Electric Convection Heater.

convenience, it is certain to meet with favor. For heating small offices, bath rooms, sick rooms, cold corners, and for taking the chill out of the air during mild weather its use is ideal.

Electricity has the peculiar advantage of being instantly available, and regulated at will. It neither destroys oxygen nor vitiates the atmosphere. It is the cleanest and safest known method of heating. Among the advantages of electric heaters, are ease of installation, simplicity of operation, portability, flexibility of location, and small floor space required.

There are certain customers in nearly every locality that are willing to pay for the luxury afforded by electric heat, regardless of its cost, provided its advantages are made known to them. These individuals, in most instances, may be readily singled out and desirable business secured with little effort.

Comparative Cost of Fuel and Electric Heat.—It should be understood that electric air radiators always operate at 100 per cent efficiency, whereas coal and gas apparatus may often operate at efficiencies as low as 10 per cent. By referring to the comparison of costs of fuel and electric heat set forth in Chapter I, it will be noted that 600 B.t.u. gas at $1.00 per thousand cubic feet operating at 20 per cent efficiency is about equivalent to electricity at 3 cents per kilowatt hour.

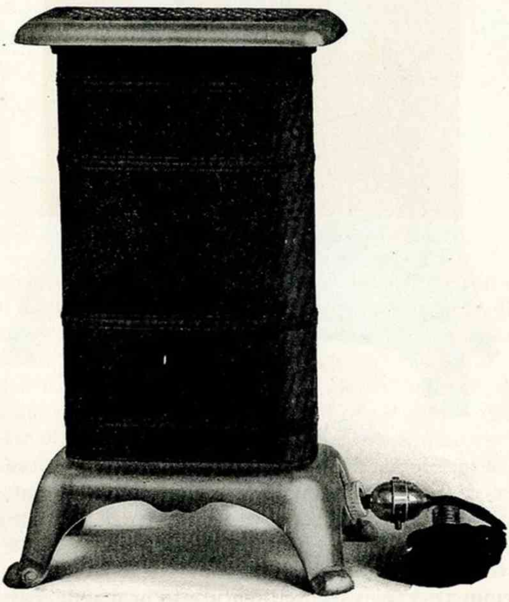


Hughes Convection Heater.

Electric Heating Systems.—A large variety of systems of electric heating are in use, but few data are available to show their relative efficiencies and merits. On the assumption that the application of electricity to the heating of air is 100 per cent efficient, it is obvious that the essential feature to be considered with each system is the proper distribution of the heated air. If the heat is intense near the heater or radiator and other parts of the room are cold the results will not be satisfactory. It is essential, therefore, that the system employed should not only heat the air but should set up convection currents that will serve to distribute it. The size, type, operating temperature, and design of the heaters have much to do with this particular feature.

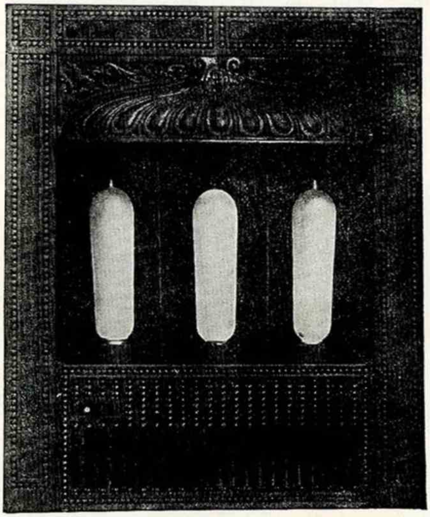
The commonly known methods of electric heating are (1) by radiant heaters, (2) by convection heaters, (3) by oil and water radiators, (4) by indirect air heating systems, and (5) by steam and hot water circulation systems.

Radiant Heaters.—Radiant or luminous type heaters are made in a variety of styles and sizes. The heat-



Estate Convection Heater.

ing elements may consist of coils of exposed wire or filaments within glass globes, which are heated to a glowing temperature. The units are usually mounted in front of polished reflectors which focus the heat in any desired direction. Some radiant heaters are man-



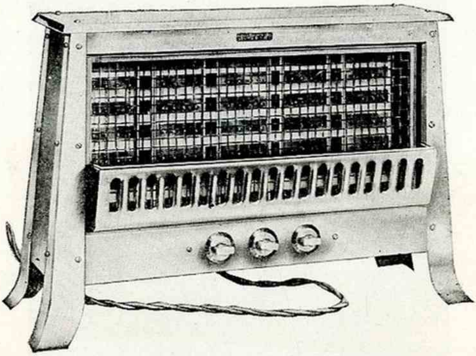
Westinghouse Flush Type Radiant Heater.

ufactured in small portable sizes, whereas others are made for use in open fireplaces or for flush wall mounting.

The heat from glower type radiators is like sunshine in that it only raises the temperature of a body which is opaque to heat waves. It passes through the air without heating it perceptibly, and only causes a rise of temperature in the air by heating objects that offer opposition to its passage, these objects in turn heating the air in contact with them by conduction.

Heat waves are unaffected by air currents and glower type radiators are therefore convenient for warming portions of the body or for warming a person in a large open space. The light, cosy glow which they emit makes these heaters very attractive and cheerful in the home or office.

It is often thought that a glow type radiator, in front of which it is uncomfortable to hold one's hands, must be emitting more heat than a resistance type, over which they may be held for any length of time

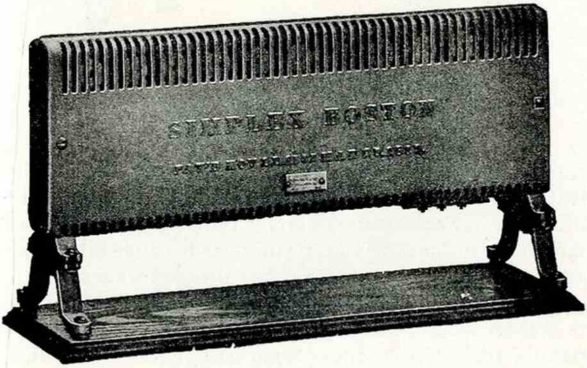


Hot Point Radiant Heater.

without any sense of discomfort. This impression is wrong, because all the energy delivered to any electric heater, regardless of the type, is transformed into heat energy. The glower type heater concentrates the heat by means of polished reflectors, while the resistor type distributes the heat through the air. Uniform temperature throughout a room cannot readily be attained with a glower type heater.

Convection Heaters.—Heaters of this type are also manufactured in a variety of sizes and capacities. They usually consist of coils of resistance wires or ribbons mounted on ornamental frames, surrounded with a sheet metal or cast iron casing, with openings above and below to permit the free passage of air through the coils. The elements are generally designed for operation at temperatures below the red heat. The warmth generated by this type of heater is transferred to the air by direct contact with the hot resistance elements and the surface of the heater. Convection currents are consequently set up which tend to equalize the room temperature. Much depends upon the design of this type of heater, if proper heat distribution is to be attained. The construction should be such as to develop ample circulation of air through the heated coils.

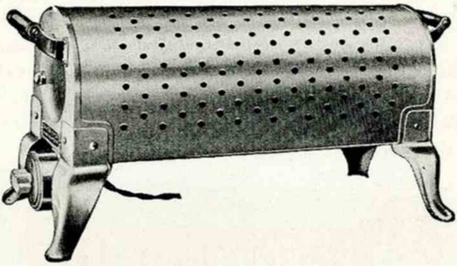
Convection heaters should never be mounted flush with the walls. They should be set a short distance away from the sides of a room. Where this is impossible, guards should be mounted on top of the heaters to deflect the heated air toward the center of the



Simplex Convection Heater.

room. The tops of the heaters should be unobstructed in order to permit free passage of air. Two or more small heaters will always be found to give a better distribution of heat than a single large one. Heaters placed under windows will warm the air admitted to a room and tend to obviate unpleasant draughts. Convection heaters in capacities larger than 750 watts are usually provided with three-heat switches to permit operation at lower temperatures during mild weather.

Oil and Water Radiators.—A large number of oil and water radiators have been placed upon the market. They are usually made in the form of ordinary hot water radiators with the heating elements inserted in the sides and immersed in liquids. Their chief advantage is in the greater radiating surface which they offer to the air in comparison with ordinary convection air heaters. The heating elements being submerged in the liquid operate at low temperatures and are less subject



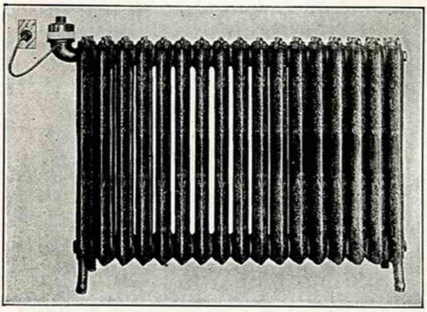
Hot Point Convection Heater.

to oxidation. The water or oil which is used holds the heat for a considerable time after the current is shut off. The oil radiators may be operated at a higher temperature than the water radiators because oil vaporizes at higher temperatures. The disadvantages of this type of heater are the slowness with which it heats up, its greater weight and lack of portability, and its higher manufacturing cost, in comparison with convection heaters.

Indirect Air Heaters.—Radiators which are used to heat the air in a passage or flue which supplies air to a room are called indirect heaters. The radiators may consist of coils of wire or cast grid resistance mounted on a frame work so as to allow free passage of air and placed in a chamber or box at the foot of vertical flues leading to the rooms to be heated. Air is admitted to the chamber from the outside, and after passing through the heated resistance, it is taken directly into the flue. Ventilating fans may be interposed between the heating chamber and the outside in order to increase the volume of air.

Installations of this character in individual capacities of several hundred kilowatts have been in successful service for a number of years. The chief advantages have been found to be a marked saving in floor space, ease of operation, cleanliness, and lack of attention required.

Steam and Hot Water Systems.—Electrically heated steam and hot water systems are similar in every respect to ordinary fuel burning equipment, except that electric steam boilers and water heaters are substituted. A number of installations have been made which have proved very satisfactory. The chief advantages are even heat distribution, ease of operation, freedom from dirt, soot, and ashes, and



Apfel Water Radiator.

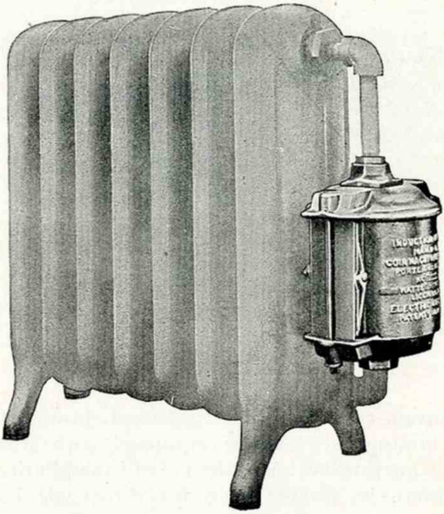
less attention required. It is apparent, however, that unless buildings are already equipped with steam or hot water heating systems, the cost of installation will be considerable greater than for direct air heating systems.

Installation of Electric Heaters.—The use of numerous small heaters of three kilowatts capacity or less, each provided with three-heat switches, creates a better diversity of load for the central station than a few large single heat heaters.

Many concerns require that buildings wired for electric heating shall be provided with 220 volt service in order to prevent the use of lights and lamp socket devices on special heating circuits. Such provision has the further advantages of reducing the costs of wiring and service connections and producing better balanced load conditions.

In making installations of electric heaters of all types every facility should be provided for convenient operation, otherwise the habit of opening windows, rather than turning off the current when the room becomes too warm, will be encouraged.

Calculation of Heat Requirements.—The energy needed to heat a building or an individual room is the sum of the heat required to warm the air for proper



Radiator with Coin Circulation Water Heater Attached.

ventilation and that which is transmitted to the outside and lost. The former varies with the use for which the building is required, and the latter with the nature of its construction, exposure, etc. They both vary with the difference in temperature between the outside and inside of the buildings.

The two most commonly known ways of calculating the heat requirements of a building are (1) by the use of the "B.t.u. method" and (2) by the application of an empirical formula. We shall call the B.t.u. method, the "watt method" because, for convenience, all calculations will be made with watts rather than with British thermal units. The watt method is naturally more accurate, whereas the empirical formula is easier handled. The empirical formula is based on the watt method but is more general in its application. It is convenient for making preliminary estimates.

Watt Method.—Calculation based on this method take into account the heat in watts (1) to heat the air required for ventilation as well as the air which leaks around windows, doors, and various crevices; (2) to supply the losses by transmission of heat to the outside through the walls, windows, floors, and ceilings. The sum of the watts required by a building for heating the air and for supplying the losses will determine the heater capacities.

Heat Absorbed by Air.—One cubic foot of air will absorb approximately 0.0054 watts per hour per degree Fahrenheit difference in temperature. In order to determine the amount of heat required for heating the atmosphere inside a building, it is necessary to multiply the number of cubic feet of air per hour admitted to the building by the difference between the outside temperature and that required within, and by the constant 0.0054.

i.e., quantity of air $\times$ temperature difference $\times$ 0.0054 = watts per hour.

The quantity of air admitted to a building depends upon (1) the ventilation required, and (2) the air leakage. Ventilation requirements may be fixed by law for some classes of buildings and for others the amount is usually fixed by the architects' judgment. The character and habits of the people living in a building also have much to do with its ventilation. The following table gives a fair average of the amount of air that is usually required for various kinds of buildings:

Air Required per Hour for Ventilation.

Hospitals	3000 cu. ft. per bed.
Assembly Halls	2000 cu. ft. per seat.
Factories and workshops	1800 cu. ft. per person.
Churches and Schools	2000 cu. ft. per person.
Offices	1800 cu. ft. per person.
Residences (a) Sleeping rooms	one complete change per hour.
(b) Living rooms	two complete changes per hour.
(c) Halls (with open stairways)	three complete changes per hour.

Heat Lost by Transmission.—The watts loss per square foot of surface per Fahrenheit degree difference in temperature, between the inside and outside of buildings and rooms, as set forth in the following table, seems to be pretty well established by the best authorities:

4-inch brick wall	0.193 watts
8-inch brick wall	0.135 watts
12-inch brick wall	0.093 watts
24-inch brick wall	0.058 watts
Reinforced concrete walls	1.2 x brick constants
Stone walls	1.3 x brick constants
Cement walls	1.5 x brick constants
Walls of frame buildings—plastered and sided	0.150 watts
Plastered partitions—lath and plaster both sides	0.100 watts
1-inch wood partition	0.120 watts
Wooden flooring (double board)	0.025 watts
Fireproof flooring	0.036 watts
Cement flooring	0.091 watts
Dirt flooring	0.068 watts
Wooden ceiling	0.031 watts
Plastered ceiling (no floor above)	0.094 watts
Plastered ceiling (single wood floor above)	0.076 watts
Wooden ceilings under slate or composition roof	0.088 watts
Wooden ceilings under iron roof	0.050 watts
Fireproof ceilings	0.043 watts
Wooden door	0.120 watts
Door 2/3 wood, 1/3 glass	0.170 watts
Single window glass	0.300 watts
Double window glass	0.170 watts
Single skylight	0.355 watts
Double skylight	0.185 watts

To obtain the watts lost by transmission, multiply the areas of the respective surfaces, by the temperature difference between the exterior and the interior of the building or room, and by the wattage constants in the above table.

i.e., area $\times$ temperature difference $\times$ constant $=$ watts transmitted.

Air Leakage.—A careful consideration of air leakage is of as much importance in the design of heating installations as is that of ventilation. The losses of heat on account of air leakage cannot be calculated readily, and are usually estimated. Air leakage simply increases ventilation, and has the same effect, as far as temperature conditions are concerned.

Store and office doors that are opened frequently increase the changes of air inside materially. Crevices around doors and windows permit the leakage of air in amounts varying with their size. Wind pressure has a large effect on the heating of a building, as it forces air inside which has to be heated. Its effect is greatest in poorly constructed buildings. During windy weather, the air in a room on the windward side of many buildings will be found to change as many as four times per hour unless the casings are fitted very tightly.

It has been found that buildings having open elevator shafts, skylights, open staircases, open fireplaces, etc., require more heat than those not having these features. More heat is always required on a mild windy day than on a cold still day. Humid atmosphere makes for greater comfort at lower temperatures, than is usually experienced with dry air.

The leakage losses, due to exposure of a building or room, depend to a greater extent upon the area of exposed walls than upon any other feature of the calculations, and are usually taken care of by adding a certain estimated percentage to the watts lost by transmission through the exposed wall and glass surface.

Factors of Safety.—It is impossible to determine accurately the exact heating requirements of any building, and the designer's judgment must, therefore, be relied upon to a great extent. The following coefficients, however, must always be considered in making up specifications for the heating of buildings or rooms:

Add 10 per cent to 50 per cent to transmission losses from sides exposed to prevailing winds.

Add 10 per cent to 25 per cent to transmission losses when building is heated only during the day.

Add 25 per cent to 50 per cent to transmission losses where building is heated intermittently with long intervals of non-heating.

Empirical Formula.—A vast number of empirical formulae have been developed for rapid calculation of the heating of buildings, but it is thought that the following formula will come closer to meeting the average requirements than most of those in use:

$$\left(\frac{NC}{180} + K\left(\frac{W}{8} + \frac{G}{3}\right)\right)(T_1 - T_2) = \text{Watts capacity.}$$

N = number of changes of air per hour.
C = cubical contents of building.
K = constant depending upon exposure and intermittent character of heating.
W = square feet of exposed wall surface.
G = square feet of exposed glass surface.
T_1 = inside temperature in Fahrenheit degrees.
T_2 = Outside temperature in Fahrenheit degrees.

Values of N:

$$N = \frac{\text{cubic feet of air required per hour for ventilation.}}{\text{Cubic contents of building.}}$$

N = 1 for residence sleeping rooms.
N = 2 for residence living rooms.
N = 3 for residence halls (with open stairways.)

Values of K:

K = 1 where walls are not exposed to prevailing winds.
K = 1.1 to 1.5 where walls are exposed to prevailing winds.
K = 1.1 to 1.25 where walls are not exposed to prevailing winds and building is heated only during the day.
K = 1.2 to 1.75 where walls are exposed to prevailing winds and building is heated only during the day.
K = 1.25 to 2 where building is heated intermittently with long intervals of non-heating.

This formula may be applied to any well constructed frame or brick building. Due allowance should be made for poorly constructed buildings. For use in any particular locality, the above formula may be modified to suit local conditions of temperature and types of building construction.

Application of Methods.—The following example is worked out by both the watt method and the empirical formula to show the application of the two methods of calculating heater capacities:

Assume 15 by 12 by 8 foot corner living room of a residence facing prevailing winds on two sides. The room has 8-inch outer brick walls, two single glass windows each having an area of 15 square feet, and an outer wooden door having an area of 21 square feet. The temperature of the room is to be maintained at 70 degrees F., when the lowest outside temperature is zero degrees F. Other rooms in the house are to be heated to a similar temperature, and the losses through the partitions, floors and ceilings are therefore neglected.

Watt Method:		Watts.
Air	1440 cu. ft. $\times$ 2 $\times$ .0054 $\times$ 70 =	1088
Exposed walls....	165 sq. ft. $\times$ .135 $\times$ 70 = 1560 + 20% =	1872
Exposed windows.	30 sq. ft. $\times$ .300 $\times$ 70 = 630 + 20% =	756
Exposed door.....	21 sq. ft. $\times$ .120 $\times$ 70 = 175 + 20% =	210
Total		3926

Empirical formula method:
Substituting values in formula on p. 128:

$$\left(\frac{2 \times 1440}{180} + 1.2\left(\frac{165 + 21}{8} + \frac{30}{3}\right)\right)(70^\circ - 0^\circ$$

$= $ Watts capacity.

$[16 + 1.2\ (23.25 + 10)\ ]\ 70 = $ watts capacity.
$(16 + 39.9)\ 70 = 3913$ watts capacity.

In order to properly heat the room a 2000 watt three-heat radiator should be installed under each window.

CHAPTER IX

INDUSTRIAL HEATING.

Scope of Application.—The field for the introduction of electric heat for industrial purposes covers a great variety of applications in which direct combustion methods and steam heat are now used. The present status of development is in a way comparable to that of the electric motor about a decade ago. The adoption of electric heat presents the same advantages over the older methods, that the electric drive does over the older methods of transmitting power. In nearly every industrial operation there is a demand for heat. The amount of power required is usually relatively small compared with the demand for heat. Many new industries have been created by the aid of electric heat through processes not otherwise possible. In other industries it has resulted in increased production, improved product, and decreased manufacturing cost.

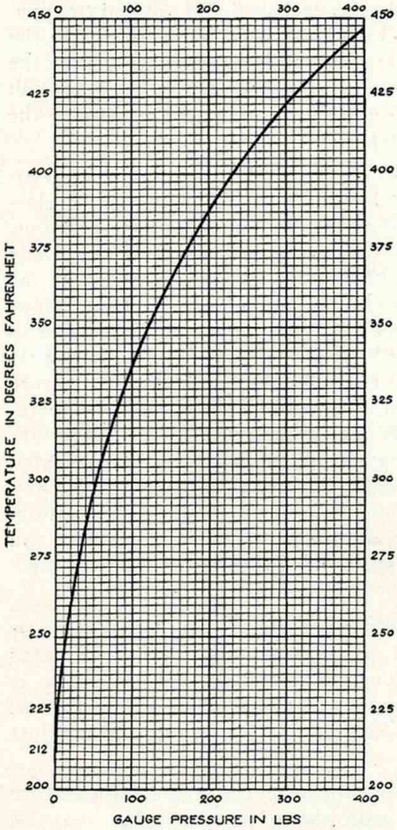
Development of Field.—Only the general exploitation of proven appliances will result in a rational development of the industrial heating field. The adaptation of electric heat to many tools and appliances is apparently a simple proposition; but the economical and efficient accomplishment of a given operation calls for special knowledge comprising science and experience. The effect of correct design and proper application of heating devices upon the future success of the industrial heating business cannot be overestimated. The questions of heat insulation, thermal storage and thermal load factor have an important bearing upon the efficiency and economy of operation that must also be considered. The many cases where heating elements have been purchased and applied to apparatus of various kinds, and results obtained by the crudest methods, are not entirely desirable from the standpoint of rational development, but they furnish ample evidence of the tremendous field existing for the application of electric heat.

Advantages of Electric Heat.—Safety, convenience, flexibility and cleanliness are apparent in electric heating as well as in other electrical applications. Sanitary conditions are improved and labor is made more available and contented. Machines may be placed in the most advantageous positions without regard to the source of heat. Constant losses due to the transmission of heat are eliminated. Wide ranges of temperature for every kind of industrial work are obtained. Uniform, yet easily controlled temperatures which are not readily affected by air drafts are made possible. Any amount of heat may be generated efficiently, at any desired temperature, and under any desired atmospheric conditions. Ease of application, saving of labor and skill, improvement of product and reduction in floor space are other advantages of electric heat.

Comparison with Fuel and Steam Heat.—Gas or other fuels permit application of high temperatures but the heat produced is irregular and the flame is accompanied by soot and fumes which soil the work, and the hot vitiated air affects the health and comfort of the operators.

Steam gives a uniform heat, but the temperature is limited by the safe steam pressure that may be used. The accompanying curve and table shows the gauge pressure required to produce various temperatures in heating devices.

In many industries where steam is required in large quantities for low temperature work, it is found advantageous to use electricity for the high temperature operations. The many objections to the production of high temperature steam in manufacturing establishments are quite obvious.



Temperature Fahr.	Pounds Pressure
376°	172
377	174
378	176
379	178
380	180
381	183
382	185
383	188
384	190
385	193
386	195
387	198
388	200
389	203
390	205
391	208
392	210
393	213
394	216
395	218
396	221
397	224
398	226
399	229
400	232
401	235
402	238
403	241
404	244
405	247
406	250
407	253
408	256
409	259
410	262
411	265
412	268
413	271
414	275
415	278
416	281
417	285
418	288
419	291
420	294
421	297
422	300
423	303
424	307
425	310
426	313
427	316
428	319
429	322
430	326
431	330
432	334
433	338
434	342
435	346
436	350

Curve and Table showing Gauge Pressure of Saturated Steam Corresponding to Increase in Temperature.

Heating Elements.—The more general application of electric heat has been delayed materially by the tendency to call for specially designed apparatus to meet every industrial need, in place of modifying the application to meet the conditions of standardized heat units.

Heating elements have been developed by different manufacturers of heating devices of such dimensions and thermal characteristics as to be readily applicable to many of the ordinary arts and trades. Rectangular, square, and round flat units, tubular cartridge units, and air drying or heating units of many shapes, sizes, and capacities are available for various applications. New alloys, improved electrical insulators of high thermal conductivity, and the more intelligent use of heat insulating materials, have done much to enlarge the possibilities of the electric heating field.

Heating Specifications. In determining the capacities of various industrial heating apparatus it is necessary to secure comprehensive data on the specific apparatus to which electric heat is to be applied, as well as on the actual working conditions which have to be met. The following will illustrate some of the points that have to be considered in industrial problems:

Heating of Water or Other Liquids:

(1) Nature of liquid.
(2) Size and shape of vessel.
(3) Temperature to be maintained.
(4) Time allowed for heating up.
(5) Amount of liquid to be heated.
(6) Material of containing vessel.
(7) Exterior surface of containing vessel (light or dark, rough or polished.)
(8) Cover of vessel.
(9) Kind and thickness of heat insulation.

Heating of Ovens:

(1) Size and shape of oven.
(2) Cycle of heating operation.
(3) Temperature to be maintained.
(4) Weight of material to be baked.
(5) How material is handled.
(6) Duration of process.
(7) Number of bakes required.
(8) Weight of trucks carrying material into oven.
(9) Character of oven insulation..
(10) Diameter and length of ventilating flue.

Electric Furnaces:

(1) Maximum temperature required.
(2) Kind of work to be done.
(3) Character of furnace to be adopted.
(4) Size and shape of chamber required.
(5) Quantity of work to be undertaken.

Branding Irons:

(1) Size and nature of the brand.
(2) Character of material.
(3) Wet or dry material.
(4) Speed required.
(5) Sample of material.

Irons, Glue Pots, etc.:

(1) Weight and size of devices now in use.
(2) Class of work to be done.
(3) Speed required.

Steam Generators:

(1) Feed water temperature.
(2) Pressure desired.
(3) Amount of steam in pounds per hour.
(4) Time allowed for bringing up to pressure.
(5) Dimensions of boiler.
(6) Character and construction of boiler.
(7) Boiler insulation.

Inasmuch as electric energy is ordinarily sold on the basis of maximum demand, as well as on that of energy consumption, it is necessary to design electric heating apparatus for low demand and long hour use, rather than high demand and short hour use. Arrangement for off-peak power consumption is also desirable when conditions will permit.

Apparatus designed with minimum wall surface in relation to content will obviously be more efficient than if made in other forms.

Applications of Electric Heat.—Perhaps the most important application of electric heat is found in the electrochemical and electrometallurgical industries where the electric furnace has revolutionized some manufacturing enterprises and actually created others.

In the metal trades industry electric welding apparatus, melting tanks, soldering devices, oil tempering baths, annealing furnaces, and various types of self heated tools have many proven advantages.

Numerous heating operations in automobile, printing and publishing, paper, laundry, confectionery, and clothing industries, may be performed with a greater degree of satisfaction with electricity than with fuel methods.

The list of heating applications which follows will convey a general impression of the vast extent to which electric heat may be applied in the industrial field:

Heating Applications.

Automobile Factories and Garages:

- Vulcanizers.
- Varnish drying ovens.
- Welding apparatus.
- Hood heaters.
- Foot warmers.
- Rectifier tube boilers.
- Solution tanks.
- Disc stoves.
- Enameling furnaces.
- Soldering irons.
- Branding irons.
- Steering wheel warmers.
- Varnish tank heaters.
- Hardening furnaces.
- Oil tempering baths.

Barber Shops:

- Water heaters.
- Curling irons.
- Sterilizers.
- Cigar lighters.
- Hair dryers.
- Disc stoves.

Beauty Parlors:

- Hair dryers.
- Curling irons.
- Disc stoves.
- Cauterizers.
- Water heaters.
- Die tank heaters.

Boiler Shops:

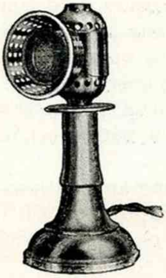
- Welding machines.
- Soldering irons.
- Hardening and annealing furnaces.

Bookbinding Shops:

- Matrix dryers.
- Embossing and stamping presses.
- Drying closets.
- Back shapers.
- Palette heaters.
- Branding irons.
- Glue pots.
- Case making and covering machines.
- Back rounders.
- Gilding wheel heater.

Breweries:

- Vat dryers.
- Glue and resin heaters.
- Branding irons.



G. E. Cigar Lighter.

Brush Manufacturers:
- Glue pots.
- Tank heaters.
- Branding irons.
- Flat irons.

Button Manufacturers:
- Hot plates.
- Japanning ovens.
- Button die heaters.
- Celluloid softeners.

Canning Factories:
- Can capping machines.
- Soldering pots.
- Soldering irons.
- Branding irons.

Cigar Stores:
- Cigar lighters.
- Branding irons.

Cleaning and Dyeing Works:
- Tailor irons.
- Hot plates.
- Laundry irons.
- Puff irons.

Cloak and Suit Manufacturers:
- Tailor irons.
- Velvet marking irons.
- Laundry irons.
- Puff irons.

Coffee and Tea Merchants:
- Percolators.
- Water heaters.
- Coffee roasters.
- Tea pots.
- Hot plates.

Colleges and Schools:
- Laboratory devices (listed elsewhere.)
- Hot plates (domestic science.)
- Ovens (domestic science.)
- Water heaters.

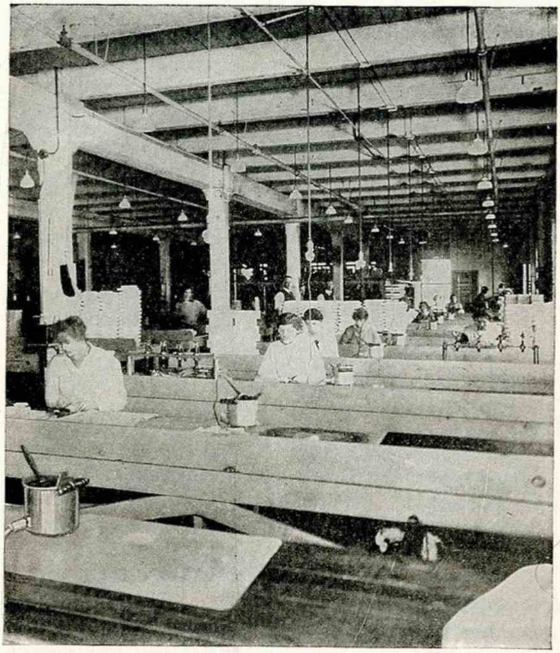
Confectioners:
- Hot plates.
- Chocolate warmers.
- Dipping tanks.
- Corn poppers.
- Batch warmers.
- Chocolate trays.
- Water heaters.
- Ovens.

Contractors and Builders:

Branding irons.
Soldering pots.
Soldering irons.
Glue pots.

Corset Factory:

Corset irons.
Disc stoves.
Form heaters.
Flat irons.



G. E. Glue Pots in Box Factory.

Creameries and Dairies:

Water heaters.
Hot plates.
Sterilizers.

Dentists:

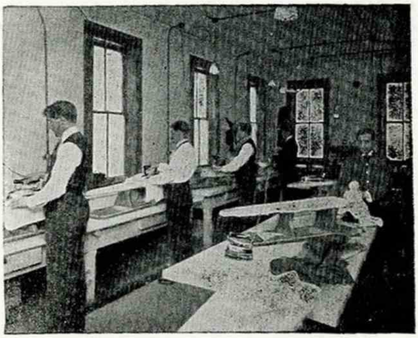
Cauterizers.
Hot plates.
Vulcanizers.
Sterilizers.
Dental furnaces.

Department Stores:

Cigar lighters.
Hot plates.
Pyrograph needles.
Flat irons.

Doctors:

Sterilizers.
Hot bath cabinets.
Water heaters.
Cauterizers.
Heating pads and blankets.
Incubators.



G. E. Irons in Cleaning and Dyeing Establishment.

Dress Goods Factory:

Pleating machines.
Flat irons.
Ironing machines.
Velvet marking irons.

Drug Stores:

Cauterizers.
Sterilizers.
Sealing wax heaters.
Water heaters.
Cigar lighters.
Paper seal moisteners.

Electrotypers:

Heating furnaces.
Solder pots.
Soldering irons.
Water heaters.

Factories (General):

Welding machinery.
Branding irons.
Glue pots and cookers.
Pitch kettles.
Soldering irons.
Water heaters.
Solder pots.
Pouring pots.

Farms:

Incubators and brooders.
Soldering irons.
Hot plates.
Branding irons.
Sterilizers.
Food warmers.

Foundries:

- Steel furnaces.
- Welding machinery.
- Soldering irons.
- Metal melting tanks.
- Core ovens.
- Solder pots.

Furniture Factories:

- Wax knife heater.
- Glue pots.
- Wax burning-in iron.
- Drying ovens.

Hair Dressers:

- Hair dryers.
- Water heaters.
- Curling irons.
- Disc stoves.

Harness Shops:

- Branding irons.
- Water heaters.
- Wax heaters.
- Creasing irons.

Hat Manufacturers and Stores:

- Flanging bags.
- Velouring stoves.
- Machine irons.
- Hand flats.
- Hand shells.
- French irons.

Hospitals and Sanitariums:

- Cauterizers.
- Sterilizers.
- Water heaters.
- Mangles.
- Hot cabinets.
- Heating pads.
- Flat irons.
- Incubators.

Hotels:

- Sealing wax heaters.
- Hot bath cabinets.
- Tailors' irons.
- Hot plates.
- Cigar lighters.
- Laundry irons.
- Curling irons.
- Heating pads.
- Water heaters.
- Towel dryers

Jewelry Stores:

- Small drying ovens.
- Hot plates.
- Sealing wax heaters.
- Soldering irons.

Knitting Mills:

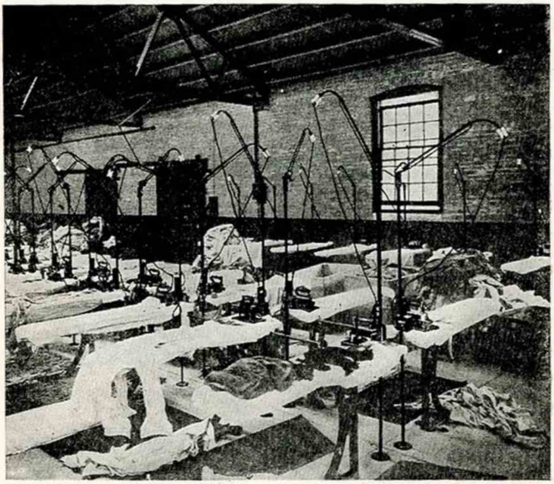
- Hosiery forms.
- Yarn conditioning ovens.
- Flat irons.

Laboratories:

- Annealing and enameling furnaces.
- Sterilizers.
- Disc stoves.
- Tube, crucible, vacuum, and muffle furnaces.
- Flask heaters.
- Shelf heaters.
- Water heaters.
- Soldering irons.
- Test tube heaters.
- Bacteriological incubators.

Laundries:

- Sleeve irons.
- Collar and cuff moulding machinery.
- Ironing machines and rolls.
- Starch cookers.
- Puff irons.
- Laundry irons.
- Marking machines.
- Steam boilers.
- Clothes dryers.



Installation of Simplex Laundry Irons Equipped with Suspension Cords.

Leather Factories:

- Leather creasing tools.
- Glue and wax heaters.
- Embossing machines.
- Crimping machines.
- Solution tanks.
- Branding irons.
- Flat irons.
- Wax knife heaters.

Libraries:

- Sealing wax pots.
- Paper seal moisteners.
- Envelope gum dryers.
- Glue pots.

Machine Shops:

- Welding machinery.
- Soldering irons.
- Metal melting tanks.
- Branding irons.
- Oil tempering tanks.
- Solder pots.
- Solution tanks.
- Oven furnaces.

Offices:

Sealing-wax heaters.
Paper seal moisteners.
Envelope gum dryers.
Water stills.

Paper Box Factories:

Box mould heaters.
Sealing wax heaters.
Drying ovens.
Glue pots.
Branding irons.
Disc stoves.

Photographers:

Burnishers.
Glue pots.
Fan dryers.
Flat irons.
Film and print dryers.
Branding irons.
Wax heaters.
Disc stoves.

Piano Stores and Factories:

Drying ovens.
Glue pots and cookers.
Solution tanks.
Branding irons.
Soldering irons.
Annealing furnaces.

Plumbers and Tinsmiths:

Roofing pitch kettles.
Solder pots.
Pipe thawing apparatus.
Soldering irons.

Peanut and Popcorn Stands:

Peanut roasters.
Popcorn poppers.
Peanut warmers.
Butter warmers.

Printers and Publishers

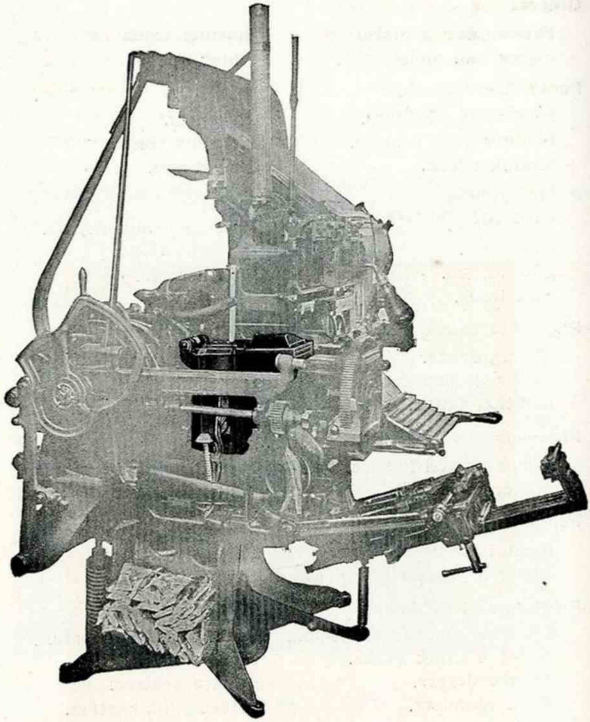
Linotype and monotype pots
Metal melting tanks.
Matrix dryers.
Back rounders.
Embossers.
Printing press heaters.
Branding irons.
Wax-heating kettles.
Glue pots and cookers.
Back shapers.
Palette heaters.
Printing ink heaters.
Drying rooms.
Stamping and embossing presses.
Wax-stripping tables.

Restaurants:

Coffee urns.
Toasters.
Food warmers.
Bake ovens.
Griddles.
Cigar lighters.
Waffle irons.
Plate warmers.
Steam tables.
Broilers.
Egg boilers.

Roofers:

Branding irons.
Solder pots.
Soldering irons.
Pitch kettles.



Linotype Machine Equipped with Coin Melting Pot.

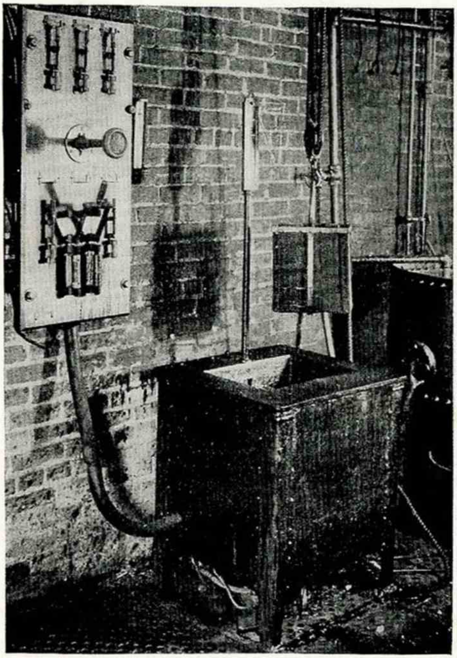
Saloons:
- Hot plates.
- Cigar lighters.
- Plate warmers.
- Water heaters.
- Percolators.

Ship Building Yards:
- Welding machines.
- Soldering irons.
- Glue pots and cookers.
- Branding irons.

Shirt Factories:
- Laundry irons.
- Ironing machines.
- Disc stoves.
- Flat irons.
- Tailors' irons.
- Cuff and collar moulding machines.

Shoe Factories and Stores:

- Thread waxing machines.
- Lining cementer.
- Stitchers.
- Embossing machines.
- Welters.
- Branding irons.
- Flat irons.
- Turn and welt machines.
- Knurling machines.
- Patent leather repairers.
- Indenters and burnishers.
- Embossers.
- Glue pots and cookers.
- Shoe relasters.
- Wax knife heaters.



G. E. No. 3 Oil Tempering Bath in Atlas-Ball Plant, Philadelphia.

Steel Mills:

- Welding machinery.
- Oil tempering tanks.
- Steel furnaces.

Street Railway Shops:
- Car heaters.
- Soldering irons.
- Water heaters.
- Welding machinery.
- Solder pots.
- Branding irons.

Tailor Shops:
- Tailors' irons.
- Clothes dryers.
- Puff irons.

Theatres:
- Water heaters.
- Curling irons.
- Grease-paint heaters.

Turkish Baths:
- Hair dryers.
- Hot bath cabinets.
- Water heaters.
- Curling irons.

Wagon Shops and Factories:
- Vulcanizers.
- Branding irons.
- Soldering irons.
- Welding machines.
- Glue pots and cookers.
- Disc stoves.

Wood Workers and Carpenters:
- Branding irons.
- Wax melters.
- Glue pots.
- Soldering irons.

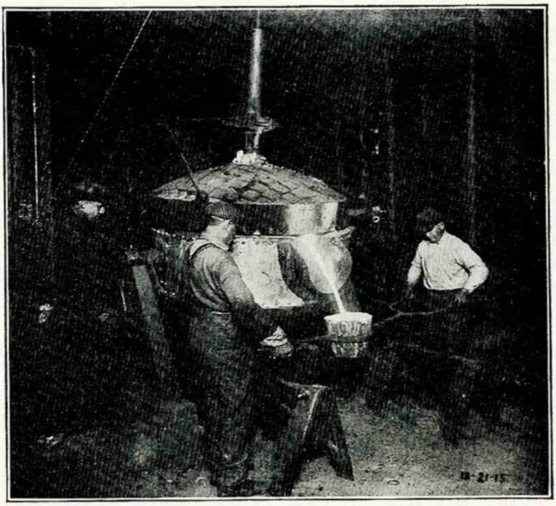
CHAPTER X

ELECTRIC FURNACES.

Economic Advantages.—The use of electric energy for producing furnace heat has revolutionized many modern industries. The field which it has created in the development of electrochemical and metallurgical processes has great possibilities. Not only does the electric furnace afford opportunity for improving and widening these industries, but its use requires large quantities of electric power, the development of which produces a market for energy that might otherwise lie dormant or go to waste. Furthermore it improves the load factor and diversity of large central station loads, and otherwise tends to foster greater economic wealth.

Only high temperature furnaces for melting and refining various substances will be considered in this chapter. The general design, manner of operation, and field of application of electric furnaces will be outlined so as to convey an understanding of the subject.

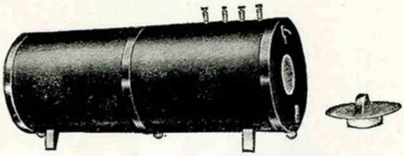
The Electric Furnace Field.—The application of the electric furnace has made it possible to manufacture a number of substances that would otherwise not be available for commercial purposes if combustion methods were the sole means of production. None other than electric furnace methods have ever been successfully employed in the manufacture of such well known substances as carborundum, aluminum, and calcium carbide. Immense industries have been built up, and great quantities of power employed for their production. There are many other processes that may be performed only with the electric furnace, but the extensive applications of which are limited by the cost of production. There is little doubt but that more of the supply of nitrogen required for soil fertilization will be drawn from the air by electric furnace apparatus, as the present rapidly depleting natural nitrate deposits become exhausted. Several plants located where electric energy is cheaply produced, now manufacture great quantities of nitric acid and nitrates and consume enormous amounts of power.


Pouring From Snyder Steel Furnace.

The electric furnace may create temperatures greatly in excess of those otherwise available. With present apparatus operating temperatures as high as 6500° F. may be attained. The exclusion of objectionable furnace gases and air, makes it possible to perform many new operations. The smelting of various metallic ores that formerly could not be handled satisfactorily or economically has been made possible.

Probably the greatest field for utilizing the electric furnace, at the present time, is in its application to such processes as are now largely performed with fuel burning furnaces. It is in this field, however, that the electric method has to compete on the basis of both cost and quality of product.

Character of Furnace Power Loads.—Some concerns using electric furnaces do not attempt twenty-four hour operation on account of the usual inefficiency of night work. This is especially true of those engaged in steel manufacturing. Some furnaces have to be shut down while the products are removed and new charges introduced. The resulting load factor is relatively high, however, as compared with average central station motor service.



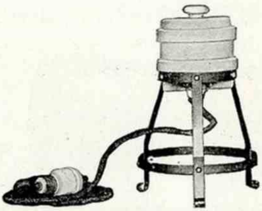
G. E. Laboratory Tube Furnace. (Max. temp. 1832° F., 2½ in. diameter, various lengths.)

Some smaller furnace installations may be shut down from three to four hours per day without serious disadvantage and this condition often makes it possible to utilize off-peak power. Where steel melting furnaces are used, it has been found advisable in many instances to mould during the day and melt at night. This practice has developed an all-night furnace load for the power company.

The variations in current in an electric furnace are usually due to changes in condition of the charge. Some furnaces are operated in series with a ballast. For direct current service the ballast has to be a resistance, whereas for alternating current service a resistance or a reactance may be used. The power factor of induction furnaces is generally low. It may be raised by lowering the frequency, or by using a synchronous motor as a condenser.

Character of Service Required.—Alternating current is used in furnace work more often than direct current. For induction furnace operation alternating current is employed, whereas direct current is required in electrolytic furnaces. In most arc and resistance furnaces either alternating or direct current may be employed.

The voltage required for furnace work is generally low (50 to 200) although in nitrogen furnaces pressures as high as 5,000 to 10,000 volts are often utilized. The size of furnace loads usually makes it necessary to reduce the voltage at the point of delivery, and consequently almost any available primary



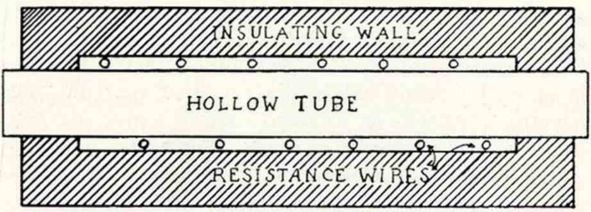
G. E. Crucible Furnace. (Max. temp., 1112° F., crucible 1 in. by 2 in. high.)

voltage may be used. The higher the voltage applied the less is the current required, the smaller the electrode cross section, and the less the heat conducted out of the furnace through the electrode. Voltages are limited, however, from considerations of the safety of operators.

Arc and resistance furnaces are usually built for 60 cycle operation in sizes under 1000 kilowatts. Larger furnaces are generally constructed for lower frequencies. Induction type furnaces usually require special low frequencies in sizes larger than 500 kilowatts capacity.

Most furnaces are operated with single-phase service. The larger resistance furnaces for manufacturing chemical products, graphite, and carbide use single-phase service. Nitrogen fixation furnaces are generally connected so as to use three-phase current. Two and three-phase energy is frequently utilized in steel making although it is contended by some manufacturers that single-phase service is more efficient and satisfactory from the standpoint of furnace operation. A single electrode furnace is somewhat cheaper and more readily manipulated; the heat losses are less; and the electrode and refractory roof costs are smaller. On the other hand, most power producers prefer to deliver two or three-phase energy for obvious reasons. Central station companies having 4-wire, three-phase distribution systems are sometimes able to supply single-phase service by suitable arrangement of tranformer connections.

Classification of Electric Furnaces.—Electric furnaces may be divided into two general classes, the resistance type, and the arc type. It is often difficult to distinguish the class to which different furnaces belong, because both the heat of the arc, and the heat resulting from the resistance to the flow of current, are frequently utilized in heating the charge.



Tube Furnace.

Resistance type furnaces may derive heat from the passage of current through resistance wires, through other resistance materials surrounding the charge, or by the passage of current through the charge itself. Examples of furnaces employing resistance wires as a means for heating the charge are found in the ordinary small crucible, tube, and muffle type furnaces often used in laboratories for operation at temperatures under 1800° F. Typical examples of the second type of resistance furnaces are those of the Acheson carborundum furnace and some of the well known high temperature electric crucible furnaces. The induction type furnace, wherein a current is induced in the charge by electromagnetic induction, is one of the best examples of the third type of resistance furnace. A sharp distinction between these three classes is often impossible because some types involve more than one principle in their design.

Furnace With Resistance in the Charge.

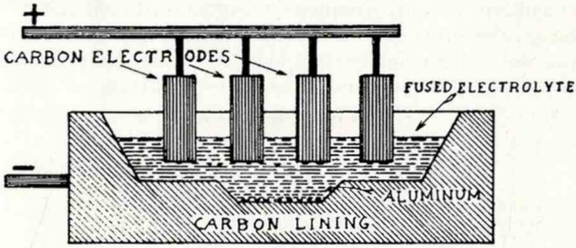
Arc furnaces may be divided into three classes, the principles of which may or may not be combined in one type of apparatus. The first class, known as the direct arc furnace, produces heat by causing an arc between the electrode and the charge. The second class known as the series arc furnace passes current from one electrode to the charge and from the charge back to another electrode. The third class, known as the indirect arc furnace, produces heat between electrodes supported above the charge.

A more complete classification of electric furnaces is given by Stansfield in his excellent text on "The Electric Furnace" as follows:

Classification of Electric Furnaces.

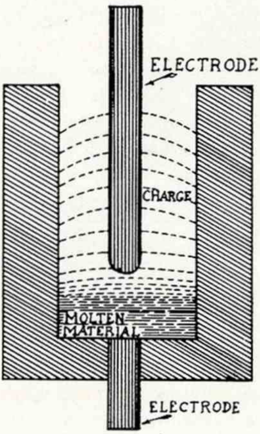
(1) Resistance Furnaces.
- (a) Using special resistance.
  - (1) Resistance wires in furnace walls (tube furnace.)
  - (2) Resistance material in the charge (carborundum furnace.)
- (b) No special resistance.
  - (1) Electrolytic (aluminum furnace.)
  - (2) Using charge as resistance.
    - (a) Solid material (graphite furnace.)
    - (b) Melting material (Heroult smelting furnace.)
    - (c) Liquid material (induction furnace.)

(2) Arc furnaces.
- (a) Direct arc.
  - (1) Single arc (Girod furnace.)
  - (2) Series arc (Heroult furnace.)
- (b) Indirect orc (Stassano furnace.)



Aluminum Furnace.

Advantages and Limitations of Electric Furnaces. The increased range of temperatures, the easy control of the heat generated, the exclusion of harmful ingredients, and the careful adjustment of atmosphere conditions, make the electric furnace ideal for many electrochemical operations.

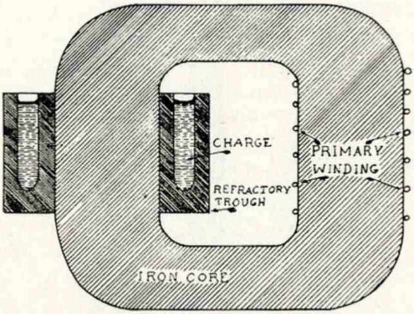


Shaft Furnace.

Comparisons are sometimes made between the cost of fuel and the cost of electricity and these figures used as a basis for deciding what method of heating should be employed. In so doing some important considerations are frequently overlooked. In the first place, the efficiency of a furnace is the ratio between the heat beneficially utilized, and the heat energy supplied. The average efficiencies of a number of different types of furnaces are given on good authority as follows:

Furnaces	Average Efficiency Per cent.
Coke fired crucible steel furnaces	2.5
Metal melting reverberatory furnaces	12.0
Open-hearth steel furnaces	25.0
Shaft furnaces	40.0
Large electric furnaces	75.0

It is apparent that although the number of heat units made available in the fuel furnace may exceed those in the electric furnace for the same expenditure of money, the higher efficiency of the latter may prove its superiority.



Induction Furnace.

Heat Energy Required.—The heat consumed in the electric furnace is utilized and dissipated as follows:

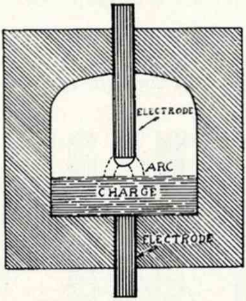
(1) To raise starting materials to temperature of reaction.

(2) To change the state of the substance as required.

(3) To provide energy for the reaction.

(4) To supply the conduction and radiation losses.

The first item may be calculated by multiplying the weight of the charge, the temperature difference, and the mean specific heat. The second may be obtained by multiplying the weight of the charge by the latent heat of fusion, vaporization, or sublimation,



Direct Heating Arc Furnace.

according as it is required to change from solid to liquid, liquid to vapor, or solid to vapor respectively. The third may or may not absorb useful heat energy and in some cases actually produces heat within the charge which reduces the amount of outside energy required.

Conduction losses take place mainly through the furnace walls and through the electrodes. The heat losses through the walls depend upon the thermal conductivity and area of the walls and the difference in temperature inside and outside the furnace. Heat losses through the electrodes depend upon their thermal as well as upon their electrical conductivity, for the reason that heat is conducted from the hot to the cold ends, and generated in the electrodes by the passage of current. The radiation losses depend upon the outside area of the furnace, the character of its surface, and the difference in temperature between its surface and that of the surrounding atmosphere.

Furnace Walls.—In the choice of material for furnace walls four properties of the substance are generally considered:

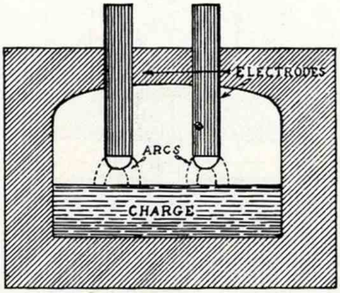
(1) Its fitness for the chemical nature of the reaction;

(2) Maximum temperature it is required to withstand;

(3) Its thermal conductivity;

(4) Its ability to withstand expansion and contraction.

For a basic charge a basic refractory is required and for an acid charge an acid lining is essential.



Direct Heating Series Arc Furnace.

Metallurgical Furnace Refractories.

Basic Lining.	Acid Lining.	Neutral Lining.
Bauxite	Silica	Carbon
Magnesia		Fire clays
Dolomite		Chromite
Lime		

For higher temperature furnace work certain compounds of carbon and silicon as well as pure carbon are especially adaptable. Pure magnesia is recommended for some purposes.

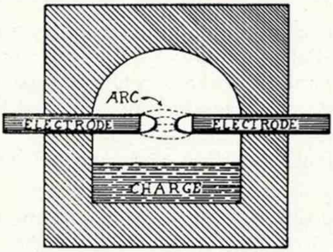
Furnace walls are usually constructed of two layers—the inner one capable of withstanding the maximum temperature and the chemical effects of the charge, and the outer one of high heat insulating quality.

Furnace Electrodes.—All electric furnaces, with the exception of induction apparatus, require the use of electrodes for introducing electric energy into them.

The most desirable qualifications of an electrode may be enumerated as follows:

(1) Good electrical conductor.
(2) Poor heat conductor.
(3) High melting or sublimation point.
(4) Lack of contaminating effect upon charge.
(5) Mechanical strength.
(6) Cheapness.

The relative importance of these qualifications depends largely upon the kind of furnace to which the electrodes are applied. On account of the losses



Independent Arc Furnace.

that take place through the electrodes it is essential that the dimensions and material be carefully considered. The consumption of electrode material in the furnace is another feature that has much to do with the furnace operating costs.

Electrodes are usually made of carbon. Graphite electrodes have the advantages of better resistance to oxidation, higher electrical conductivity, and greater purity, but they are more expensive.

CHAPTER XI

ELECTRIC FURNACE APPLICATIONS.

Fundamental Considerations of Commercial Enterprises.—The ultimate success of any industry based on the application of the electric furnace may depend upon any one of a number of local conditions:

(1) Availability, character, and cost of raw materials.

(2) Cost of transporting raw materials to furnace.

(3) Availability and cost of electric power.

(4) Availability, character, and cost of labor.

(5) Cost of transporting finished product to market.

(6) Extent, stability, and competitive conditions of market.

A casual observer is likely to assume that any enterprise requiring the application of the electric furnace depends solely upon cheap power for its success. That random conclusions of this sort are often misleading may be observed by applying the above six considerations to almost any commercial electric furnace project. It is true that electric equipments producing large quantities of cheaper grade products in competition with fuel apparatus often require very low power rates to insure success. On the other hand many refining processes are carried on to advantage where power costs are not extremely low.

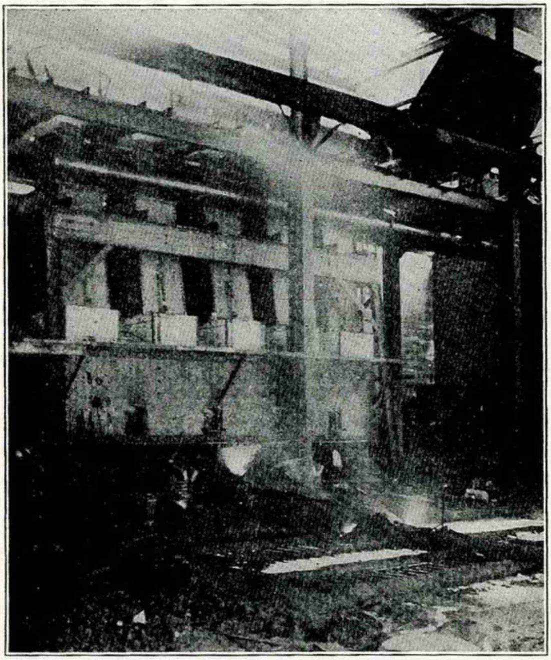
The availability of raw materials, the proximity and cheapness of water transportation, and the labor and market conditions, considered aside from power cost, have each had a potent influence in determining the feasibility of locating electric furnace enterprises at Niagara Falls, and in France, Norway, Sweden, and Switzerland.

Production of Ferro-Alloys.—Iron alloyed with chronium, tungsten, manganese, silicon, etc., is known as a ferro-alloy. It is somewhat similar to cast iron, but differs in that some of the metals or other materials have replaced part of the iron. The chief use of ferro-alloys is in the production of steel. The constituents are usually less costly to obtain in ferro-alloys than in the pure state. The small quantity of iron with which they are alloyed simply mixes with the charge in the furnace during the process.

Most of the ferro-alloys are produced by reducing the metallic oxide with iron or iron ore and carbon. Ferro-silicon is made by smelting a mixture of silicon, in the form of quartz or quartzite, with carbon, and iron or iron ore. The latter is of great value in the production of steel where it acts both as a deoxidizer and as a preventive of objectionable blowholes in steel castings.

The electric furnace has proven itself far superior to fuel furnaces in the production of ferro-alloys because of the higher and more easily controlled temperatures it affords, and on account of the absence of objectionable ingredients, and the higher percentage of desirable constituents in the product. The manufacture of many ferro-alloys formerly considered commercially impractical have been undertaken since the application of the electric furnace has become more fully understood. The production of silicon, which is of great value to the chemical industry on account of its resistance to the action of acids, was formerly carried on on a very small scale but is now manufactured extensively by electric furnace methods. Many thousands of horsepower are now devoted to the production of ferro-alloys and silicon in the electric furnace. Vertical electrode type crucible or ore smelting furnaces are usually employed for this work.

Smelting of Iron Ores.—The electric furnace is being employed to some extent in the production of pig iron. In Sweden, about 40,000 h,p, are utilized in this industry. The more recently developed processes have proved technically successful, and in localities where fuel cost is high and conditions are such that electric energy can be supplied at low rates, the field of application of the pig iron furnace is large. The average amount of energy required has been found to be between 1800 and 2000 kw-hr. per ton of iron smelted.



Iron Smelting Furnace at Heroult, Cal. (capacity 2400 kw., 20 tons per day).

Whereas fuel is used in a blast furnace for producing heat for the reduction of iron oxide it is only required in the electric furnace for the latter purpose. The amount of fuel required is therefore at least 70 per cent less and a much inferior quality may be used.

Many types of furnaces have been developed for the smelting of iron ores. They all consist of refractory smelting chambers provided with two or more electrodes. A shaft mounted above the smelting chamber is filled with ore, flux, and fuel which gradually moves downward as the materials are melted. Heat is produced by the current passing between the electrodes through the charge.

Smelting of Copper, Zinc and Other Metals.—A discussion of the feasibility of producing iron and steel is given elsewhere. The reduction of ores of copper, tin, lead, and other metals, is accomplished by smelting them with fuel. The electrical method may be adopted in a number of places where fuel cost is high and power cost is low as it has been found that the reduction can be carried on more accurately in the electric furnace than in fuel fired furnaces.

On account of the volatility and the ease of oxidation of zinc, serious difficulties have been encountered in the treatment of the ores. The electric furnace method has actually been adopted to some extent and the ores smelted satisfactorily. Great hopes are entertained by authorities on the subject of ore treatment for the electric zinc smelting furnace because of present difficulties with fuel apparatus, and on account of the success already attained with the electric installations.

Production of Graphite and Carbide.—Graphite is produced in the Acheson furnace by subjecting a charge of carbonaceous material (usually ground anthracite coal) surrounding a graphite or carbon core, to great heat. At Niagara Falls, N. Y., several million pounds of graphite are annually produced in this manner.

Carborundum is produced by heating a mixture of coke, silicious sand, salt, and sawdust. The coke is used as a conducting core to start the flow of current. The output of carborundum in 1905 was nearly six million pounds, and about 7,000 h.p. was utilized in its production. It is said that about 7600 kw-hr. are required per ton of carborundum manufactured.

Calcium carbide is produced in great quantities in the electric furnace for making acetylene. It may also be used in the production of calcium cyanamide by heating it with nitrogen and in the production of ammonia by passing steam over the red hot carbide. The former is of use as a fertilizer and the latter may be made into ammonium sulphate for the same purpose. The total production of calcium carbide in the electric furnace amounted to about 250,000 tons in 1909. Several types of so-called ingot furnaces and resistance furnaces have been developed for this purpose. About 6000 kw -hr. are usually required per ton of product.

Electrolytic Furnace Processes.—When a direct current is passed through a fused salt electrolytic action may take place. The metal of the salt is liberated at the cathode, or negative electrode, whereas the remainder of the salt is liberated at the anode. The principles that apply to the electrolysis of fused salts are similar to those pertaining to the electrolysis of salts in solution. A certain amount of current passed through the fused salt will always produce a certain amount of decomposition and it is therefore possible to calculate the amount of energy required to separate a definite weight of a compound into its elements. When an anhydrous salt is used as an electrolyte a red heat is usually required to bring it to a fluid condition and its electrolysis is a furnace operation. Electrolytic processes may be intended either for purification or the recovery of metals.

Chlorine and caustic soda are made by the use of common salt as an electrolyte, carbon as the anode electrode, and molten lead as the cathode. The clorine collected at the anode is used for making bleaching powder, and the sodium liberated at the cathode alloys with the lead, and when treated with steam, combines to form caustic soda.

Metallic sodium is usually made by using the fused anhydrous caustic soda as an electrolyte with a nickel anode and a carbon or metallic cathode. (Casner Process). Other processes for producing sodium direct from salt have been attempted with some success.

Potassium is obtained by electrolytic processes similar to the sodium processes.

Barium, magnesium, strontium, and calcium, are obtained by electrolysis of the fused chlorides.

A method of treating various sulphide ores has been tried out with some success. It is done by decomposing the fused ores of such metals as lead, iron and zinc by the action of chlorine.

Zinc may be obtained from the fused chloride. The furnaces employed are usually provided with carbon anodes and zinc cathodes.

Production of Aluminum. The most important metal that can be commercially produced solely with electricity in the electrolytic furnace, is aluminum. It was originally produced in very small quantities by complicated chemical methods. Prior to the expiration of the Hall patents the manufacture of aluminum in the United States was controlled by the Aluminum Company of America, but since that time other financial interests have taken up its production. Nearly a hundred thousand horsepower of electric energy is in use for this purpose in the United States, although the largest percentage of the world's output is now manufactured in Europe.

The process consists in passing current through melted aluminum compounds. The electrolytic action liberates the aluminum from the fused compounds and splits up the alumina into oxygen and aluminum. The types of furnaces most generally used consist of carbon lined tanks provided with carbon electrodes which extend from the top and dip into the fused electrolyte. Direct current only can be used in this process. The carbon electrodes are made the positive and the tank the negative terminals.

Electrolytic Furnace Refining.—Although it is entirely feasible to refine metals in the electrolytic furnace, the method has not been generally employed on account of the expense and difficulty of high temperature operation. The principles involved are similar to those of refining in aqueous solutions. The metal to be refined is made the anode and some fused salt of the metal is used as an electrolyte. Upon the passage of current through the furnace the pure metal is deposited upon the cathode.

Production of Nitric Acid and Nitrates.—The principle on which furnaces for this work are designed is the forcing of air through an enormous arc and removing and cooling the air quickly. The oxygen and nitrogen of the air partly combine to form a very small amount of nitric oxide, the percentage varying with the temperature. The nitric oxide, while cooling, combines with oxygen to form various oxides of nitrogen.

After the gases have cooled they are allowed to react with water in spraying towers, forming nitrous and nitric acid. The former decomposes into nitric acid and nitric oxide. The nitric acid may be marketed, or it may be utilized for dissolving limestone and producing calcium nitrate which is useful for fertilizer.

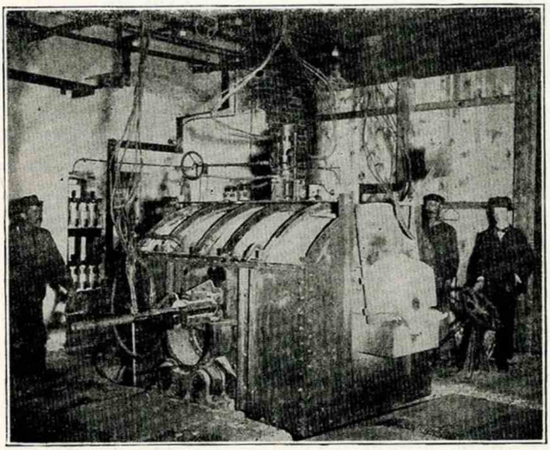
Three-phase alternating current is generally used in the main circuit of the furnaces now in operation and, in order to maintain a steady arc, resistance or inductance coils are connected in series with it. The latter wastes less energy, but necessarily reduces the power factor of the apparatus. Pressures as high as 5000 volts are often used. A magnetic field produced by a direct current electro-magnet supplied with energy from some auxiliary source is often employed to direct the arc upward or downward.

Many thousands of horsepower are utilized in the fixation of atmospheric nitrogen by electric furnace methods, and as the demand for nitrates is rapidly increasing, the industry gives promise of a healthy growth.

Miscellaneous Electric Furnace Products.—Glass may be melted to advantage in the electric furnace. Alundum, which is used as an abrasive, may be made by fusing bauxite in an electric furnace and cooling slowly. Quartz used for making laboratory crucibles, dishes, tubes, etc., may be fused in the electric furnace. The production of phosphorus, which can only be handled away from the air, is readily made in the electric furnace by heating mineral phosphates or bone ash with carbon and silica. Monox, a substance used in inks and paints, is produced in the electric furnace from silicon and oxygen. Carbon-bisulphide, made by passing sulphur vapor over hot charcoal, is a liquid used as a solvent for oil and rubber, and being volatile, it is sometimes employed for producing poisonous gases.

Production of Electric Furnace Steel.—The use of electricity in melting and refining steel is entering upon a period of rapid growth. The development of commercial apparatus has passed beyond the experimental stage as proven by the fact that there are now over three hundred such furnaces in actual service, about seventy of which are located in various parts of the United States. Since there are between thirty and forty million tons of steel produced annually in this country by fuel methods, the opportunity for introducing electric furnaces is great.

Advantages of Electric Steel Furnace.—As far as cost is concerned, it is unquestionably cheaper to produce the highest quality steel in the electric furnace. For large quantity production of the lower grades of



Rennerfelt Steel Arc Furnace.

steel, it is sometimes possible to make the steel cheaper by fuel methods. For small quantity production the cost is always in favor of the electric furnace. This situation opens up a wide field for relatively small furnaces having a capacity for fifty tons per day or less, although they may be obtained in any size or capacity desired.

Electric furnace steel may be made to any analysis or specifications. Purity of steel is a mark of quality and it is now recognized that electric furnace steel is the purest that can be produced. Among the many superior qualities claimed for electric furnace steel are toughness, greater tensile strength, higher elastic ratio, more solidity and fewer blow holes, higher magnetic properties, and greater malleability. It is coming into great demand for large castings where quality is the first consideration. One great advantage of the electric furnace in the refining of steel is that electricity, unlike fuel, introduces no additional impurities into the molten metal, and a complete charge may be left in the furnace as long as desired without injuring its composition. Impurities, such as sulphur, phosphorus, oxygen, etc., are gradually absorbed in the slag and rabbled off.

Electric Steel Smelting.—Steel may be produced directly by smelting iron ore or indirectly from wrought-iron or pig iron. Whereas the former method is more complicated and has not yet been taken up commercially, it has big possibilities. The reduction of the ore is usually done in the furnace shaft, and the refining in an open hearth or ladle.

Production of Steel from Metals.—The electrical method of making steel from metallic ingredients, known as the indirect method, has proved to be entirely practical commercially and is being rapidly adopted. Pig iron, wrought iron, scrap steel, or mild steel, are melted together in this process and refined to whatever extent is considered necessary.

Resistance Furnaces.—Resistance, induction, and arc furnaces are each used in the steel-making industry. Resistance type furnaces, notably the Gin Steel

Furnaces, are heated by passing a heavy current through the charge under low voltage. The charge is placed in narrow winding channels and the current introduced at each end through water cooled electrodes. This type of furnace has not proven altogether satisfactory in actual service, and later designs provide for heating the charge on the induction principle.

Induction Furnaces.—Heat is produced in these furnaces by inducing a current in the charge placed in one or more annular rings which act as transformer secondaries. A great many advantages are claimed for this type of furnace. In the first place, no electrodes are required and all the difficulties and expense which attend their use are eliminated. The loss of heat by conduction to the outside through the electrodes is obviated. There are no electrode impurities introduced. The steel is contained in a closed receptacle resembling the crucible furnace. The distribution of heat is uniform and the natural circulation set up serves to mix the charge. The heat of the furnace walls and cover is less intense than in the arc furnace and the lining does not wear away so rapidly. Although this type of furnace may create a relatively low power factor, it is much less subject to extreme variations in load than are arc furnaces.

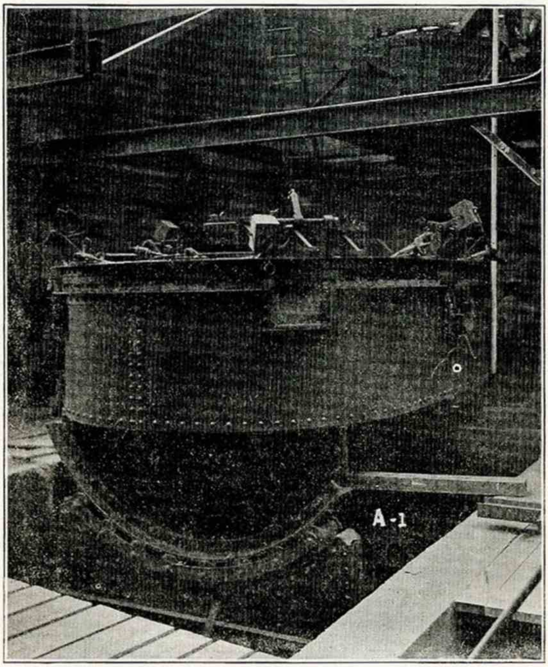
The efficiency of electric transformation in this type of furnace is not high. It is necessarily somewhat limited in capacity because the power factor becomes less as the size is increased unless the frequency of the current is correspondingly reduced. Pressures as high as 6000 volts may, however, be applied directly to the furnace, thus obviating the necessity of providing special transformers, unless the power is to be transmitted a considerable distance.

Types of Induction Furnaces.—The Kjellin furnace is of the single-phase type, and consists essentially of an iron core around one leg of which is wound a primary winding, enclosed in a refractory core and cooled by forced draft or water jackets. The hearth surrounding the coil is provided with an annular groove in which the charge is placed. The furnace is usually built in a circular iron casing which is lined with firebrick. The annular trough is surrounded with a more refractory material such as dolomite or magnesite bricks.

The Colby furnace is similar in principle to the Kjellin furnace. It consists of a laminated iron core around which is wound a copper tube primary cooled by circulating water. The annular crucible secondary surrounds the primary winding. It is claimed that this design operates at a much higher power factor. The character of the primary winding requires the use of lower potentials. It has proved successful in small designs but has not as yet been developed in large sizes. The Frick furnace resembles the Kjellin furnace, but is generally designed for two-phase operation.

The Rochling-Rodenhauser furnace is so designed as to obviate two of the most objectionable features of other induction furnaces. It is provided with a distinct open hearth so that refining possess may be carried on in the furnace, and is designed to operate in larger sizes and at higher power factors. This furnace is built for either single or three-phase operation. In the single-phase type two annular troughs, surrounding two separate sections of the primary coil meet in the center of the furnace and are there expanded into a much larger chamber. The three-phase type is provided with three annular troughs, surrounding three separate single-phase windings. These troughs also converge in the center into a much larger chamber.

In order to maintain the heat in the enlarged chamber a separate secondary winding, of a few turns of heavy conductor, is connected with iron pole pieces imbedded in the furnace walls at opposite sides of the chamber. When the furnace walls heat up they conduct current from these pole pieces through the charge, and thus form a closed circuit for the induced currents and an auxiliary means of heating the charge in the chamber. This winding also serves to neutralize the great self-induction produced by the charge, and a far better power factor is obtained than in the Kjellin furnace. The use of three-phase types has the advantage of causing a circulation of the charge due

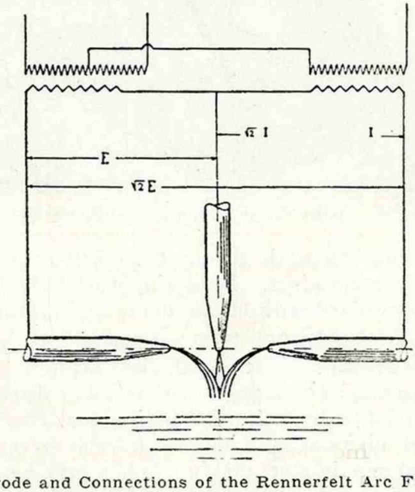


Rochling-Rodenhauser 2-Ton Induction Furnace.

to the rotary magnetic field set up and results in a more uniform product. Both single and three-phase types are provided with lateral doors and arranged for tilting to pour steel and slag.

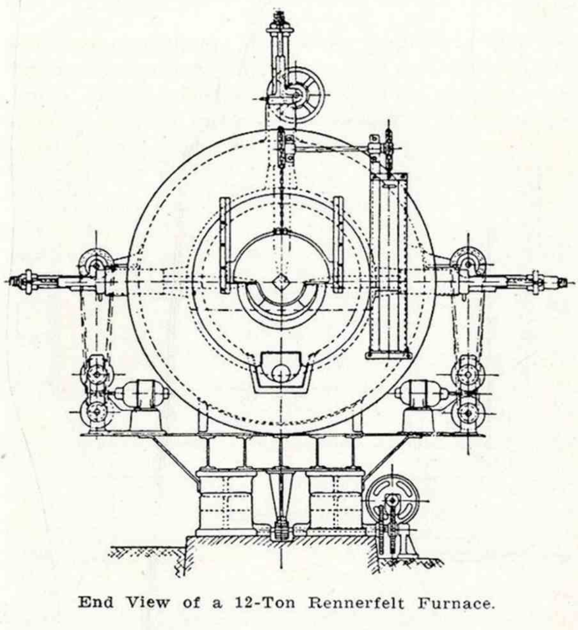
Arc Furnaces.—The usual classification of steel arc furnaces are (1) independent arc, (2) direct heating arc, and (3) direct heating series arc. There are a number of advantages of the arc furnace over the induction furnace in steel making. They may be started with a cold charge more readily. There is, however, considerable loss of heat which is conducted to the outside through the electrodes. The slag is obviously heated hotter than the metal and as the impurities are absorbed in the hottest portion of the charge the arc furnace is well adpated to refining purposes. These furnaces are also less complicated in design and have a lower first cost. The power factor of the load is much higher than that produced by the induction furnace, and the necessity of utilizing special frequencies in the larger sizes is less marked. The load is, however, subject to wide variations, especially in the direct heating are furnaces when cold scrap is melting down or flux is thrown into the chamber. Either direct or alternating current may be used in the arc furnace.

Under average commercial conditions arc furnaces show better cost results in heating cold metal than in heating molten iron from a fuel furnace. Combustion melting introduces impurities from the metal, oxygen and nitrogen from the blast, and sulphur from the fuel.



Electrode and Connections of the Rennerfelt Arc Furnace.

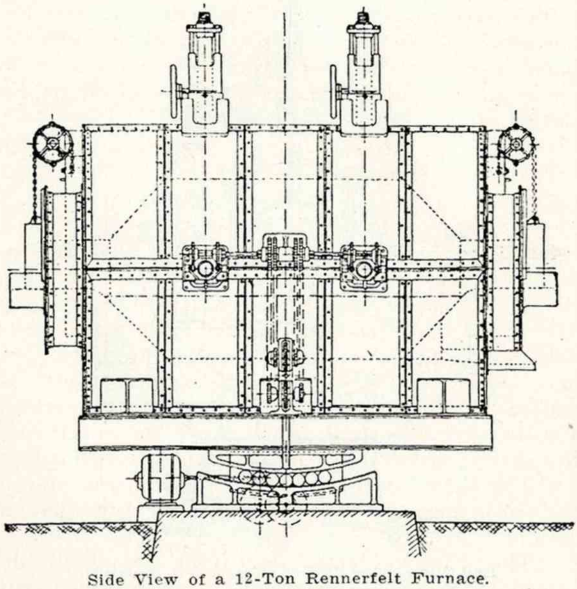
Independent Arc Furnaces.—Heat is produced by one or more arcs above the charge in a refractory chamber in this type of furnace and the steel is heated by radiation from the arc. The Stassano steel making furnace is an example of this class. It usually consists of a chamber lined with magnesia blocks and three electrodes supported from the sides at an angle of about 15° with the horizontal. It is mounted on trunnions and may be tilted for skimming the slag or pouring the metal. The length of the arcs drawn may be regulated at will and movements of the charge do not vary the load. It is said that the load is almost non-inductive and very steady.



End View of a 12-Ton Rennerfelt Furnace.

Types of Independent Arc Furnaces.—The Stassano furnace in types similar to that described above was the forerunner of the Rennerfelt. The former started with a radiating arc, playing almost horizontally over the bath, whereas the latter furnace forces the flame down on the charge by employing a special electrode arrangement.

Polyphase current of any frequency or voltage may be used but three-phase current is generally supplied to the transformers and changed by means of the Scott connection to two-phase three-wire current at 70 to 110 volts. One electrode enters centrally through the roof and two horizontally through the sides. The diameters of the electrodes varies from 1½ in. for the small sizes up to 4 or 5 in. for the large sizes. The middle or combined electrode carries about 40 per cent more current than either of the side elec-



Side View of a 12-Ton Rennerfelt Furnace.

trodes. If direct current is used the horizontal electrodes are coupled in parallel, whereas the vertical electrode is connected with the other pole.

The furnace is generally built with a horizontal cylindrical steel shell, supported on rollers or trunnions with one charging and casting door on the side or in the end of the furnace. The shell is lined with asbestos board, next to which firebricks are built in rings. An acid or basic lining is then placed over the firebricks.

The electrodes in the smaller furnaces are manually operated, whereas they are automatically regulated in the larger types. It is not necessary to adjust the horizontal electrodes during the furnace operation.

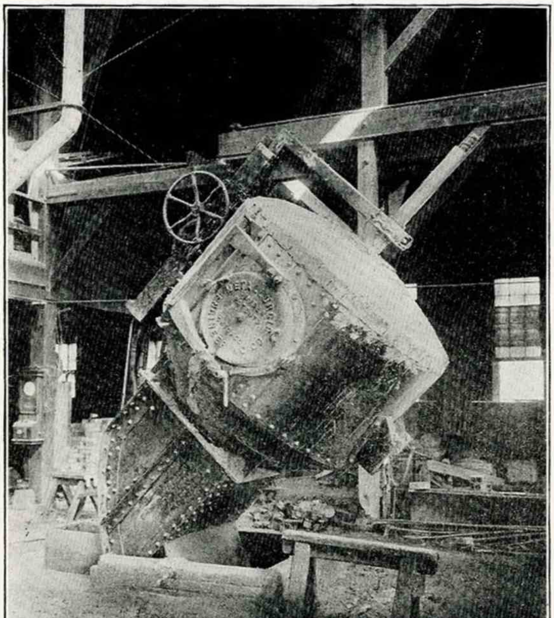
Direct Heating Arc Furnace.—The charge forms one pole of the circuit in this type of furnace and is thus heated directly as well as by radiation. The simplest types consist of an enclosed chamber lined with refractory material and provided with two electrodes, one at the top which is adjustable and one which is fixed in contact with the charge at the bottom. The arc is made to play between the upper electrode and the charge.

Types of Direct Heating Arc Furnaces.—The Girod furnace is a typical example of the direct heating arc furnace. It is provided with one or more adjustable carbon electrodes of one polarity supported from the top. The lower electrodes are made up of a number of iron or steel bars passing through the bottom of the furnace and making contact with the charge. The casing is of iron or steel lined with magnesite or dolomite. The cover is lined with silica bricks and may be lifted off. The furnace is made round, or square with rounded corners. It is easily operated, and the electric current, which passes through the entire charge, makes it heat quickly when started cold.

The Keller steel furnace is similar in principle to the Girod furnace, although differing somewhat in design.

The "Electro-Metals" steel furnace is usually designed for two-phase operation. It is provided with two adjustable carbon electrodes which enter through the roof. A permanent carbon electrode in contact with the metallic shell is built into the bottom of the furnace. The magnesite lining covers the bottom electrode completely. One phase is connected to each top electrode, and the other pole of each phase is connected to the bottom electrode. When the furnace is started cold, current passes between the two upper electrodes through the metallic charge. As soon as the lining is heated it begins to conduct current from the bottom electrode through the charge to each top electrode. This furnace will operate more steadily than the Girod or Keller because if one arc is broken the whole supply of energy is not cut off.

The Snyder steel furnace is of the single electrode direct heating arc type and has met with con-



Snyder Steel Furnace.

siderable favor. There are about 15 of these furnaces in use in the United States and Canada at the present time, varying in capacity from 6 to 30 tons of steel castings per 24 hours. Several furnaces are being used for smelting ferrosilicon, one for melting brass and seven for special chemical work.

Series Arc Furnaces.—As the name implies the direct heating series arc furnace has two or more arcs in series. The current passes from one electrode through an arc to the charge and from the charge through another arc to another electrode. The hearth is usually made of burnt magnesite or similar material.

Types of Series Arc Furnaces.—The Heroult is the best known example of a series arc steel furnace. It has made the most favorable impression in this country, as evidenced by the fact that there are now about forty in use in the United States. It is usually lined with dolomite brick next to the casing with an interior lining of crushed dolomite. The roof is made of silica brick covered on the outside with a steel casing. The two electrodes are cooled with water jackets, and are each automatically adjusted by the variation of the furnace voltage.

The operation of a five-ton Heroult furnace is shown in some data prepared by Professor Eichhoff of Charlottenburg:

Generator Capacity.	Condition of Charge.	Length of Heat.	Kw-hr. per ton.
750 kw.	Cold	6.05 hr.	725
750 kw.	Cold	6.63 hr.	795
750 kw.	Cold	7.22 hr.	868
643 kw.	Hot	2.57 hr.	265
643 kw.	Hot	3.15 hr.	324

The Keller furnace is another type of series arc direct heating furnace. It is provided with four carbon electrodes and may be used for single, two or three-phase operation.

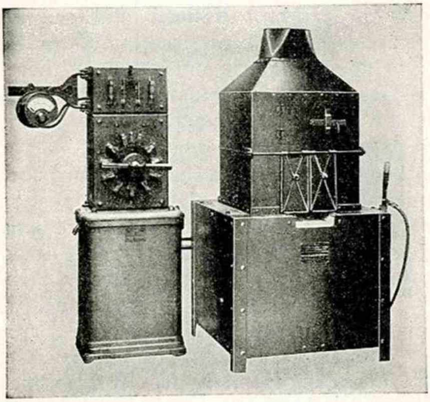
CHAPTER XII

LOW TEMPERATURE ELECTRIC FURNACES AND OVENS.

Field of Application.—Aside from the electric furnaces used in electrochemical and electro-metallurgical processes there are many other electric oven and furnace applications designed for industrial heating operations which require relatively high, moderate, or low temperatures. The possibilities for applying electric heat in this manner are so many and varied that only a small percentage of them will be considered. The various processes will be classified with reference to their temperature requirements and to the kind of work which they are intended to accomplish.

Advantages of Electric Operation.—The points of superiority of electric furnaces to fuel furnaces are numerous and vary considerably with the character of the work to be performed. Some of the obvious advantages are the elimination of fire and explosion hazards. The danger of overheating or burning the charge is also removed. For tempering, forging, hardening, annealing, etc., the uniform heat obtainable is ideal. The reduction in scale formation during the heating of tools, saves the metals and insures a better finished product. Unlike fuel equipment, the electric furnace gives off little heat to the surrounding atmosphere and the working conditions are therefore far more satisfactory in hot weather.

Furnace Processes.—Resistance furnaces may be used for vitreous enameling, for heating bolt and rivet stock, for welding and forging steel parts, for hardening high speed steel, and for melting such metals as copper and gold. The temperatures required for this work may vary from 1800° to 2500° F. Furnaces operating at temperatures from 850° F. to 1800° F. are often used for (1) case hardening, (2) annealing brass, copper, malleable iron, carbon steel and high speed steel, (3) hardening some high speed steels, and carbon steel, (4) melting aluminum, silver, zinc, etc. Temperatures varying from 500° F. to 850° F. are often employed for boiling varnishes, heating oil tempering baths, sherardizing, some forms of annealing, and for



General Electric Type RHF 25 kw. Hardening Furnace Outfit.

melting lead, tin, babbitt, etc. Temperatures of from 200° F. to 500° F. are utilized for heating cores, vulcanizing, drying impregnated woods, and baking enamels, lacquers, japans, insulating compounds, etc. Lower temperatures may be employed for various drying purposes, bacteriological processes, incubation, etc.

Carbon-Resistance Type Furnaces.—For temperatures ranged from 850° F. to 2500° F. this type of furnace is often used. The walls are usually constructed of fire brick supported on iron framework. The heating chamber is lined with refractory material and equipped with a main and an auxiliary resistor. Powdered coke is the main resistor and is laid to a depth of several inches upon the furnace floor. The roof is the auxiliary resistor. It is made of special refractory material that becomes an electrical conductor when heated to a high temperature. Both the main and auxiliary resistors are in contact with the carbon electrodes at opposite sides of the furnace. By controlling the ventilation in this type of oven an oxidizing, neutral, or reducing atmosphere may be secured. If the ventilation is cut off, the oxygen in the air combines with the carbon. Neutral and reducing temperatures are essential in the treating of various metals and the value of electric operation is therefore apparent. These furnaces are usually controlled by thermostatic devices which operate relays and switches mounted on main control panels.

Another type of carbon resistance furnace consists of two piles of flat carbon plates on opposite sides of the furnace. The two sets of resistors are usually connected together at the top and current introduced at the two lower ends by means of heavy carbon electrodes. Heat is generated by the resistance which the carbon plates offer to the flow of electric current. The Hoskins Company manufactures small crucible, muffle, and drill furnaces of this type. It also makes carbon resistance tube furnaces using carbon rings to which energy is supplied from opposite ends of the tubes.

Metallic Resistance Type Furnaces.—For producing any desired temperature up to 1800° F. the heating units may be made of metallic resistance material. They are adaptable to all kinds and classes of work where a clean, dry, uniform heat of low or moderate temperature is required. There are so many different designs of metallic resistance furnaces, which depend upon the class of work for which they are to be used, that only a few will be described. They are usually controlled thermostatically. The heating elements may be in the form of grids or coils of wire.

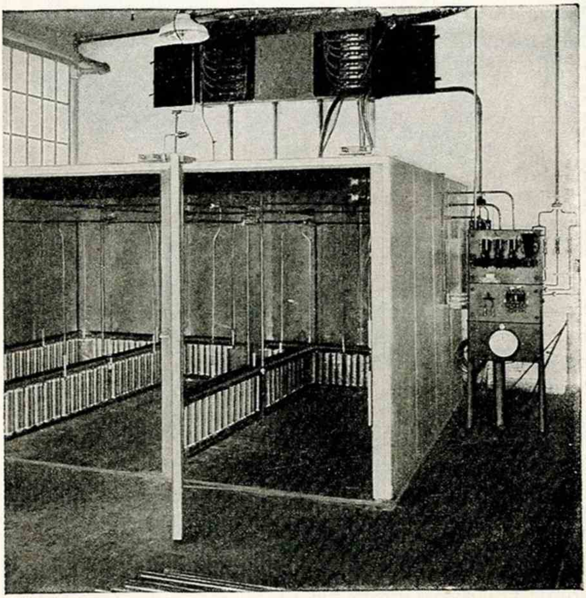
Some of the industrial processes that may be performed with electric heat, and the temperatures required are given in the accompanying table:

Process.	Temperature Range. Deg. F.
Baking of japan	300- 600
Baking of varnish and paints	100- 300
Baking color enamels	100- 300
Baking foundry cores	350- 500
Baking insulations	200- 500
Annealing copper	350- 700
Annealing aluminum	500- 800
Annealing glass	900-1000
Tempering steel	200-1000
Melting lead	620- 700
Melting tin	450- 500
Melting babbitt	450- 700
Wax and compounds	150- 500
Heating coils	100-1000
Heating metal molds	200-1000
Lumber drying kilns	100- 200
Boiling varnishes	150- 500
Soldering	400- 650
Glue pots	100- 200
Melting type-metal, linotype machines	625- 700
Sheradizing	650- 700

Furnace Selection.—In order to select the proper type of furnace for any kind of work it is necessary to know the temperature to which the material is to be heated, the number of pounds and character of material to be treated, the weight and dimensions of each piece, and whether the material is to be melted, forged, hardened, tempered, or annealed.

A furnace should be selected of the proper kilowatt capacity and dimensions for the work in hand. Its thermal efficiency should be high, and it should be designed as nearly as possible for continuous operation at its maximum capacity in order to insure economic and satisfactory results.

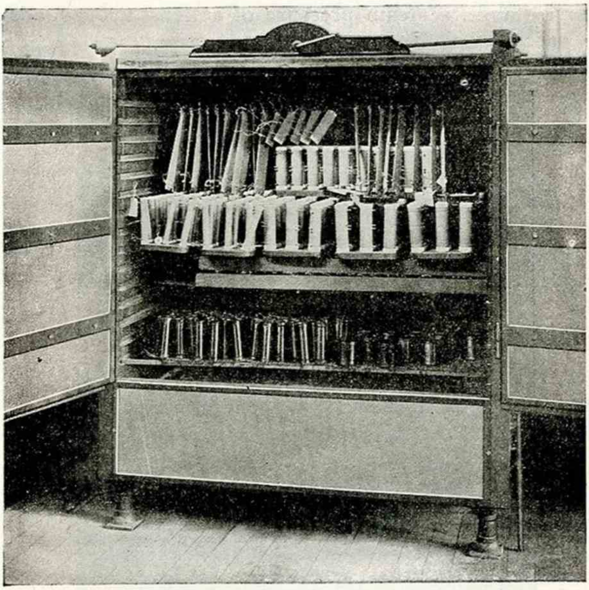
Enameling Ovens.—The extremely rapid progress that has recently been made in the utilization of electricity for baking enamels, lacquers, japans, etc., has opened up a very wide market for central station power. After making careful preliminary investigations into the relative merits of fuel and electric enameling ovens the Overland Automobile Company has installed 6000 kilowatts capacity in enameling ovens having a total content of 50,000 cubic feet. The Ford Company has also arranged to equip a large number of ovens with electric heaters at its main factory and at its various assembling works throughout the country. Both concerns have remodeled fuel ovens, instead of waiting to build new electric ovens, which is conclusive evidence of their confidence in the superiority of electric operation. A number of other large concerns are arranging to take similar action.



Japan Baking Oven.

Advantages of Electric Enameling Ovens.—Electricity supplies a clean, dry heat that is under positive control and uniform in all parts of the oven. The radiant heat drives off the water vapors, produces no additional moisture, and gives off no harmful products of combustion. The enamels have a finer finish, and brighter gloss, are of better quality, and can be turned out with greater speed than with any type of fuel equipment. The hazard from fires and explosions is also reduced by electric operation.

In baking enamel it is important to drive off the water vapors and to oxidize the enamel film in order to secure a bright, fine finish. Each cubic foot of gas burned in a fuel oven throws off two cubic feet of water vapor which constantly adds to the moisture to be removed. In the gas oven the oxygen of the air is consumed very rapidly thereby retarding the oxidation of the enamel film. The excessive ventilation required in the gas oven to remove moisture and other

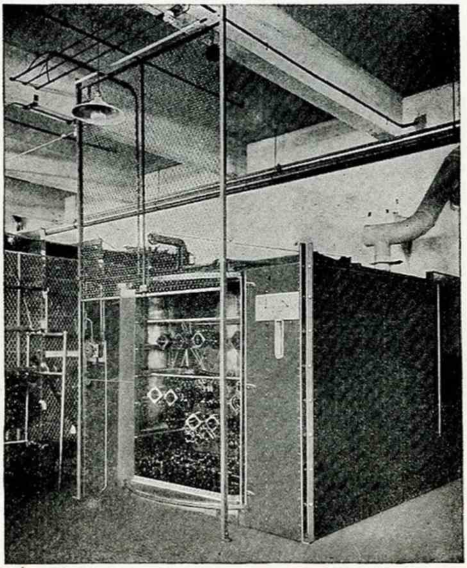


Drying and Baking Oven Loaded.

products of combustion, and to supply sufficient air for the proper oxidation of the enamel film, not only carries away great quantities of heat but picks up dust particles from the outside air which are deposited on the soft enamels.

The radiant heat supplied by the electric method is distributed uniformly throughout the oven whereas the fuel heat is likely to be more intense at the top than at the bottom, especially when rapid ventilation has to be provided. The danger of overbaking is entirely done away with in the electric apparatus. The labor cost is reduced, and the ovens being thermostatically controlled, no watchmen are required at night.

Steam heat cannot be used for high temperature enameling on account of the excessive steam pressures required. In order to attain a temperature of 400° F. for instance, a steam pressure of at least 250 pounds is necessary.

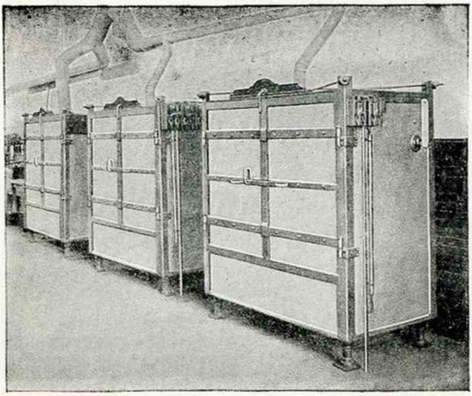


Combined Steam and Electric Japan Baking Oven (One compartment being loaded and the other baking).

Greater Production.—Electric ovens have been found capable of turning out from 40 per cent to 60 per cent more product than other types. Practically all the available thermal energy is directly applied to useful work in the electric oven. It may be operated at very nearly the limit of safe operating temperatures without fear of destroying the product.

Although, in some cases, the total cost of electricity for heating an oven is greater than where fuel is used, the improvement of the work, and the increased output, usually warrants its adoption.

Characteristics of Enamels.—Different grades of enamel are required for different classes of work. They vary in their analyses and in their baking treatment. Some harden at low temperatures, and others will stand relatively high temperatures. Some material to which enamel is applied, will not stand high temperatures, whereas other material may be heated



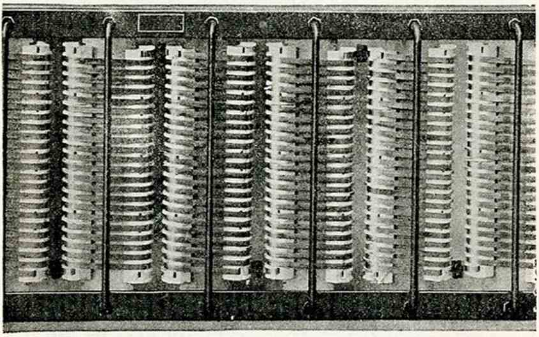
A Set of Drying and Baking Ovens.

as hot as the enamel will permit. Three or four hours' application of heat at 160° F. will dry Japans that require twenty-four hours or more to harden. Enamels that will bake in 45 minutes at 500° F. require from four to five hours when the temperature is maintained at 300° F.

The greatest economy is derived from the use of high temperature enamel. By bringing up the temperature rapidly, and doing the work quickly, convection and radiation losses are reduced.

Equipping Fuel Ovens for Electric Heat.—An oil or gas fired oven may be fitted with electric heaters by replacing the burners and other fixtures with electric units. If the old oven is not thoroughly insulated against heat losses it should be reconstructed to insure satisfactory operation. The ventilation of the oven should be reduced, and arrangements made to cut it off entirely after certain temperatures are attained.

There are several kinds of enameling ovens designed for electric heat. They are all thoroughly insulated against heat losses. The units may be placed on the floor, or mounted on the walls, depending upon the size of the oven, and the shape and quantity of the work.



General Electric 400 Volt Oven Heating Unit.

Revolving Type Ovens.—In this type of oven the work is pushed into the oven on a carriage, and while one charge is baking the side opposite may be loaded. It is revolved by a motor attached to a worm gear. The space taken up by this type of oven is relatively small, and it does not have to be cooled down each time a charge is inserted.

Drying Ovens. — Electric heat has been successfully employed for drying varnishes. In practice, ovens varying in width from 12 to 18 ft., and in length from 15 to 35 ft., are usually employed. The dryers are designed with wood or iron frame works covered with fibre board, sheet iron, wood and asbestos, in a way to build up dead air spaces and retain the heat. Thermostatic control devices, for maintaining uniform temperatures, are usually provided.

The average temperatures required inside the dryers for securing the best results are as follows:

	Deg. F.
Varnishes on wood	110 to 125
Varnishes on metal	110 to 130
Stains on wood	100 to 125
Fillers on wood	110 to 125
Primers on wood	115 to 125
Primers on metal	120 to 140
Rough stuff on metal	120 to 140
Enamels on metal	140 to 170

The maximum temperatures should be avoided unless the woods are free from moisture and easily softened ingredients.

The periods required for drying various coatings subjected to the above temperatures are approximately as follows:

	Hours.
2 and 3 day varnishes require	3 to 6
4 and 5 day varnishes require	4 to 7
5 and 6 day varnishes require	4 to 8
7 and 8 day varnishes require	6½ to 10
Fillers require	4 to 6
Water stains require	2 to 2½
Rough stuff requires	2½ to 3½
Primers require	4 to 8

The most desirable humidity to maintain during operation varies with the varnish composition. Some quick drying varnishes require no artificially produced moisture, whereas others need it to retard surface drying. Premature drying often interferes with the evaporation of volatile elements and the necessary penetration of oxygen into the coating. Simple devices for adding moisture to the air may be obtained.

Heat Losses Through Oven Walls.—Some interesting tests of thermal insulation of electric ovens printed in the Electrical World of May 27, 1915, page 779, afford information of considerable value to the oven designer. The apparatus used consisted of a specially constructed double walled oven having interior dimensions 34½ in. wide, 35½ in. high and 55⅞ in. long. The walls were made of half-inch asbestos board, calked with 85 per cent magnesia plaster, with a space between the inner and outer walls of approximately two inches. Six kilowatts capacity in heaters, arranged for a wide range of load, were installed in the inner chamber. Careful tests of heat losses were made under the following conditions:

(1) With the outer walls removed.

(2) With the outer walls in place, leaving an air space between the inner and outer shells.

(3) With three wooden strips on baffle plates placed horizontally between the walls around the entire oven dividing the space between the shells into a series of four air spaces.

(4) With the space between the walls packed with cotton waste.

(5) With the space between the walls packed with mineral wool.

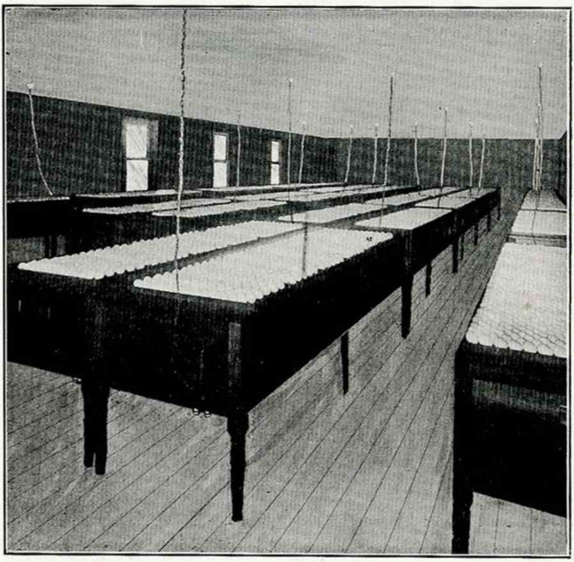
The tests of course indicated the greatest losses with the outer shell removed. The use of the outer wall increased the efficiency about 60 per cent. The baffle plates used in the third test had no appreciable effect. The cotton waste improved the thermal efficiency nearly 50 per cent and the mineral wool nearly 90 per cent. A summary of the results obtained is shown in the table.

Test.	Nature of Wall.	Thermal Resistance Rating.
1	Single shell	1
2	Double shell and simple air space	1.62
3	Double shell and cellular air space	1.62
4	Double shell packed with cotton waste	2.38
5	Double shell packed with mineral wool	3.07

CHAPTER XIII

INCUBATING AND BROODING.

Modern Methods.—Although artificial incubating and brooding has been practiced for many years in Europe, Asia, and the United States, the latter country has been most progressive in developing means for utilizing electric heat as a substitute for heat produced by fuel combustion methods. The superiority of electricity is quite obvious to anybody familiar with the poultry business. The number of fuel heated incubators and hovers in use in this country reaches



Portion of White Hatchery, Petaluma, Cal.
(Capacity 40,000 eggs.)

well into the millions, but the vast field which the application of electric heat to these devices has opened up for the manufacturer of heating apparatus and the distributor of electric energy is little appreciated. In one small town in California about 10,000,000 chicks are hatched annually by artificial means. The hatching and brooding of these chicks would require about 3,000,000 kw-hr. per year, if electric operation was substituted for fuel.

The character of the load is desirable from the standpoint of the central station. The machines are non-inductive, and the diversity factor is naturally high. Where a large number of machines are in use the load is not one that varies greatly with the season of the year as might be supposed.

The processes of incubating and brooding are outlined in order to convey a clearer appreciation of the advantages afforded by the application of electric heat.

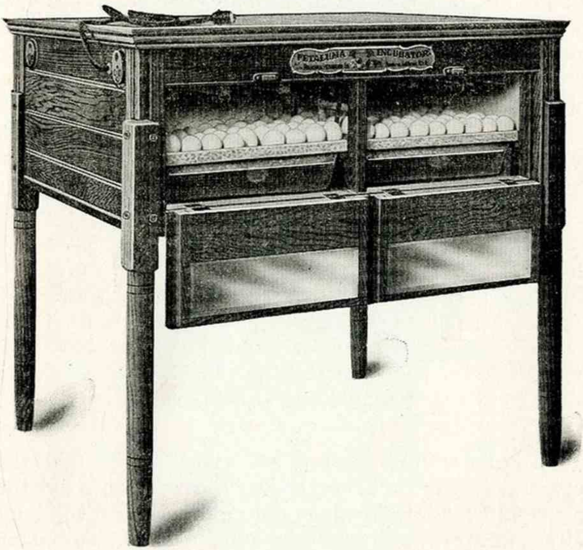
Poultry Incubating.—All kinds of eggs may be hatched by artificial means. The period of incubation varies with the kind of egg and with temperature conditions. If the heat has been maintained at too low a temperature during the period of incubation, or if the eggs have been chilled or overheated, the hatching may be delayed somewhat.

The average incubating periods of various kinds of eggs by both natural and artificial methods are as follows:

	Days.
Hen egg	21
Pheasant egg	23
Guinea egg	27
Duck egg	28
Peafowl egg	28
Turkey egg	28
Goose egg	32
Duck egg (Muscovy)	34
Ostrich egg	42

The hatching of chickens by artificial means is perhaps most commonly known, and is therefore described.

Incubating of Chickens.—The eggs are placed on portable trays at an angle of about 45 degrees, with the small ends down, leaving the air cells in the large ends. These trays are then placed in the incubator, and the temperature brought up gradually to 102° F., and maintained at that point for from four to six days, when a test is made. This test consists in holding the tray of eggs to the light. If they are fertile the operator will observe a spider like shadow within the eggs, showing that they are germinating. The eggs that are not fertile will be perfectly clear, and will be removed from the tray. Another similar test is often made about the fourteenth day. After the first test is made, the temperature is usually brought



Petaluma 200 Egg Incubator.

up to 103° F. and maintained at that point until the hatch is off. The temperature is always taken with the bulb of the thermometer even with the horizontal plane of the eggs.

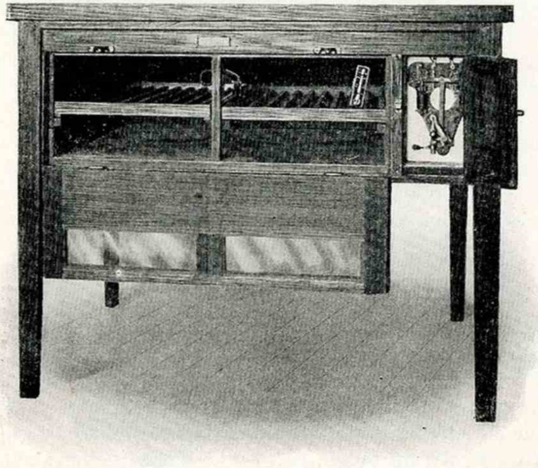
After the eggs have been in the machine about seventy-two hours, they are cooled daily by removing the trays from the machine for from one-half hour to two hours, depending upon the temperature of the incubating room. When they have cooled to about the temperature of one's body, (which may be observed by holding one of them against the cheek), they are put back in the machine. The eggs are cooled to allow the germ to rest, for otherwise the chick when hatched would be weak and nervous. Each time the eggs are cooled they are turned at a different angle, but the small end is always kept pointing downward.

Esco 100 Egg Incubator.

Constant observations are made to see that the egg is drying down properly. By the eighteenth day the air cell in the large end should be dried down to about 30 per cent of the total volume of the shell. To hasten the drying process, ventilation may be increased provided no drafts are produced. In case the eggs dry down too rapidly, the bottom of the incubator may be sprinkled, or a slight spray of water given the eggs.

After the eighteenth day the incubator is closed until the chicks are taken off. A slight film of moisture, on the lower edge of the inside glass, usually indicates that the air is of proper humidity for "pipping." As the chicks "pip" through their shells, they drop through the trays to the space below, known as the nursery. After they are about twenty-four hours old, they are removed to the brooders.

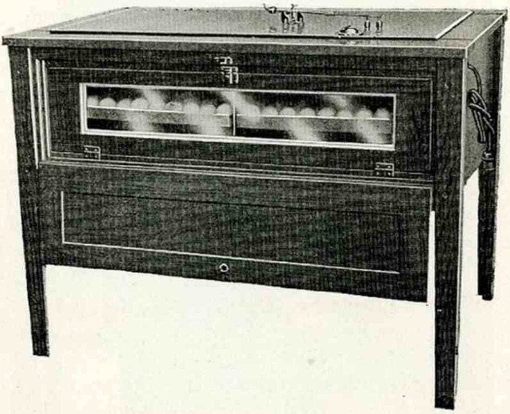
Electric Incubators.—These appliances usually consist of square or oblong cases mounted on wooden supports. They may be double walled with shoddy, mineral wool, asbestos, or other heat insulating material interposed, or single walled lined with heavy paper. Tight fitting double doors, the inner one always of glass, are provided along the front for examining the interior and moving the egg trays. These trays are made of either wood or metal and are inserted in the machine about four inches from the bottom. The heating elements are usually mounted near the top of the egg chamber, although in some makes of double deck incubators heating elements are placed near the bottom, as well as at the top.



Electro-Hatch 200 Egg Incubator.

Single deck types are claimed to be more satisfactory than double deck machines, on account of the more uniform heat that may be applied on a single plane. On the other hand, the double deck type requires less energy for heating a given number of eggs. In the single deck types provided with top heating units, the temperature is naturally higher above the eggs, and lower below them. The temperature in the nursery below the trays is therefore maintained at about 95° F., which is considered most desirable for newly hatched chicks.

The thermometers used in incubator work should be high grade instruments, because it is essential to know at all times just what temperatures are being



Esco 200 Egg Incubator.

maintained. A slight error in the thermometer will have a large influence on the success of the hatch.

Most of the thermostats that have been developed for use with electric incubators are extremely sensitive and are capable of maintaining the desired temperature to within ¼° F. to ½° F. These devices should be simple in construction, positive in action, and absolutely reliable, in order to insure the best results.

A well constructed single deck machine is generally provided with an average of about 75 watts heating capacity per 100 eggs. The average current consumption has been found to be about 10 kw -hr per