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The Development of Industrial Electric Heating for Low Temperature Enameling

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THE development of the electrically heated enameling oven within the past seven years is due to a concentration of effort on the part of electrical manufacturers and central stations upon a single industry—the automotive; and was accelerated by a willingness on the part of that industry to co-operate.

Previous to this development, the ovens were heated with gas, the burners being usually placed directly in the oven, and the heating being accomplished by the heated air of combustion bathing the work *en route* to the ventilation ducts placed in the roof of the oven. The ovens were poorly constructed, practically no attention being paid to thermal insulation, due to the low price of fuel. The art of enameling was extremely crude, the enameling departments being at the mercy of men who professed to possess so-called "trade secrets," the majority of whom knew little about the technique of enameling, and were at a loss to account for the large percentage of rejects that frequently occurred.

The first experiments made to electrify enameling ovens consisted in placing makeshift electric heating units in old gas ovens. Practically nothing was known as to the chemical action resulting from the baking of enamels, hence the first effort was to duplicate the results then being obtained with gas. Enamels of the kind under consideration consist of an asphaltic compound, carried in a suitable colvent with enough oil to make it resilient after baking. It was known that the solvent was driven off, and that the oils underwent oxidation, but practically nothing was known as to the ventilation problem involved. In burning the gas directly within the oven, an excessive amount of air was necessarily and fortunately introduced, automatically and unintentionally taking care of a condition that was not generally known to exist.

The first experiments using electric heat disclosed three points of advantage, namely, elimination of fires due to a combustible fuel, reduction in time required for baking, and a baked product having a smoother surface. Tests subsequently made by the research department of the Detroit Edison Co. revealed the fact that the baking in an electrically heated oven was accomplished largely by radiant heat, which seemed to penetrate the enamel quicker and to a greater depth than when heated by convection currents as in the direct gas ovens. The lack of products of combustion within the oven accounted for a cleaner product.

It was found, however, that the cost of operation was excessive as compared to gas, and knowing that a large amount of heat was being carried off in the vent ducts, it was thought that this source of loss could be eliminated, since no air was required for combustion. The first experiment consisted in closing up the oven as tightly as possible, and attempting to bake, but it was discovered that the enamel would not bake, regardless of the length of time that work was in the oven, but remained in a "tacky" condition. This brought out the fact that a certain amount of air was required for oxidizing the enamel.

A continuation of these tests to determine the proper amount of air for oxidizing purposes resulted in a violent explosion of the oven, which almost completely demolished it. This forcefully brought attention to the composition of the enamel, which was found to consist of approximately 50 per cent naphtha as a solvent for the asphaltum, which was distilled off as a gas. Most of the heating elements used at that time were operating at a temperature of approximately 900 deg. F., hence it was thought that if heaters were designed to operate at sufficiently low temperature, the ignition of the naphtha vapors could be eliminated, and a restricted amount of ventilation be used.

A small test oven was constructed, electrically heated, with positive means for controlling the air entering, and the gases leaving the oven. Samples of many kinds of enamels were obtained and subjected to the same tests. These experiments consisted in placing a small vessel

Interior view of one of the ovens of the Cadillac Motor Car Co. Note vent ducts on floor, projecting out from sides.

containing enamel within the oven, and with the inlet and discharge ducts closed, raising the temperature of the oven to a high temperature, cutting off the heaters to insure a stabilized uniform temperature within the oven, then opening the inlet and next the exhaust duct. Within a few seconds after opening the vent ducts, an explosion would occur. Similar experiments were made at reduced temperatures, with explosions in each case. Explosions were readily obtainable at a temperature of 550 deg. F., and in several cases, at the baking temperature of the enamel itself, demonstrating the impracticability of attempting to operate with a heating element of sufficiently low temperature to eliminate the possibility of explosions when restricting the ventilation.

During these tests, it was noted that after each explosion the flames appeared to burn from the floor. It was first thought that this was the result of the enamel being blown out of the container, but more thorough investigation disclosed that the flame was due to the ignition of the volatile gases, which appeared to settle on the floor. Tests were then made to determine definitely the action of the volatile gases within the oven, and it was found that they were heavier than air and would first descend to the floor, filling up the oven like so much water. The gases were driven off very rapidly upon heating, consequently, before the baking temperature was reached, the mixture within the oven would be too rich to explode. Upon releasing some of the gas and admitting fresh air, the proper explosive mixture would be obtained. Under normal conditions of ventilation, the gases, after descending to the floor, would become heated, and ascend to the roof, passing out through the vent duct.

As a result of these tests, the following facts were established:

1. With restricted ventilation, explosions were possible in enameling ovens, regardless of the temperature of the heating element.

2. A sufficient amount of air must be admitted to the oven to keep the mixture "lean," or sufficiently dilute to make an explosion impossible.

3. The vapors should be withdrawn at or as near the floor as possible.

The first oven to be put in operation using the floor method of ventilation was also equipped with the roof method of ventilation in case the former failed, or it was found necessary to use a combination of both. Air was admitted back of the heaters. Tests not only showed that it was possible to ventilate from the floor, but that it was the proper way of ventilating when volatile gases must be removed. Repeated tests showed that one-third less air could be used when ventilating from the floor, and that the length of time required for baking was reduced 25 per cent.

The reduction in the time required for baking was not an unlooked for advantage. Heaters, as well as gas burners, were restricted as to location within the oven. The work, after being dipped or sprayed with enamel, is allowed to drip or "set" before entering the oven. Upon heating, the enamel softens, and a certain amount flows off, dripping on the floor. Heaters placed on the floor under the work would soon be covered with enamel, the coking of which would ultimately cause a fire, even if the enamel did not ignite immediately when coming in contact with the heating element. For this reason it was found advisable to place the heaters along the side wall, but as near the floor as possible. With heaters placed in this position, and ventilating at the roof, the direct path for the heated air was up the side walls, across the roof, and out. This left a large space in the middle of the oven difficult to heat, the work necessarily remaining in the oven until that space was heated. In order to heat the coldest portion of the oven up to the desired temperature, the other parts had to be considerably overheated, which was not evident since the thermometer bulb was placed in the door, the coldest part of the oven. Ventilating from the floor, the heated air passed up along the side walls across the roof, and down through the middle of the oven, and out, producing a much more uniform distribution of temperature by bringing the hot air through the middle of the oven and down to the cold floor.

Simultaneously with these tests, oven builders were being interested in designing and building better insulated ovens, and it was soon demonstrated that an oven having 4 inches of high grade insulation was a paying investment over one having 1.5 inches of poor insulation, which was then standard practice.

Furthermore, attention was called to the enormous amount of through metal in the form of bolts and channel iron extending from the inside to the outside of the oven, which in many cases accounted for 50 per cent of the entire radiation loss. This, in course of time, has been reduced to a large extent, consistent with good mechanical construction.

Electrical manufacturers began to appreciate the difficulties encountered in oven work, and to design heating elements specially adapted to ovens. Approximately 95 per cent of all electrical troubles occurred in the terminals or connectors. Copper wires were first used to connect the heaters, the method for making the connections being left largely to the skill and imagination of the electrician doing the work. But bars were substituted for wire, aluminum bus bars for copper, and finally cold rolled steel bus bars were adopted, which has now become standard practice.

In adopting the cold rolled steel bus bar construction, an important step was made in the development of the heater, by a design which permitted the bus bars to be mounted directly on top of the heater, on insulators, attached to the heater frame, and having standard cold rolled steel connectors of sufficient shapes and combinations to permit an installation of the complete equipment within the oven by a workman using only a wrench.

One of the most important developments was that of automatic temperature control for the ovens. Magnetic contactors were in use in connection with the operation of motors, and were first used in connection with ovens as remote controlled circuits, using "on" and "off" push button stations inserted in the magnetic coil circuit. Mercury and vapor tension thermostats were in use for indicating temperature or ringing alarm bells, to which were added adjustable "high" and "low" contact hands, controlling the temperature through definite limits. Suitable relays were added so that the "making" or "breaking" of the high or low contact on the thermostat would cause the main magnetic contacts to open or close, as the case may be, depending upon the temperature within the oven.

Small ovens, 100 Kw. capacity and under, usually have the heaters all placed on one circuit, which is automatically controlled. In many installations, and particularly in larger ovens, the heaters are divided into two or more circuits, one of which may be a constant heat circuit not actuated by the thermostat, and of slightly less than sufficient capacity to maintain the radiation and ventilation losses, or in other words, to maintain the operating temperature without any work in the oven. The rest of the heaters are placed on a temperature control circuit, and are cut on and off automatically as may be required to maintain uniform temperature.

Natural ventilation was used entirely with gas ovens, and for a considerable time with electric ovens. It was found, however, that on certain days a longer length of time was required for baking than on others, and investigation showed this to be due to atmospheric conditions. Investigations also showed that many explosions of gas ovens had occurred on such days, as the result of insufficient ventilation. In ventilating electric ovens from the roof, 20 changes of air at room temperature was figured as sufficient, but later when using the floor method of ventilation 10 changes of air at oven temperature was estimated to be sufficient to keep the volatile gases sufficiently dilute to prevent explosions.

With atmospheric conditions affecting the amount of air entering the oven, it was necessary to provide positive means of insuring a definite amount of ventilation at all times. Furthermore, it was difficult for oven

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builders to design the ventilating system so as to give the required number of changes of air per hour, the tendency being to err on the safe side, with the result that in most cases, under normal conditions, an excess amount of air was entering the oven, causing an excessive loss, and low efficiency of operation. To provide for these conditions, motor driven exhaust fans were used for exhausting a definite amount of air per hour from the oven, insuring positive ventilation, provided the exhaust duct remained open to the atmosphere at all times.

In the baking of enamels, there is given off, in addition to the volatile vapors, a vapor containing oil and asphaltum compounds, in the form of a brown smoke. A tarry substance condenses from this vapor upon reaching a temperature below its distillation point, which is usually at some part of the vent duct external to the oven. This substance solidifies, cokes, and in course of time will gradually fill up the duct unless means are taken for keeping the ducts clean. The gradual restriction of the cross section does not become apparent, and has resulted in many disastrous explosions.

In order to eliminate the possibility of explosions due to vapors condensing and solidifying in the vent ducts, a system has been perfected which, in connection with a motor driven exhauster, automatically shuts off the power the instant the exhaust duct becomes restricted in any manner, or in the event the runner of the exhaust fan becomes loose on its shaft, as happened in one case.

When electrically heated ovens first came into use, gas ovens were being operated at temperatures from 300 to 350 deg. F., and the baking period was from 3 to 4 hours. With electric ovens the baking period was reduced to less than one-half, and with enamels baking at 450 deg. F., the baking period was reduced to one hour, and in some cases to 30 minutes. However, too short a bake is injurious to the enamel, since the vapors are driven off too quickly, not allowing the enamel sufficient time to flow smoothly, also causing craters, due to the rapid expulsion of the vapors, which craters do not have time to heal over before hardening.

In the proper baking of enamels, it is essential that the work and the enamel be heated uniformly, hence the larger the mass the slower it should be brought up to its maximum temperature. Enamel on being heated softens and tends to flow. In fact, it will flow excessively if the heating is done rapidly. A certain amount of softening is essential to produce a smooth finish, but actual flowing and dripping of the enamel off the work should be avoided, since that is not only a waste, but results in lumps being formed at the points where the dripping takes place.

Two things are essential in the baking of enamels, a uniform protective coating of enamel, and maximum adhesion between enamel and the work. The greatest amount of adhesion and the thickest and smoothest surface of enamel is obtained when the work is heated at such a rate as will permit the metal to become uniformly heated at the same rate as the enamel on its surface. Many defects in enameling are traceable to ignoring or being in complete ignorance of this fact.

Much trouble is experienced by manufacturers of automobile fenders, with the rivets and heavy rims coming out of the oven bare or only partly covered. The cause is usually attributed to oil or grease and to improper cleaning, and after more thorough cleaning of the parts, it is found that the trouble has not been appreciably remedied, the bare spots having to be touched up by hand. The real cause is due to the work being run into

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a hot oven or subjected too rapidly to a high temperature, the sheet metal heating up rapidly but the rivets and heavier parts lagging in temperature sufficient to permit the enamel to flow entirely off that part.

The electrification of enameling ovens has permitted the liberation of an enormous amount of heat in an oven in a very short period, consequently, with the necessity for production confronting the user, he is apt to attempt to speed up the baking operation to the limit. The man responsible for the capacity and type of equipment being installed may not have sufficient information in connection with that particular plant operation to predict exactly the results finally obtained. For this reason it is not sufficient to convince a customer that he should purchase electrically heated ovens, and obtain his order, but it is even more essential that an inspection be made of the installation when in operation and results obtained, for the purpose of assuring the success of the entire operation.

Before the adoption of electric heat, oven operations were practically limited to batch processes, due to the difficulty in controlling the temperature, securing and maintaining the correct temperature distribution. The use of electric heat has been responsible for the development of continuous conveyor type ovens of all types, shapes and forms to fit in best with a manufacturer's particular process or location.

The installation of electric ovens at Cadillac Motor Car Co., Detroit, Mich., is an example of the development of the art of baking enamel on automobiles, and is a tribute to the work of the pioneers in industrial electric heating. This magnificent installation also shows the confidence of a large automobile manufacturing company in the superiority and economy of electric heating.

The ovens are designed for a capacity of 100 cars per 9 hour day, 26,000 pounds of work being baked in four ovens each hour. The ovens are the continuous conveyor tunnel type, elevated so as to allow an inclined entrance and exit to give an air seal at each end. The work is hung on the conveyor, is dipped automatically in enamel, and passes through four ovens in succession, the dipping each time being done automatically.

In the first half of each oven, the heaters are placed along the side walls, and approximately three-fourths of the total amount of the air required for ventilation is exhausted from this section, at the floor line. In the second half of the ovens heaters are placed on the floor, the ventilation in this portion being partly from the floor near the side walls, and partly from the ceiling. Heaters along the side walls are protected by wire screen, and those on the floor by sheet metal baffle plates, in case any pieces of work should fall off the conveyor in passing through the oven.