becomes hot its resistance progressively decreases and the voltage must then be decreased to keep the rate of generation of energy constant. If this is done in a series of steps the results are not satisfactory, for when the maximum kilowatts are reached and the voltage is lowered one step the kilowatts are decreased proportionally, and in large furnaces it is a long time before the resistance drops to the point where the desired rate of generation of energy is again reached. This is a most inefficient method of working and the consequent loss will more than pay the interest on the cost of suitable apparatus for regulating the voltage.

Even at the time when these much larger furnaces were built the theoretical conditions involved in their construction were not understood, nor indeed for long afterwards. Thus, when the Niagara furnaces were first built the dimensions of the resistors were found to be altogether wrong, and about that time, when the writer took charge of the furnace department, experiments were tried with flat resistors, though an appreciation of the theoretical conditions of the problem shows at once that, other things equal, the resistor of circular cross-section must be best.

In any furnace in which the charge surrounds a resistor heated by means of an electric current it is obvious that the important consideration is the rate of generation of energy per unit surface of the resistor. The surrounding charge, or whatever it is desired to treat, can at a definite temperature absorb heat at a definite rate. Therefore, if it is desired to preserve the charge at a definite temperature it is necessary to generate the heat only so fast as the charge will absorb it. In other words, it is necessary that the watts should be a certain definite amount per unit surface of the resistor. The knowledge of the absolute value of the temperatures in such furnaces as those used in making silicon carbide is very scant, although some excellent work is now being done on this subject; but from the data obtained experimentally and the theoretical considerations of the working of such furnaces, it is possible to calculate relative temperatures with considerable accuracy.

This was well illustrated in the experimental work done by the writer in the difficult problem of making what Acheson called "siloxicon." This substance is formed by the reduction or partial reduction of silica and is combined in some way with carbon. The great difficulty in making the material is due to the fact that at a temperature very slightly above that at which the reduction of silica by carbon begins the process goes too far and the well known crystalline silicon carbide is formed. In order to calculate the dimensions of a resistor suitable for making the material the only data available were those which could be obtained from a study of conditions in the silicon carbide furnace. Without going into details it is sufficient to say that working in this way a furnace was soon designed which made large quantities of "siloxicon" without the formation of any serious quantity of crystalline silicon carbide.

The object in devoting so much consideration to this subject is because it illustrates in a marked manner the comparative ease with which electric furnaces can be adjusted to delicate temperature conditions. This is, of course, well known as regards small laboratory furnaces, but what we are considering now is a furnace about 30-ft. (9 m.) long, 12-ft. (3.6 m.) wide and 6-ft. (1.8 m.) high, having a capacity for a charge of about 60 tons.

The greatest progress in the electric furnace since Siemens' time has been in the arc furnaces of the kinds he used; in the induction furnaces of Ferranti and Colby; and in the resistance furnace of the Cowles type; but so far as the furnace depending on the use of a heating resistor, other than the charge, is concerned there has not been any great advance as regards apparatus of large capacity. The explanation of this is found in the structural difficulties involved. It is believed, however, that those can be overcome, and, moreover, that it is well worth while spending considerable effort in this direction. In the laboratories with which the writer is connected much time has been devoted to a study of this type of furnace, and more or less successful furnaces worked out. This kind of furnace for example lends itself very readily to a form of apparatus which is bound to be developed sooner or later where the heating is accomplished by means of fuel as well as the electric current. This has been done with success in furnaces on a large scale where the preliminary heating is carried on by means of fuel until a temperature is reached where it becomes economical to use the electric current to get the higher temperatures desired. Moreover, in such furnaces we may usefully employ nearly all of the electric current by jacketing with burning gases which eliminates nearly all radiation from the interior of the furnace by supplying the inevitable heat losses from fuel rather than electricity.

The question of the loss of heat through the walls of electric furnaces is a matter that is now attracting a great deal of attention for its importance is very great. The writer has recently had occasion to give this matter careful consideration owing to the inefficient working of an electric furnace designed for some special smelting work. The testing of this furnace showed that the heat losses amounted to 50 per cent. but merely covering 25 per cent. of the outer surface of the furnace with a moderately good heat insulator reduced this loss nearly 20 per cent.

Before closing the remarks on this type of furnace it may be of interest to note some experiments recently carried out with an electric kiln at the writer's laboratories. The kiln is the invention of Mr. John L. Harper and is of the continuous channel type. Two long channels run parallel to each other and through each of these passes a train of trucks in opposite directions. The centre part of the kiln is heated electrically. With this arrangement, the trucks with their contents passing from the high temperature part of the kiln, give up their heat to the trucks going to the high temperature part. Theoretically with an arrangement of this sort all that is required of the electric energy is to supply the heat losses from the kiln. Various experimental furnaces of this kind have been built, the chief object in view being a study of the structural features of the kiln, such as the best form of resistor, refractory linings, etc., also tests of the control of temperature maximum temperature available, control of atmosphere, heat insulation, etc. The kiln was used for various purposes, but the prinicpal experiments were made on porcelain with the production of "biscuit" and glazed ware. The control of temperature was found to be very good and the kiln was extremely simple to work, requiring very little attention.

It is not pretended that in this paper the subject of the development of the electric furnace has been more than superficially treated, the attempt being simply to take a few examples which would illustrate how the electric furnace has developed and indicate some of the problems involved in its construction and working to-day. This, naturally, confined the subject to a certain extent to matters within the writer's own experience; but it is hoped that this may prove somewhat more interesting than a mere catalogue of modern furnaces compiled from the literature on the subject.