The Application of Electric Heat in the Glass Industry

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GLASS is usually produced by melting the appropriate raw materials in the conventional gas or oil fired furnace with regenerators and recuperators. In recent years electric heat has been applied to glass melting and also for annealing glassware, after it has been worked on the machines to its finished shape. At normal temperature glass is a non-conductor of electricity with a resistance of 10^{11} ohms per cm as compared with a resistance of $1{\cdot}78 \times 10^{-6}$ ohms per cm for copper. But at the temperature of 1400-1500°C molten glass has a resistivity of 1 to 2 ohms per cm. This feature permits the melting of glass electrically. As the molten glass forms a resistor for the passage of electricity, the energy is dissipated in the glass and keeps it molten. The conductivity is electrolytic as the alkali ions carry the electric current. The glass must however be heated to a molten state initially for the purpose.

The advantages of electric melting of glass are: (1) Heat will be generated within the glass, (2) The furnace is smaller than a fuel fired furnace for the same output, and there will be no combustible gases, and no regenerators recuperators, flues or stacks, (3) Better quality of glass is possible at a higher temperature, (4) The temperature is more uniform and can be controlled easier, and (5) The glass is melted rapidly with cleaner, quieter and more comfortable working conditions. Due to the concentration of heat in the glass, the furnace surroundings can be kept cool.

Glass melting furnaces with electric heat have been developed in Norway, Sweden and Switzerland as power is relatively cheap. In recent years similar processes have been adopted in England, France and U.S.A. Even when the economic factors are not predominant certain inherent advantages of electric smelting outweigh other factors, as in the case of silica glass. Electricity is being used for melting as well as for annealing glass. For the all electric process arc, induction, indirect resistance and direct resistance furnaces have been used. But among these, the direct resistance process has been found to be the most satisfactory.

Three distinct processes are involved in a conventional furnace *viz.*, (1) Melting area where the raw batch reacts to form glass at a temperature of 1300-1350°C, (2) The refining area where the residual gas bubbles left after the initial melting are removed from the melt at a temperature ranging from 1400-1500°C, and (3) The cooling area where the glass is allowed to settle, become seed free and homogeneous at a working temperature of 1000-1200°C. The temperature in the tank must be controlled and convection currents avoided, to prevent unmelted batch or seedy glass entering the working end. In addition to using physical barriers, the following procedures are adopted to control the temperature: (1) Current may flow laterally across the tank, the power input from each pair of electrodes being properly adjusted, (2) Current may flow longitudinally between the end electrodes, the shape of the tank being such as to cause the current density to be greater in some parts than others, (3) With current flowing longitudinally horizontal electrodes may be used across the tank, the spacings and applied voltages being adjusted as found necessary.

The first and third are more flexible than the second, the first using less energy input, but the combined system No. 3 with concentrated electrodes is the most successful. All three types have been used with some modifications so that the glass is hotter at the bottom than at the top and glass is drawn off from the bottom.

The combined system is more commonly used in Europe. Some of the types are tabulated below:

The power consumption may be taken to vary from 1000 to 1500 kwh/ton in general. Some special glasses require higher energy up to about 2400 kwh/ton. In the Swiss designs the electrodes also heated up and provided a degree of indirect heating so that the system comprised a combination of direct and indirect resistance heating. Three phase supply was used and most of the current flows down the tank between the

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Design	*Capacity tons/day*	*Energy Consumption kwh/ton*	*Remarks*
French (Sauvegeon)	1.5	4900	Early design — graphite electrodes. Window glass
Norway and Sweden (Racders and Cornelius)	not given (3 to 9 amp/sq. cm.)	1200	Later furnace consumed 730 kwh/ton
French	Low Current density	2400	Graphite electrodes fixed on sides of tank
Switzerland (Borel and Electroverre)	2 Tanks — 25	2000 window and 2400 bottle glass	Round graphite rods side of tank and electrodes closely opposite each other.
St. Gobaint and Romont, French and Swiss. (Peyches and Borel)	45-55	1600	Horizontal electrodes fully across tank
American (Cornelius)	25 Bottle glass	960	
Spain (J. Finger)	5	915	The cornered tanks
England Gell and Halm	15	1250	Borosilicate glass 80.5% silica 800 kwh/ton for soda lime glass

pairs of electrodes and some flows accross the gap between opposite electrodes. Subsidiary indirect heating is afforded by metallic resistors to control the temperature at which glass is fed to the machines. In the St. Gobaint and Romont system the electrodes extend all the way across the tank at right angles to the flow of glass which undergoes same thermal treatment all the way across. The energy concentrates round the electrodes near the surface, produces a convection barrier and prevents the unmelted batch from moving down the tank. The convection currents help to produce a more homogeneous glass. In the American furnace the tank is divided into 3 compartments connected by a submerged throat for melting, refining and working. Soda lime silica bottle glass can be melted at the rate of 1 ton/3 cft./day at 1640°C, using nolybdenum electrodes, resistant to hot glass and having a melting point of 2610°C. In some cases electric boosting is employed to increase the capacity of fuel fired furnaces by about 60 per cent. For 2400 kwh/day 5 tons of glass extra can be obtained (480 kwh/ton).

Annealing is another application of electric heat which gives better control of temperature with forced air circulation. Annealing is necessary to prevent permanent stresses being set up, as the glass cools after forming. Annealing consists of two stages: (1) Heat treatment at a constant temperature in the annealing range for

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49. **High temperature induction furnaces—**

P. H Dundas (Research, **14**, 262, 196). The design of laboratory high temperature induction furnaces has been treated from the theoretical and practical aspects. This article is intended to give a new approach to the use of induction heating as an important high temperature tool.

50. **Significance of inorganic chemistry in process metallurgy—**

E. Wainer (Ind. and Eng. Chem., **53**, No. 7, 3A, 1961).

51. **Mechanism of electron transfer and related processes in solution—**

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52. **The thermodynamics of strong electrolytes: Part I—model of the ideal electrolyte; Part II—Limits of validity of cell lattice; Part III—ionic interaction coefficients, Part IV—interaction of solvated ions—**

M. A. V. Devanathan (J. Sci. and Ind. Res., **20B**, 256, 262. 1961); M. A. V. Devanathan and S Srinivasan (ibid, **20**, 269, 1961); M. A. V. Devanathan (ibid, **20B**, 273, 1961).

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a sufficient time to relieve stress, and (2) Cooling at a slow controlled rate to a temperature below the annealing range so that stresses are not set up in the ware. Cooling may then proceed at a quicker rate, the only limit being that the ware must not be allowed to break under temporary stresses due to temporary differentials. The output from a continuous glass melting furnace is annealed by passage through a continuous annealing oven or lehr the ware being carried on a continuous steel mattress.

With power rates fixed at a reasonably low figure, electric melting of glass could be undertaken with advantage.

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