An important economic task is the proper use of fuel and power, which involves upgrading industrial processes while ensuring more economical fuel and power use and environmental protection.

One way of improving efficiency in glass production is to use a glass charge after preliminary heat treatment. As it is technically difficult to provide preliminary heating for what is usually a loose powder batch, the preparation technology needs to be altered. It is much simpler to heat a granulated or briquetted batch.

Researches by Corning Glass Works and Battelle-Columbus Laboratories [1] have shown that flue gases can be used to heat the batch and provide a considerable fuel saving, while at the same time reducing the discharge of volatiles to the atmosphere by 40-90%, since the volatiles are trapped by the batch.

When a batch is heated to 750°C, it takes up about 1650 kJ [2]. If one assumes that the heat consumed in melting the glass is 2930 kJ/kg, it is evident that about 57% can be supplied to the batch during preliminary heating. Then fixed furnace sizes and heat fluxes can produce a throughput with preliminary heating 2.3 times higher.

The State Glass Institute has researched heat treatment in stack gases for granulated batches used in making sodium silicate [3]. It was found that such treatment is possible with aerodynamic retardation for a falling layer of granules. At the Salavat engineering glass plant, the Salavatsteklo production cooperative has devised and tested a prototype plant for heating granulated batches. This is a vertical shaft consisting of three conical chambers expanding towards the top and placed above the furnace. The granulated batch falls from above and is heated in the upward flow of stack gases. In the experiments, the throughput was varied from 25.2 to 52.8 ton/day. The stack gas temperature was 730-880°C, maximal granule temperature at the exit 480°C on treating 40.8 ton/day. The throughput was increased by 23%, while the fuel consumption was reduced by 20%, and the batch carry off was reduced by a factor 1.6.

The US Environmental Protection Agency concluded an agreement with Corning Glass Works to develop this technology for heating glass batches in order to reduce atmospheric pollution and power consumption [4]. The measurements were made mainly with soda-lime batches, which account for about 75% of all glass made in the USA. Some of the studies were made with borosilicate material. Granule drying conditions were identified to give strengths sufficient for subsequent processing. The granules were heated to 750-800°C. No difficulty arose with granule sintering at that temperature. The reactions during heating were examined by thermography, since it was assumed that some of the gases would be lost and this would reduce the amount of gas to be removed from the glass during clearing. Preheating increased the throughput or provided for a temperature reduction. If the granules are heated to below 600°C, there is little reaction, but the reaction occurs to about half at 800°C, which allowed the final melting temperature to be reduced by 50°C, fuel consumption reduced by 15%. It is anticipated that $8.5 \times 10^{12}$ J a year will be saved by converting about 35% of the glass furnaces to preheating.

In [5], general research results are given from American firms on the use of agglomerated batches with preheating and without it. The purposes were to identify the scope for increasing the throughput, reducing the specific power consumption, improving the glass quality, extending the raw-material range (including the use of very dusty fine-grain materials), reducing the particle discharge to the atmosphere, and improving batch preservation.

The firm of Owens-Corning for example has used granules heated to 800°C, which gave a reduction of 100°C in melting temperature, while the firm of Giegerich used granules heated to 700°C, which increased the melting rate by a factor two, whereas the use of granules...
instead of powder without preliminary heat treatment increased the melting rate by only 20-40%. The energy consumed with unheated granules was 25% less than that with powder, while it was 50% less with granules heated to 816°C. In all cases, the amount of solid discharged with the stack gases was reduced.

Japanese patent 52-147880 records that a preheated granulated charge saves energy, reduces the melting temperature, increases the intervals between furnace repair, and improves the glass quality. The only disadvantage of this technology is the cost of making the granules.

Zippe in the Federal German Republic has developed a new method of preheating a powder charge and glass cullet with stack gases. Indirect heating was used, with the outgoing gases at 500°C, where there was a heat exchanger built into the loading bunker. The heat exchanger consisted of a bunker divided by vertical channels, in which there were countercurrents of the charge and the stack gases. A batch is heated to 350-400°C in the loader, while the stack gas temperature is reduced to 200°C. The firm has developed an apparatus for batch heating with an output of 100 ton/day. The time spent by the batch in the heat exchanger was 4 h. The stack gases were not contaminated by batch dust, so no filtration was needed.

The heat exchanger did not require any additional space or water-cooling system. Calculations showed that the new method increased the throughput by 33% and saved up to 25% of the energy [6].

Soviet specialists (Author's Certificate 897719) proposed premelting in a glass batch by means of a device in the form of a drum whose cross section decreases towards the furnace, which is fitted with a loading window and burners. The drum is made stepped and has separate melting and superheating zones. The device increased the throughput by a factor 1.2-1.5 and reduced the melting-part size. The working life in the flame-fired ovens was also increased.

US patent 4374660 employs glass batch and cullet heating to 540°C by means of stack gases. If heating to 780-815°C is required, burners are used in addition. The preheating chamber receives the charge and the cullet separately, with the coarse cullet going to the bottom large-cell grid and the batch to the upper finer one. The gases leaving the regenerator enter under the cullet layer and pass through it and the batch. The cullet is heated, and some of the particles suspended in the stack gas are removed. The gas then passes through a cyclone to separate the suspended particles. In a 200-ton oven, the preliminary heating to 540°C reduced the heat consumption by 25%. The oxides of nitrogen discharged to the atmosphere were also reduced in amount.

Other American researchers [7] have determined the effects of briquetting and fritting on the heat consumption in glass melting. A batch is briquetted on a roll machine at 3.5-4% water content. The binding agent was dried dolomitized limestone. The fritting was performed at 815°C. The performance from briquetting and fritting was determined from the heat consumption. When glass is produced from raw briquettes, the heat consumption is reduced by 22% by comparison with a powder batch, or by 52% with fritted ones. Briquetting also eliminates the batch carry off.

Preheating exchangers can be classified as follows as regards heat-transfer mechanisms: recuperative, regenerative, and mixer ones.

In the recuperative type, the heat is transferred from the hot outgoing gas to the batch through a wall, with the batch passing through tubes (US patent 4353726) or through slots [6], around which the gas flows. As a rule, the preheater is set up directly on the furnace. The disadvantages of recuperative heat exchangers include the relatively low heat-transfer coefficients between gas and batch, the need to use heat-resistant steels because of the high gas temperatures, and the lack of scope for utilizing the carryover products.

In the regenerative type, the stack gases transfer their heat to metal or ceramic spheres whose diameters are larger than the batch particles (US patent 4409011). The batch and the hot heat carrier enter an inclined rotating drum. The heat transfer is by direct contact. The cooling spheres are removed from the drum and reenter the heat exchanger for reheating, while the heated batch passes to the furnace.

Japanese patent 56-104968 deals with using the heat in stack gases from the melting furnace and hot air from the annealing section to heat glass cullet, batch, and secondary air supplied to the burners. The gases emerging from the regenerator are mixed with hot air drawn from the annealing section and directed to a shaft-type exchanger to heat the cullet to 450-550°C. The rest of the stack gas and air mixture passes to a similar exchanger,