Top heating of the glass surface in an electrically heated pot furnace

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Glasets yttemperatur har betydelse för kvaliteten på handanfångat, degelsmält servisglas. Denna artikel beskriver ett projekt där en eluppvärmd degelugn har försetts med elektrisk tillskottsenergi i valvet ovanför glasytan.

Det primära målet med undersökningen var att i eluppvärmda degelugnar ta fram ett koncept för tilläggsenergi på glasytan. Tilläggsenergin tillfördes med hjälp av valvelement. Det sekundära målet var att optimera fördelningen av energitillförsel från väggelement och valvelement för att minimera energiförbrukningen och förbättra glaskvaliteten.

Försöksugnen har sedan hösten 1995 med framgång använts för produktion av servisglas på Sandviks Glasbruk. Kvaliteten hos tillverkat glas har jämförts med kvaliteten hos glas tillverkat i en konventionellt eluppvärmd degelugn.

Energiförbrukningen var ungefär lika stor i försöksugnen som i referensugnen.

In this project an electrically heated pot furnace has been equipped with additional electrical energy in the crown above the glass surface. But first some information about the background of the project.

It is well-known that electrically heated glassmelting pot furnaces have been used in Scandinavia since the early 60's.

The glass types produced at that time, and also today, are mainly lead crystal, 5-24 % and 30 %, plus soda lime glass.

During the last years new types of more environment friendly glass have been developed in order to achieve:

1. Lower melting temperatures
2. Longer pot life
3. Less cords in the glass
4. Lower energy costs
5. Lead free melting etc.

In certain respects the new lead freee glass compositions have other properties than the earlier glass types. The surface tension is for example different, which can lead to difficulties at gathering made by hand. The viscosity of the glass can also be somewhat different. The different surface tension can result in increased number of gathering blisters. Experience from production has shown that the temperature of the glass surface is of great importance for the quality of hand gathered tableware glass, molten in pot furnaces.

A project group was established in order to find solutions of problems with low glass surface temperature. The Nordic Pot Furnace Project was started in 1991. A study made by Glafo in 1989 of the temperature profile in pot furnaces was of importance for this work. This project showed that a combination of gas fired crown burners and a gas fired bottom burner resulted in a better glass quality than a conventionally heated pot furnace.

Orrefors Sandvik Glassworks had discovered that the temperature of the glass surface was falling when the pot was emptied. This does probably result in an inferior quality of the glass by the end of the working day. This problem is minimized if the furnace is fitted with modern control equipment.

Most of the pot furnaces at Sandvik Glassworks are electrically heated. So called scalped pots are used. The energy is supplied by Kanthal Super elements, which heat up the exterior of the pot by radiation. The energy goes through the pot wall and heats up the glass batch. A smaller part of the radiation energy is led via the crown through the scalp to the glass surface.

In 1994 Sandvik Glassworks decided to start a development project. A working group was established in order to make field tests with one of the 12 electric furnaces at Sandvik. The participants in this group were Sandvik Glassworks, Glafo, Sydkraft Elförsäljning AB, Kanthal AB and AB Ramco.

Goals

The project had the following goals:

- To obtain a higher percentage of saleable glass.

- To lower the energy consumption.

- To work out a concept of additional energy on the glass surface in electrically heated pot furnaces.

- To optimize the distribution of energy supply from wall elements and top elements.

Furnace design

An existing single pot furnace was rebuilt by Ramco. 9 top heating elements were placed above the scalp of the pot (see figures 1 and 2). These were of Kanthal Super quality with a heating power of 30 kW.

The scalped pot was surrounded by 12 side Kanthal Super elements with a heating power of 115 kW.

The furnace heating was thyristor controlled via a temperature regulator.

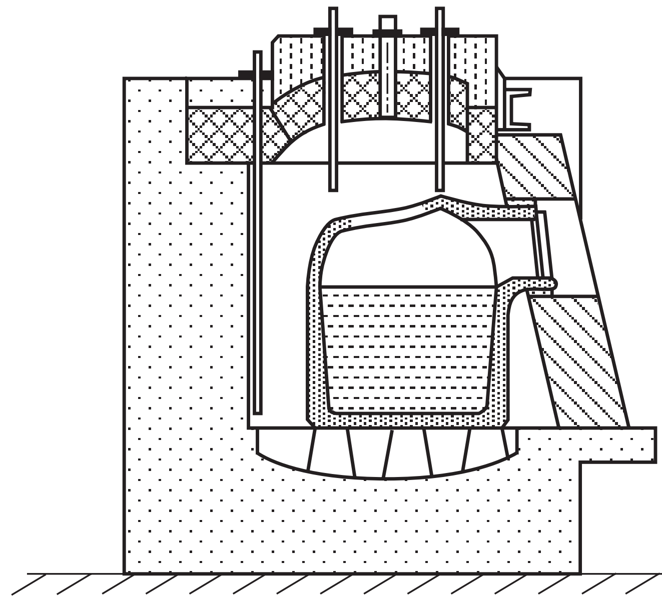

Figure 1 *Electric pot furnace.*

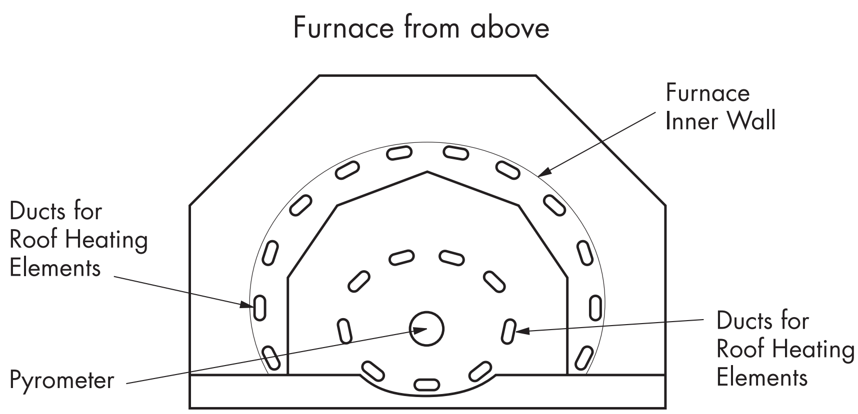

Figure 2 *Layout of heating element.*

The crown and skew back blocks were reconstructed and adapted to the installation of the Kanthal Super top elements. The crown was designed like a dome, enabling the heat to re-radiate on the glass surface in the pot in the best possible way.

Operation of the furnace

The usual glass quality at Sandvik Glassworks, Glasma quality no. 26 D (lead free crystal), has been used during the project. The pot quality has also been the same as usual. The type of glass manufactured in the test furnace has been tableware glass, and similar glass has been manufactured in the reference furnace.

A typical melting cycle is as follows:

- 15.15 hours - The furnace temperature is raised from working temperature, approx. 1160 °C.
- Approx. 15.45 hours - Glass batch is put into the furnace at approx. 1300 °C.
- Approx. 18.00 hours - The temperature reaches the melting point 1400 °C.
- Glass batch is put into the furnace another one or two times later in the evening.
- The temperature remains at 1400 °C until 02.45 hours, and then the gathering opening is closed.
- 06.00 hours - The work starts at approx. 1160 °C.

The temperature is measured and controlled by a thermocouple, which is placed as per figure 2, during the melting cycle. During the working phase the temperature is measured with a radiation pyrometer, placed in the crown according to figure 2.

The top elements were used during the working phase, set on a constant heating power. The temperature was regulated by the side heating elements via the temperature controller.

Reference test

The furnace placed next to the test furnace has been used as a reference. This furnace is a so called Ramco furnace, where the glass in the scalped pot is heated up with 12 Kanthal Super elements. The elements are placed around the pot in the same way as in the test furnace. The temperature was measured with a thermocouple. The production in this furnace has also been tableware glass.

Measuring energy and power

The measuring of the energy consumption in the reference furnace was started before the rebuilding of the test furnace. Thereafter, the meter was moved to the test furnace, which was equipped with a separate meter for the top elements. The registration of the energy consumption, kWh/kg molten glass, was done twice a day.

The depth of the rest glass was measured every day after the work was finished. This figure was then recalculated into kg rest glass. By calculating the pot volume and deducting the sum of the rest glass plus cullets, the amount of glass in the form of pellets added is shown.

We have chosen to define the amount of molten glass as the sum (cullets) + (pellets x glass producing factor). The rest glass has not been included in this calculation, as it has already reached working temperature when the furnace is heated up for melting.

Results of the test

The usual inspection has been the main quality control method also for this project. By routine, statistics on first quality and rejected parts + second quality are made at Sandvik Glassworks. Rejected parts and second quality are then divided into glass defects (cords, stones and bubbles) and breakage and work defaults.

During the weeks 539-541 totally 10.761 pieces of glass molten in the test furnace were manufactured. The percentage of first quality was 77,7 %, second quality was 4,7 % and rejected parts was 17,6 %.

A statistical follow up of the quality of the products manufactured during the whole year of 1994 in the test furnace, i.e. before the furnace was equipped with top elements, shows that the result of first quality was 76,2 %, second quality was 4,4 % and rejected parts was 19,4 %.

The percentage of first quality was thus 1,6 % higher and the percentage of saleable glass, i.e. first quality + second quality was 1,8 % higher during the test period, compared to the results in 1994.

A comparison between glass produced over a long period after the above mentioned test period shows that the percentage of first quality glass increases when top heating is used. Over this longer period the total percentage of saleable glass was 4,3 % higher for glass manufactured in the furnace with top heating.

A more detailed analysis of the above mentioned results shows that the number of rejected parts caused by bubbles has decreased by 0,7 %.

Energy consumption and power

Table 1 shows the energy consumption measured in kWh/kg molten glass in the furnaces during the

Table 1 *Energy consumption of electric pot furnaces.*

	Latest design top and side heaters		Conventional design side heaters	
	Average	Coeff. of variation (%)	Average	Coeff. of variation (%)
Production				
kg/24 h	273	14	267	25
Energy consumption				
kWh/day	467	20	470	8,1
kWh/night	1038	11	960	4,1
kWh/24 h	1505	7,2	1430	3,4
day kWh/kg	1,8	28	1,9	11
night kWh/kg	3,9	21	3,9	10
24 h kWh/kg	5,6	16	5,8	10

weeks 539-541. The energy consumption during weekends is not included.

The figures in table 1 show that the energy consumption in kWh/kg molten glass is approximately the same for the two furnaces. The consumption is somewhat lower in the test furnace with top heating, but the difference is within the margin of error.

Conclusions

The main goals for this project have been achieved. The furnace has been used successfully for production of tableware glass since the autumn of 1995.

The quality of the glass produced in the test furnace, equipped with top heating, is better than the quality of the glass produced in the conventional reference furnace. The percentage of saleable glass was 4 % higher in the test furnace.

An analysis of the glass faults during the same period also shows that the percentage of bubbles is lower in the glass manufactured in the test furnace. The reason for this could be that the glass at the surface of the pot has a higher temperature.

The energy consumption during the test period was almost the same for the two furnaces.

An optimization of the distribution of the energy supply between the top- and side elements has not yet been achieved.

The estimated pay off time for the investment in top heating is approximately 1,3 years.

The result of the project has been successful.

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