

"Method for the economical melting of glass and a glass-melting
furnace used therefore"

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The invention concerns an energy-saving method for melting glass in a glass-melting furnace in which the raw mixture is melted in a melting unit, refined in a shallow refining unit adjacent to the melting unit, and is afterwards homogenized in and drawn off an homogenizing unit with a deeper vat adjacent to the refining unit. The exhaust vents for the burnt gases and the input for the raw mixture are thereby situated at the melting unit's top-end and, at points below the input for the raw mixture, energy is introduced via electrodes. Furthermore, burners introducing heat energy are disposed in the refining unit, together with heat exchangers for exchanging energy between the exhaust gases and the combustion air to be fed into the burners. It also concerns a glass-melting furnace with a melting unit, a shallow refining unit immediately adjacent to the melting unit and, neighbouring on the refining unit, an homogenizing unit of increased vat depth equipped with an outlet for the glass, with a device for introducing the raw mixture disposed at the top-end of the melting unit and with electrodes for introducing electrical energy arranged below the input device for the raw mixture, with fossil-fuel burners disposed in the refining unit, together with heat exchangers transferring heat energy from the exhaust gases to the combustion air to be fed into the burners. Although glass-melting furnaces invariably operate with fuel-saving recuperators or regenerators, they have the disadvantage of possessing a relatively low grade of efficiency. This is not the result of a lack of isolation of the vats but rather, because the heat of the exhaust gases exceeds to a considerable degree the energy required to pre-heat the combustion air. There are limits to any increase in the combustion air temperature, because the means of heat exchange rapidly become too costly. The concomitant high increase in concentrations of poisonous NO^x gases is also disadvantageous.

A number of attempts have been made previously to employ usefully the excess heat of exhaust gases, including employing it to

pre-heat the raw mixture before introducing the latter into the glass-melting vat. These attempts failed, however, because as a result of the temperature increase of the mixture, a pre-melting of some of the components can occur, which causes, on the one hand, the heat-exchange surfaces to become coated, and, on the other, in addition to the pre-melting of some components, as a result of the direct contact between the exhaust gases and the raw mixture, a separation of various other components of the raw mixture can occur, respectively, certain components become so agitated that the dust content of the exhaust gases reaches inadmissible levels and very costly dust filters become necessary.

As a result of the publication of EP-A1-0 230 492 a glass-melting furnace of improved efficiency was achieved by having the exhaust gases cooled in allowing them to flow over a broad surface of a raw glass mixture floating on the hot glass melting. The remaining, already reduced, amount of energy was then transferred to the combustion air in heat exchangers.

This furnace is disadvantageous in that raw glass mixture can be carried over into the refining and homogenization units, thus lowering the glass quality to an undesirable degree.

In US-A-3 198 618, another furnace is developed, in which the exhaust gases flow over a layer of raw mixture floating on the hot glass melting. The disadvantage of this construction is the absence of a refining unit in which the glass can be satisfactorily refined but also, as a result of the use of bubblers, a vertically rotating current is induced which allows unrefined glass or glass mixed with the raw mixture to reach the work vat.

With regard to the prior state as described above, it is the task of this invention to create a method of melting glass and a glass-melting furnace, from which the above-mentioned disadvantages have been eradicated. Furthermore, the proposed furnace possesses a much improved degree of efficiency compared with all furnaces of the prior art, but is, at the same time, more

economical to manufacture. It also operates at particularly low levels of NO_x concentrations and generates a low level of dust content in the exhaust gases without requiring construction elements that are difficult to control and must withstand the high temperatures of the furnace or the heat exchangers.

The upper furnace temperatures and the temperature encountered in the heat exchangers (recuperators) are even lower than those of customary furnaces of the prior art.

Above and beyond the afore-mentioned advantages, the furnace according to the present invention can be manufactured economically and is reliable to operate, whereby fossil and electrical energy sources are, if required, largely interchangeable.

This task is solved inventively by means of a method of a kind described in the introduction: a large percentage of the energy required for melting is fed into the refining unit by means of fossil fuel burners, the exhaust gases flow over the melting unit in the opposite direction to the flow direction of the raw mixture. The gases are drawn out of the furnace close to the raw mixture input point. A current moving in the opposite direction to that of the raw mixture flows from the refining unit through the melting unit at surface level and provision are made to absorb the flames from the refining unit at the latter's boundary and in the upper part of the melting unit, whereby the space above the operating surface is divided into zones with differing temperatures, the highest temperature being in the refining unit.

The process can thereby be so advantageously operated that in the refining unit (zone I) with its highest temperature, the burners fire with a reduced amount of air, in order to reduce the NO_x -formation and in the adjacent unit with its lower temperature, seen from the direction of exhaust gas flows (zone II), the burners disposed at the inflow point are operated with excess air, in order to complete the combustion.

In the case of a furnace of the above-mentioned type, the solu-

tion to the task relating to the invention is such that the temperature of the hot exhaust gas current flowing from the refining unit in the form of a countercurrent to the movement of the raw mixture of the melting unit floor, decreases from the refining unit to the raw-mixture input point and that the melting unit (zone II) is fitted with a radiant heat shield that extends downwards to a point immediately above the operating surface of the vat.

Furthermore, the electrodes disposed below the raw mixture input insure advantageously the induction of a current descending from beside themselves towards the refining unit which the current of hot glass in the melting unit directs downwards, whereby the countercurrent flowing towards the refining unit at the bottom is augmented.

The heat exchange resulting from heat radiation from the burner unit which reduces efficiency is effectively forestalled by means of the radiant heat shields arranged between the melting unit and the refining unit.

The particular advantage of the method according to the invention and its glass-melting furnace comprizes the cooling of the temperature of the exhaust gases to between 800° and 1000° C at their exhaust vent by pre-heating the raw mixture lying on the hot glass melting and the recuperators' warming the air flowing in a countercurrent to approximately 700° C without any great technical expenditure.

As is evident, the glass-melting furnace, together with its method of operation, is capable of solving for the first time, and in a particularly advantageous manner, the problems under consideration. The principle according to the invention comprizes the arranging of the raw mixture on the hot glass melting and pre-heating it there by means of the exhaust gases, simultaneously effecting the cooling of these gases to such a degree that the remaining heat energy can be employed almost entirely to pre-heat the combustion air. The maintenance of the glass in a liquid

state and the achievement of an optimal set of currents in the raw-mixture preheating area of the vat is guaranteed by introducing comparatively low quantities of electrical energy.

Further advantageous arrangements of the invention are listed in the subclaims 3 to 5 and 7 to 10.

In the following, further embodiments of the invention are exemplified in drawings.

- Fig. 1 shows a longitudinal section through a glass vat according to the invention;
Fig. 2 shows a horizontal section through a vat similar to the one shown in Fig. 1, and
Fig. 3 shows a horizontal section through another embodiment of a vat according to the invention.

Conforming with these figures, the glass-melting furnace according to the invention consists of an elongated, rectangular vat with a refining unit 2 and a melting unit 3 that are interconnected with each other, whereby the length of the melting unit 3 is approximately two to two-and-a-half times greater than that of the refining unit 2. The shallow portion of the vat is designated the refining unit 2, in which the burners 20 for firing oil or gas are arranged.

The vat is furnished on the burner side with a partition wall 16, and, on the raw mixture input side, with a partition wall 17 and a longitudinal wall 18. The upper furnace is constituted by a ceiling 1. The melting unit bottom is designated as 9.

In the melting unit (zone II) 3, bottom electrodes are so disposed that they prevent a solidification of the melting in this area, in particular, in the immediate area of the raw-mixture input. Further, solidification is also prevented by inducing in the melting unit 3 a surface current that carries continuously the intensely heated glass from the refining unit 2, where it has been heated to a high temperature by means of the burners 20, to

the area of the raw mixture input.

The raw mixture input takes place in the conventional manner across the entire breadth of the partition wall 17.

In detail, the vat is constructed according to conventional techniques, as this has been described in earlier applications of the applicant, so that a further description can be dispensed with. This is especially true of the design of the heat shields, the roofing, the furnace bottom, the burners, the electrodes and the output 19 at the end of the homogenizing unit farthest from the raw mixture input and of the design of the exhaust gas vents 22 directly adjacent to the raw mixture input.

In the vat interior at the output end of the refining unit 2, there is a radiant heat shield 5 which extends downwards to immediately above the operating surface 4 and which prevents heat radiation into the melting unit 3. As is generally known, in instances of high chamber temperatures, the largest amount of energy is dispersed by radiation and it is thus essential to the invention that the energy introduced into the refining unit 2 by means of the burners 20 remains concentrated in that area.

As further high amounts of heat radiation from the melting surface and, in particular, from the radiant heat shield 5, are directed towards the output side, the melting unit 3 is furnished with another radiant heat shield 7 near the raw mixture input as well as another heat shield 8 between the radiant heat shields 5 and 7. Such an arrangement reliably prevents an appreciable heating of the raw mixture by means of heat radiation energy, and ensures that this heating takes place more or less exclusively by means of the exhaust gases which flow out of the refining unit 2 through the melting unit 3 to the exhaust gas vents 22.

Optionally, the bottom 9 at the the feed-side end of the refining unit 2 can be furnished with a threshold. Essential is, however, that the bottom's falling away evenly to the raw mixture input induces a flow pattern, in which hot glass on the melting's

surface flows back to the raw mixture input and, together with the bottom electrodes⁶, prevents a solidification of the glass there. The bottom in the refining unit is disposed horizontally.

The exhaust gas cooled to about 900°C is fed into recuperators after having been expelled from the furnace. It flows away from these at a temperature of about 150-200°C. At this temperature, the energy of the exhaust gases has been largely transferred to the combustion air.

In the recuperators, the combustion air is pre-heated from room temperature to about 700°C by the cooling exhaust gases and is then fed through tubing to the burners 20. As a result of the relatively low air temperature, the combustion has the advantage that the flame temperatures are relatively low and higher concentrations of NO_x cannot occur. The exhaust gases are not only cooled to a considerable degree, it also shows extremely low concentrations of NO_x so that an operation of the glass-melting furnace is also possible in regions requiring low emission values, for instance, in cities, since by virtue of the low exhaust temperatures the selection of a dust filter poses few problems.

It is important from the standpoint of the operation of the vat that the feed-side end of the melting unit 3 serve exclusively to pre-heat the raw mixture and that the actual melting of the raw mixture first take place at the burner-side end of the melting unit 3, whereby a refining of the glass take place in the refining unit 2 before this is drawn off in the conventional manner via an bottom outlet 19.

Disposed about the refining unit 2 are a number of "bubblers", which can introduce air through the bottom. By means of this air, and assisted, if necessary, by bottom electrodes - a strong circulation of the glass in the refining unit 2 is achieved, so that from the top to the bottom within the refining unit 2, only a very slight temperature gradient can occur. In this manner, the achievement of bottom surface temperatures of approximately

1550°-1560°C are assured, whilst the temperature in the arched roof above the refining unit 2 operating surface does not exceed a temperature of 1580°C. In contrast, the temperatures in the melting unit 3 are much lower. From the raw mixture input to the refining unit, they reach 1100°C to 1300°C.

The homogenization of the glass takes place under reduced heat in the homogenizing unit 2a so that an optimal temperature stratification develops, preventing rotary currents and with them, the transport of contamination into the outlet 19.

As a result of the radiant heat shields 5, 7 and 8, a gas velocity over the raw mixture of approximately 10-15 m/s can be achieved. In addition to the heat radiation transfer, a certain degree of convective heat transfer occurs. The radiant heat shields are, for example, so constructed as to correspond with those horizontal and straight arches employed in dog house arches.

The electrical energy introduced can moreover be so selected in relation to the energy introduced via the burners that the NO_x content of the gas flow does not exceed permissible values. In the case of the employment of a high portion of electrical energy, the NO_x content of exhaust gases sinks, and by reducing this amount, the NO_x content rises.

The glass-melting furnace according to the invention can be manufactured economically, because, by virtue of the lower temperatures involved, inexpensive, fire-resistant materials can be employed.

It is in the nature of this invention that the entire glass-melting furnace, as well as the tubing for the exhaust gases and for the preheated combustion air are heavily insulated. Nevertheless, to the astonishment of any expert, the specific energy consumption can be reduced to the previously unattainable value of 3100-3400 kJoule/kg glass.

In the refining unit designated as zone I, the burners are

operated with such a low amount of combustion air that practically no NO_x formation occurs, as fuel burning is incomplete. The fuel gases are then transferred to zone II, namely the melting unit, and there, at the point in zone II at which current flow begins flow, where a temperature approximately 150°C lower than in zone I prevails, burners are operated with excess combustion air, in order to insure a complete burning of the carbonaceous fuel. In this manner, any loss of efficiency can be avoided. By virtue of the substantially lower temperature prevailing here, practically no NO_x formation occurs, so that the exhaust gases are essentially NO_x -free when released into the atmosphere. The glass melting furnace can therefore also be operated to advantage in densely populated areas.

It is additionally essential that the furnace is operated with a raw mixture containing a large portion of broken, recycled glass, the rest being a conventional raw mixture, so that it is possible to operate the furnace with cheap raw materials. As a result of the ever increasing quantities of broken recycled glass which cannot at present be sorted according to colour, broken glass possessing differing oxidation potential enters the melting vat. In the reaction of glasses of differing oxidation potential with one another, a thick foam develops on the surface of the melting which reflects flame radiation and hinders considerably the transfer of heat into the melting itself.

This foam can be reduced to a considerable degree by employing of a reducing flame, so that even under the most disadvantageous conditions due to the utilization of large quantities of recycled broken glass, the new vat operates more efficiently than vats of the conventional kind.



WHAT IS CLAIMED

1. Economical method of melting glass in a glass-melting furnace, in which the raw mixture is melted in a melting unit (3), is refined in a shallow refining unit (2) adjacent to the melting unit (3), and is subsequently homogenized in and, thereafter, drawn off an homogenizing unit (2a) of greater depth lying next to the refining unit (2), whereby the exhaust gas vent and the raw mixture input lie at the top-end of the melting unit (3) and, under the raw mixture input, energy is introduced via electrodes (6) and burners (20) for introducing energy are disposed in the refining unit (2), with heat exchangers (10, 11) for transferring energy between the exhaust gases and the combustion air to be fed to the burners (20),

characterized in that

the preponderent amount of the energy for melting originates from the introduction of heat energy by fossil fuel burners (20) in the refining unit (2), that the exhaust gases flow over the melting unit (3) in the opposite direction to that of the raw mixture current, escape close to the raw mixture input and the gas flow moving in the opposite direction to the raw mixture current flows over the entire surface (4) of the melting unit (3) and that provisions are made to absorb



at its boundary and above the melting unit (3) the flame radiation from the refining unit (2), whereby the space above the hot glass melting is subdivided in zones with differing temperatures, among which the highest temperature is present in the refining unit (2).

2. Method according to patent claim 1, characterized in that in the refining unit (2) (zone I) with the highest temperature, the burners (20) are operated with reduced quantities of air, in order to decrease the formation of nitric oxides and in the adjacent unit (zone II), as seen from the perspective of the exhaust gas flow, with its lower temperature, the burners (20) disposed at the inflow are operated with excess air to complete the combustion.
3. Method according to claim 2, characterized in that the temperature in zone II is set at approximately 150°C lower than that in zone I.
4. Method according one of the claims 1 to 3, characterized in that the raw mixture contains a large portion of recycled glass.
5. Method according to claim 4, characterized in that, after their exit from the heat exchangers (10, 11), the exhaust gases flow through the old glass and are cooled to a temperature equivalent to the condensation point of their components.
6. Glass-melting furnace for the implementation of the method according to claims 1 to 5 with a melting unit (3), a shallow refining unit (2) adjacent to the melting unit (3) and a homogenizing unit (2a) with a deeper vat, the whole connected to the refining unit (2) and furnished with an glass outlet (19), with a device for introducing the raw mixture situated at the top end of the melting unit (3) and, ordered below the raw mixture input, electrodes (6) for introducing energy, with burners (20) in the refining unit (2) for introducing energy, with heat exchangers (10, 11) for energy

exchange between the fuel exhaust gases and the combustion air to be fed into the burners, characterized in that, in order to develop a hot gas flow as a countercurrent to the movement of the raw mixture at the bottom of the melting unit (9) from the refining unit (2) towards the raw mixture input point and that the ceiling (1) of the furnace between the refining unit (2) (zone I) and the melting unit (3) (zone II) is furnished with at least one heat radiation shield extending to a point immediately above the operating surface.

7. Glass-melting furnace according to claim 6, characterized in that the evenly inclined bottom extends over the whole length of the melting unit (3) and the bottom of the refining unit (2) is horizontal.
8. Glass-melting furnace according to either of the claims 6 or 7, characterized in that the melting unit (3) is furnished with at least one heat radiation shield (7).
9. Glass-melting furnace according to one of the claims 6 to 8, characterized in that the heat exchangers are recuperators equipped with both a high temperature and a low temperature section (10 and 11) .
10. Glass-melting furnace according to claim 7, characterized in that the bottoms (9) of the refining unit (2) and the melting unit (3) are furnished with means of injecting air (bubblers).



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