



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : C03B 3/02	A1	(11) International Publication Number: WO 91/16272 (43) International Publication Date: 31 October 1991 (31.10.91)
--	----	---

(21) International Application Number: PCT/GB91/00670

(22) International Filing Date: 26 April 1991 (26.04.91)

(30) Priority data:
9009336.0 26 April 1990 (26.04.90) GB

(71)(72) Applicant and Inventor: McNEILL, Keith, Russell [GB/GB]; Cliff Cottage, Long Lane, Earlsheaton, West Yorkshire WF12 8LG (GB).

(74) Agents: HUSTWITT, Philip, Edward et al.; Hustwitt & Co., St. George's House, 44 Hatton Garden, London EC1N 8ER (GB).

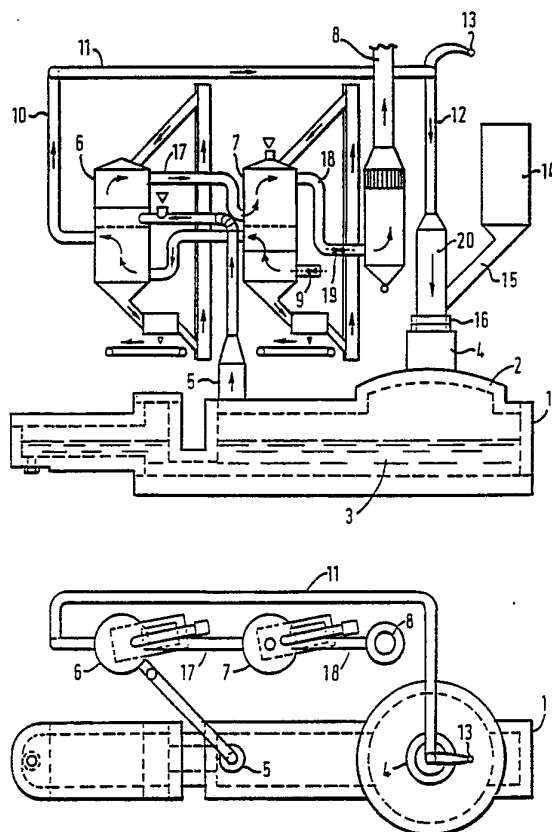
(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.

(54) Title: METHOD OF FEEDING GLASS BATCH TO A GLASS-MELTING FURNACE

(57) Abstract

In a method of feeding glass batch to a glass-melting furnace for making a vitreous material, a heated airstream containing air at a temperature in excess of 1,000 °C is passed down vertical cylinders (12, 20) towards the crown (2) of the glass-melting furnace (1). Powdered glass batch is introduced into the vertically moving heated airstream in the lower and wider cylinder (20) and infra-sound is applied to the vertically moving heated airstream by an infra-sound generator (13) to vibrate the heated airstream and effect heat transfer from the airstream to the glass batch particles so that the glass batch particles are heated and the temperature of the heated airstream is reduced to a temperature below 700 °C, thereby reducing the propensity of the air to produce NO_x. Fuel is subsequently added as the heated glass batch particles and the cooled airstream move downwardly towards the crown (2) of the furnace (1), and a stream of glass batch, burning fuel and air is passed downwardly through the crown (2) of the furnace (1) in a manner such that there is direct contact between the flame of the burning fuel and the surface of molten glass within the furnace (1), and the glass batch is melted.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland	KR	Republic of Korea	SN	Senegal
CI	Côte d'Ivoire	LI	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark				

METHOD OF FEEDING GLASS BATCH TO A GLASS-MELTING
FURNACE

This invention relates to a method of feeding glass batch to a glass-melting furnace.

In accordance with the present invention a method of feeding glass batch to a glass-melting furnace includes the step of feeding powdered glass batch vertically downwardly through a hot air environment, applying infra-sound to the hot air environment containing the powdered glass batch to facilitate transfer of heat from the hot air environment to the powdered glass batch and, subsequent to the said heat transfer, adding fuel to the heated glass batch to raise the temperature of the glass batch to melting temperature.

The application of the infra-sound facilitates transfer of heat from the hot air environment to the powdered glass batch by imposing a vibrational relative movement between the hot air and the powdered glass batch.

Preferably in accordance with the present invention the heat transfer from the hot air environment to the glass batch cools the hot air environment to a temperature of the order of 700°C or even to a temperature lower than 700°C.

- 2 -

Such cooling of the hot air environment is important in substantially reducing the propensity of the airstream to produce nitrogen oxides (NO_x) when the airstream reacts with fuel immediately upon the combustion resulting from the introduction of the fuel.

The hot air environment is advantageously provided by an airstream which is pre-heated by waste gases from the glass-melting furnace. The airstream is preferably pre-heated to a temperature of the order of $1,200^\circ\text{C}$.

Such pre-heating may be effected in stages by passing air from the atmosphere through successive heat exchangers.

More specifically in accordance with the present invention, there is provided a method of feeding glass batch to a glass-melting furnace for making a vitreous material comprising the steps of passing a heated airstream containing air at a temperature in excess of $1,000^\circ\text{C}$ vertically downwardly towards the crown of the glass-melting furnace, introducing powdered glass batch into the vertically moving heated airstream, applying infra-sound to the vertically moving heated airstream to vibrate the heated airstream and effect heat transfer from the airstream to the glass batch particles to heat the glass batch particles and

- 3 -

reduce the temperature of the heated airstream below 700°C, subsequently adding fuel as the heated glass batch particles and the cooled airstream move downwardly towards the crown of the furnace, and passing a stream of glass batch, burning fuel and air downwardly through the crown of the furnace such that there is direct contact between the flame of the burning fuel and the surface of molten glass within the furnace, and the glass batch is melted.

In the embodiment of the invention which will be described, the fuel is added around a circumference of the downwardly moving airstream and heated glass batch particles, but the fuel may be injected into the downwardly moving airstream and heated glass batch particles.

By the use of the present invention it has proved possible to form glasses having high melting points, for example a melting point in excess of 1400°C, which have proved difficult to produce in conventional furnaces.

The present invention will be further understood from the following detailed description of preferred embodiments thereof which is made, by way of example, with reference to the accompanying drawings, in which:

Figures 1a and 1b are respectively elevation and plan views of apparatus including a furnace

- 4 -

for carrying out the method of present invention,

Figure 2 is a graph showing the relationship between the production of nitrogen oxides (NO_x) upon gaseous combustion in pre-heated air and the temperature of the pre-heated air when the fuel is introduced and combustion is commenced, and

Figure 3 is a diagrammatic representation of an alternative apparatus for carrying out the method of the present invention.

Referring to Figures 1a and 1b of the accompanying drawings, there is shown a glass-making furnace 1 having a crown 2 and containing molten glass 3. The crown 2 of the furnace 1 supports a cylinder 4 through which heated glass batch and flame are fed into the interior of the furnace.

Waste gases from the furnace 1 exit through a vertical duct 5 and are drawn through upper part of heat exchanger 6, ducting 17, upper part of heat exchanger 7 and further ducting 18 by a fan 19 to the base of a chimney stack 8 through which the waste gases are vented to atmosphere after suitable filtration.

The heat exchangers 6 and 7 each comprise a moving pebble bed regenerator based on the pebble bed heater described by C.L. Norton Jr. in the Journal of The American Ceramic Society, Volume 29, (1946) No. 7, pages 187-193. The pebble bed

- 5 -

regenerators 6 and 7 may be additionally used to remove oxides of nitrogen (NO_x) and oxides of sulphur (SO_x) by addition of ammoniacal water and alkali respectively, as described in my co-pending International Patent Application No. PCT/GB 89/01361.

However, by use of the preferred method in accordance with the present invention, the quantities of NO_x produced on combustion may be so small that a special treatment with ammoniacal water to remove NO_x from the waste gases may not be required.

Air from ambient atmosphere is drawn by a fan 9 through a lower part of pebble bed regenerator 7 and thereafter through a lower part of pebble bed regenerator 6 so that the air acquires heat in the pebble bed regenerators 7 and 6. The air is heated during its passage through the pebble bed regenerators 7 and 6 by taking heat from the heated pebbles moving under gravity in those pebble bed regenerators so that the air is heated to a temperature of the order of 1200°C . The heated air is then fed through ducts 10 and 11 and down a vertical cylinder 12, which is concentric with cylinder 4 above the crown of furnace 1.

An infra-sound generator 13 generates sound waves at a frequency of 15-20 cycles per second at a level of the order of 140 decibels, and these sound waves are passed directly down

SUBSTITUTE SHEET

- 6 -

the cylinder 12, through a wider cylinder 20, and further through cylinder 4 into the interior of the furnace 1 where the sound waves are reflected from the surface of the molten glass 3.

A glass batch in powder form is fed from a hopper 14 through a channel 15 into the heated air in the wider cylinder 20. The particles of glass batch so introduced are in suspension in the heated air which is being vibrated in the wider cylinder 20 by the action of the infra-sound. The infra-sound causes a vibrational relative movement between the heated air and the particles of powdered glass batch. An enhanced heat transfer between the hot airstream and the powdered glass batch is thus effected and the temperature of the heated air is reduced to a temperature in the range of 500°C to 600°C.

Accordingly much of the waste heat recovered from the glass-melting furnace is transferred to the glass batch before any fuel is added. The lowering of the temperature of the heated air as a result of this heat transfer results in a lowering of the temperature of the furnace waste gases and therefore a lowering of the propensity of the air to produce NO_x as will be discussed later in relation to Figure 2 of the accompanying drawings.

The partially heated glass batch passes

- 7 -

downwardly from cylinder 20 to cylinder 4, into which fuel, for example gas or oil, is injected vertically downwardly through vertical inlets in a part 16, which surrounds the lower end of cylinder 20 and enables fuel to be injected to mix with the air and glass batch passing through cylinder 4 where the fuel ignites. As the glass batch passes down through cylinder 4, the burning fuel in cylinder 4 raises the temperature of the glass batch substantially to the melting temperature of the components of the glass batch and the flame and heated batch both contact the surface of molten glass 3 in the furnace 1. The direct flame contact upon thinly distributed batch on the hot molten surface in the furnace 1 encourages melting and maturing of the batch into hot molten glass.

In operation of a furnace as described above, in which the batch was a mixture of flyash and limestone which was difficult to melt, an output of 24 tonnes per day of glass was obtained from a batch area of 7m² in the furnace, when the furnace was operating on cold air and the melting point of the glass was 1440°C. The constitution of the final glass was

45% CaO

30% SiO₂15% Al₂O₃

the balance being Fe₂O₃, TiO₂, a little alkali etc.

- 8 -

Reference is now made to Figure 2 of the accompanying drawings, which is a graph showing the relationship between the production of nitrogen oxides (NO_x) upon gaseous combustion in pre-heated air and the temperature of the pre-heated air when the fuel is introduced and combustion is commenced.

The graph of Figure 2 shows that the rate of NO_x production in the presence of fossil fuels, gas or oil is low when the preheat temperature of the air is below 700°C . Above 700°C the rate of NO_x production increases very significantly and from 800°C upwards the rate of NO_x production escalates at a rapid rate.

Typically on conventional furnaces, fuel is introduced into air pre-heated to a temperature in a range of about $1000 - 1100^\circ\text{C}$ as indicated by arrows C, D in Figure 2, which results in the production of NO_x to an extent of about 2000 ppm of NO_x per cubic foot of waste gas.

However, by the use of the method according to the present invention as described with reference to Figure 1a and 1b, the pre-heat temperature of the air is reduced to be within the range of $500 - 600^\circ\text{C}$ as indicated by arrows E and F in Figure 2, and the amount of NO_x produced is only of the

- 9 -

order of 300 ppm of NO_x per cubic foot of waste gas.

In Figure 3 of the accompanying drawings there is shown diagrammatically an alternative apparatus for carrying out the method of the present invention using static bed heat regenerators for preheating the air.

Referring to Figure 3 there is shown a glass melting furnace 25 having a reaction tower 26 through which the furnace 25 is vertically fired and fed. Tower 26 has upper and lower co-axial cylindrical sections and an infrasound generator 29 mounted to direct infrasound waves down the tower 26. Preferably the sound waves have a frequency of 15 to 20 cycles per second and an energy level of 140 decibels. The infrasound waves are directed vertically down the tower 26 and reflected from the surface of molten glass 30 in the furnace 25, to impart vertical vibrations to the gas in the tower 26.

Powdered glass batch is fed intermittently and substantially axially into the top of the tower 26 as shown at 31. Heated air is also introduced substantially at the top of the upper section 27 of the tower 26 as shown at 32.

The heated air introduced at 32 is at a temperature of the order of 1200°C and by virtue of the infrasound waves the molecules of the heated

- 10 -

gas will be vibrated in the upper cylindrical section 27 of the tower 26 so that a good heat transfer from the hot air to the powdered glass batch introduced at 31 occurs in the upper cylindrical section 27 of the tower 26. The temperature of the hot air is reduced to a temperature in the range 500 to 600°C by the time the pre-heated glass batch reaches the junction between the upper and lower cylindrical sections 27 and 28 immediately below which the fuel, which may be oil or gas, is introduced into the wider lower cylindrical section 28 of the tower 26. The resulting combustion in the lower cylindrical section 28 raises the temperature of the glass batch substantially to the melting temperatures of the components of the batch and the heated glass batch drops fall on the surface of the molten glass 30. The flame from the combustion in the lower cylindrical section 28 also impinges on the surface of the molten glass 30 and fans out over the surface of the molten glass 30 ensuring full melting of the glass batch components and maturing of the glass of the desired composition which is recovered from the furnace through feeder tube 33.

In the apparatus of Figure 3 the hot air is ambient air heated by waste gases from the furnace using static regenerator beds 34 and 35. Waste gases are taken from the furnace 25 as shown

- 11 -

at 36 and fed alternatively to static bed regenerator 34 or static bed regenerator 35 according to the position of valves V1 and V2. In the position illustrated in Figure 3 valve V1 is closed and valve V2 is open, so that the waste gases can pass to the top of regenerator bed 35 but cannot enter regenerator bed 34.

Fan 37 is therefore able to draw the hot waste gases through open valve V2, regenerator bed 35 and open valve V6, after which the waste gases are passed to a chimney (not shown) for discharge into the atmosphere after suitable filtration. Regenerator bed 35 is thus in the waste gas receiving part of its cycle, whereas regenerator bed 34, as will now be described, is in the air delivery part of its cycle.

Air from the atmosphere is drawn under the influence of a fan 38 through ducts to feed either valve V7 or valve V8. In the operating position of the apparatus shown in Figure 3, where waste gases are heating regenerator bed 35, valve V8 is closed and air drawn from the atmosphere by fan 38 passes through open valve V7 into the base of regenerator bed 34 which was heated by furnace waste gases in the immediately preceding waste gas receiving part of its cycle. The air passes through regenerator bed 34 and is removed

- 12 -

from the upper part of that bed 34 through open valve V3 and fed to the top of the upper cylindrical section 27 of the reaction tower 26 at 32 as previously described.

The positions of all of the valves V1 to V8 are reversed from the closed to the open or the open to the closed position at regular intervals of between 15 seconds and 3 minutes depending on the size of the regenerator beds 34 and 35, in order to maintain both regenerator beds 34 and 35 at maximum temperature.

When a reversal of the regenerator system is to be made the operating conditions of the valves are changed in the following order.

First, valves V2 and V6 are closed and valves V8 and V4 are opened. These valve changes stop the introduction of waste gases into regenerator bed 35 and allow atmospheric air drawn into the system by fan 38 to be passed through valve V8, heated regenerator bed 35 and valve V4 to the line or ducting 32 and the upper end of upper cylindrical section 27 of the reaction tower 26. At this instant heated gas is being supplied to the upper cylindrical section 27 of the reaction tower 26 through both regenerator beds 34 and 35.

Once the flow of heated air to the reaction tower 26 through regenerator bed 35 has been established, the operating conditions of valves

- 13 -

V3, V7, V5 and V1 are changed so that valves V3 and V7 become closed and valves V5 and V1 are opened. Waste gases received from the furnace through line or ducting 36 are now directed into the top of the regenerator bed 34 and drawn by fan 37 through regenerator bed 34 before being passed to the chimney for discharge.

The operation of the valves as described ensures that there is always a flow of hot air to the reaction tower 26.

The static regenerator beds 34 and 35 may consist of refractory or metal balls of 19mm diameter. The bed material which in this example consists of the 19mm balls can be discharged intermittently for cleaning, and replaced by clean balls fed into the beds under gravity.

In operation of the apparatus of Figure 3 in a method in which glass is melted at 1440°C, waste gases at about 1300°C are passed through the regenerator bed 34 or 35 which is in the waste gas receiving part of its cycle, and the relevant bed is heated near to this temperature. During the succeeding air delivery part of the cycle of that regenerator bed, atmospheric air to be used for combustion is heated to a temperature of the order of 1200°C, a heat transfer from waste gases to combustion air in excess of 90% being achieved.

- 14 -

By the use of the apparatus of Figure 3 in which the upper cylindrical section 27 of reaction tower 26 allows time between the point where the glass batch is mixed with the heated combustion air introduced at 32 and the point where fuel is added at the top of lower cylindrical section 28, the glass is preheated at the expense of the heat contained in the combustion air introduced at 32. In consequence the temperature of the combustion air is reduced to a temperature below 700°C before the fuel is added, and the quantity of NO_x which results from the introduction of the fuel and the consequent combustion is also reduced to the order of 300 ppm of the waste gas as explained above with reference to Figure 2.

- 15 -

CLAIMS

1. A method of feeding glass batch to a glass-melting furnace, which includes the step of feeding powdered glass batch vertically downwardly through a hot air environment, applying infra-sound to the hot air environment containing the powdered glass batch to facilitate transfer of heat from the hot air environment to the powdered glass batch and, subsequent to the said heat transfer, adding fuel to the heated glass batch to raise the temperature of the glass batch to melting temperature.

2. A method according to Claim 1 wherein the heat transfer cools the hot air environment to a temperature of the order of 700°C.

3. A method according to Claim 1 or Claim 2 wherein the hot air environment is provided by an airstream pre-heated by waste gases from the glass-melting furnace.

4. A method according to Claim 3 wherein the airstream is pre-heated to a temperature of the order of 1,200°C.

- 16 -

5. A method of feeding glass batch to a glass-melting furnace for making a vitreous material comprising the steps of passing a heated airstream containing air at a temperature in excess of 1,000°C vertically downwardly towards the crown of the glass-melting furnace, introducing powdered glass batch into the vertically moving heated airstream, applying infra-sound to the vertically moving heated airstream to vibrate the heated airstream and effect heat transfer from the airstream to the glass batch particles to heat the glass batch particles and reduce the temperature of the heated airstream below 700°C, subsequently adding fuel as the heated glass batch particles and the cooled airstream move downwardly towards the crown of the furnace, and passing a stream of glass batch, burning fuel and air downwardly through the crown of the furnace such that there is direct contact between the flame of the burning fuel and the surface of molten glass within the furnace, and the glass batch is melted.

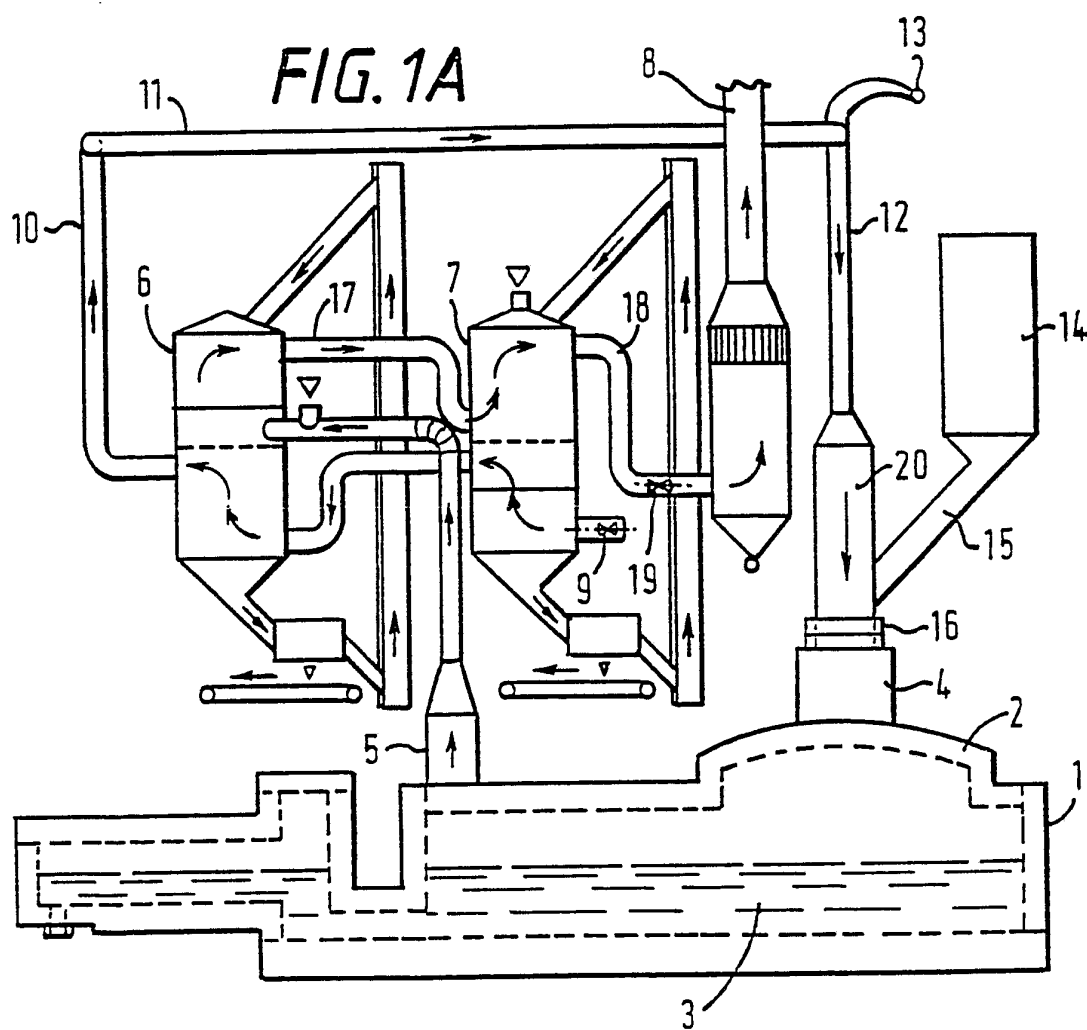
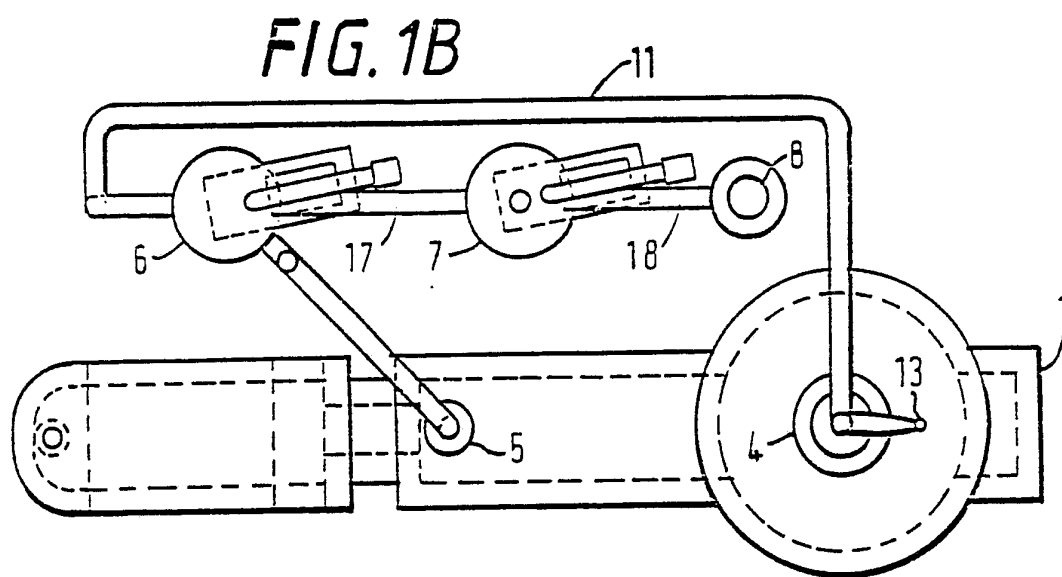
6. A method according to Claim 5 wherein the fuel is added around a circumference of the downwardly moving airstream and heated glass batch particles.

- 17 -

7. A method according to any one of the preceding Claims wherein the glass batch forms a glass having a melting point in excess of 1400°C.

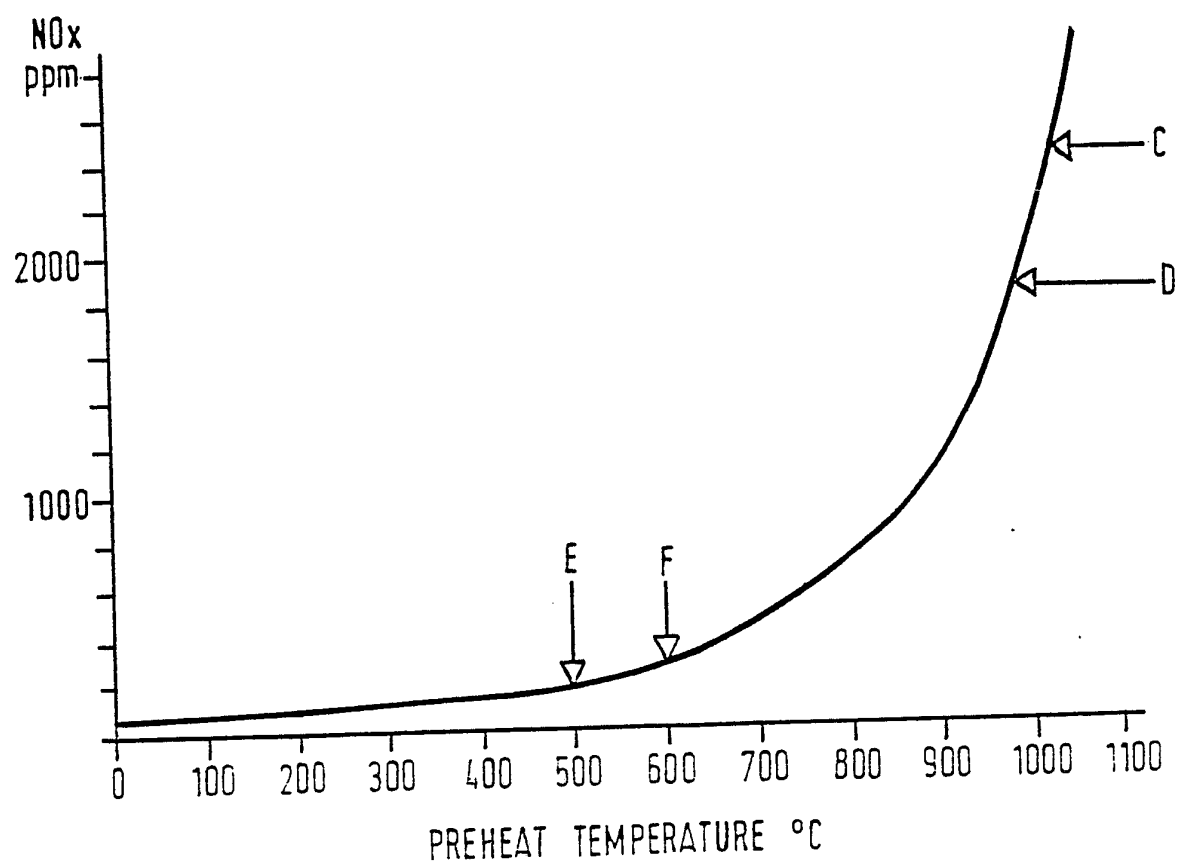
8. A method of feeding glass batch to a glass-melting furnace substantially as hereinbefore described with reference to the accompanying drawing.

1/3



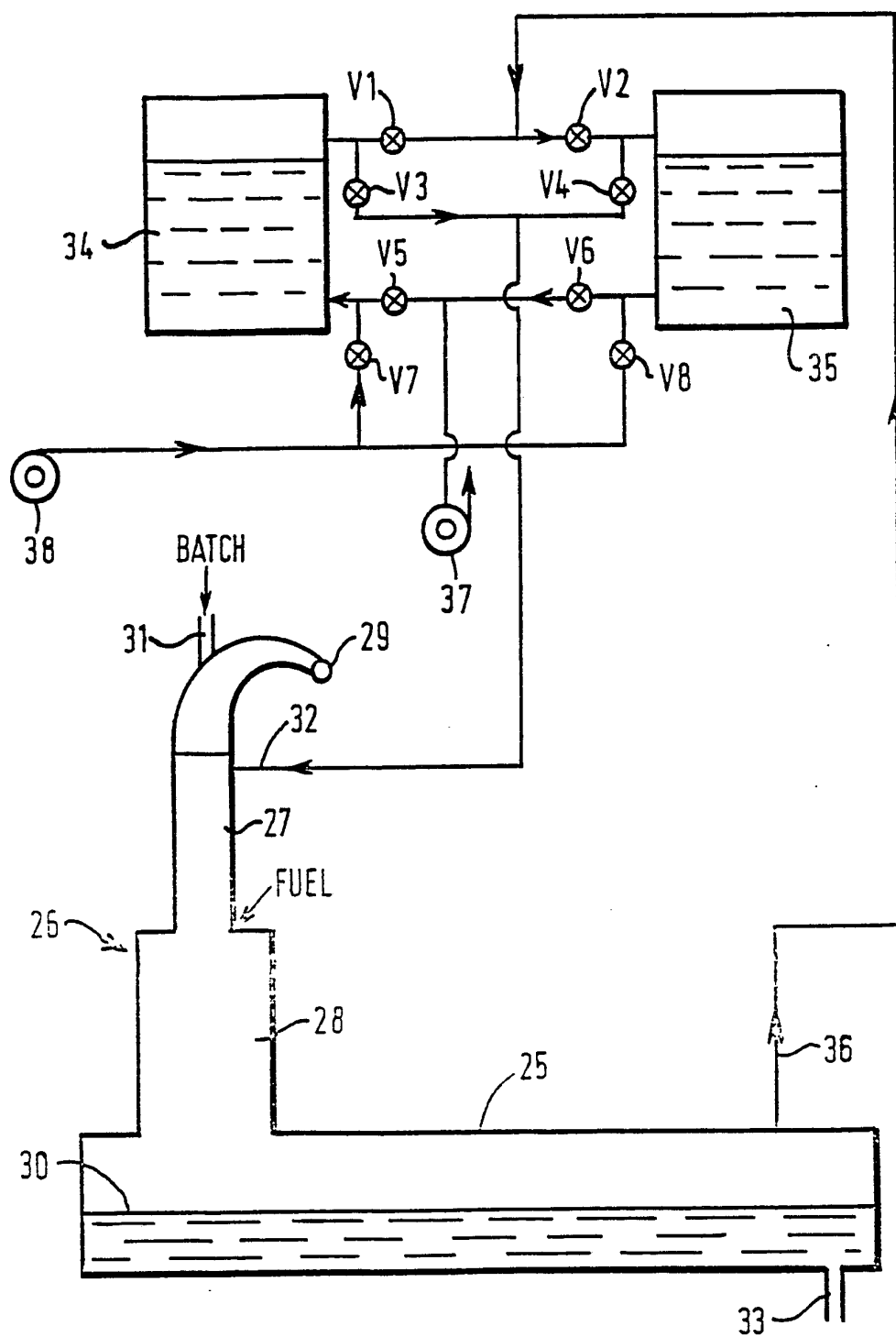
2/3

FIG. 2



3/3

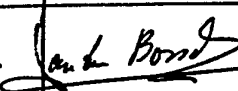
FIG. 3



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 91/00670

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 C03B3/02		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	C03B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
P, X	WO, A, 9013522 (MCNEILL) 15 November 1990 see the whole document ---	1-8
A	US, A, 4752314 (FASSBENDER) 21 June 1988 see the whole document ---	5
A	FR, A, 2370701 (KAWASAKI JUKOGYO KABUSHIKI KAISHA ET CENTRAL GLASS CO., LTD.) 09 June 1978 see the whole document ---	5
A	FR, A, 1395208 (UNION CARBIDE CORPORATION) 01 March 1965 see the whole document ---	1, 5
A	FR, A, 2120115 (TOKYO SHIBAURA ELECTRIC CO., LTD.) 11 August 1972 see the whole document ---	1, 5
	-/--	
<p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"I" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
24 JULY 1991	05 AUG 1991	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	VAN DEN BOSSCHE W. 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	CH,A,270199 (VETRO ITALIANO DI SICUREZZA) 16 November 1950 see the whole document ---	1, 5
A	DE,C,931432 (KERAMISCHE INDUSTRIE PAUL GATZKE) 09 December 1954 see the whole document ---	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

GB 9100670

SA 47116

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24/07/91

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9013522	15-11-90	GB-A- 2234505	06-02-91
US-A-4752314	21-06-88	EP-A- 0298589 JP-A- 1024021	11-01-89 26-01-89
FR-A-2370701	09-06-78	JP-C- 1077263 JP-A- 53061611 JP-B- 56019290 JP-C- 1093917 JP-A- 53061612 JP-B- 56038532 JP-C- 1112082 JP-A- 53061613 JP-B- 56019291 JP-C- 1093918 JP-A- 53061614 JP-B- 56038533 BE-A- 860814 DE-A,C 2750746 GB-A- 1554677 US-A- 4135904	25-12-81 02-06-78 07-05-81 27-04-82 02-06-78 07-09-81 16-09-82 02-06-78 07-05-81 27-04-82 02-06-78 07-09-81 01-03-78 24-05-78 24-10-79 23-01-79
FR-A-1395208		US-A- 3337324	
FR-A-2120115	11-08-72	GB-A- 1333130 US-A- 3748113	10-10-73 24-07-73
CH-A-270199		BE-A- 471207 BE-A- 471907	
DE-C-931432		None	