

A GLASS-MELTING FURNACE

Field of the Invention

This invention relates to glass-melting furnaces, especially to furnaces suitable for use in a method of treating toxic waste including toxic waste resulting from incineration of industrial or domestic refuse.

Background to the Invention

The present Application is divided from co-pending UK Patent Application No 2 228 476 the content of which is incorporated herein by reference.

Industrial and domestic refuse are conventionally destroyed by burning all the refuse in incinerators. The gases produced in this incineration contain a variety of toxic materials which must not be released into the atmosphere and these toxic materials are therefore filtered from the incinerator gases using precipitators and scrubbers. The waste material extracted from the precipitators contains organic poisons such as dioxins, as well as heavy metals. The quantities of the heavy metals, chlorides and sulphates present in this waste material are such that the heavy metals may be leached from the waste material by water in concentrations which frequently exceed the concentrations permitted to be released in the environment under environmental regulations in many countries.

The heavy metals which are present in this toxic waste material in quantities such that the heavy metal will be

leached from the waste material in concentrations above permitted environmental regulations, are particularly zinc, cadmium, mercury, nickel, copper and lead. Other heavy metals which are frequently present in the toxic waste resulting from incineration of industrial and domestic refuse are iron, chromium, titanium, vanadium, beryllium and arsenic.

Because this toxic waste material cannot be disposed of in the environment, attempts have been made to treat it in order to render it safe for disposal in the environment. For example attempts have been made to dispose of the toxic waste material by incorporating it with cement to form solid blocks which are then placed in land fill sites. However it has been found that the soluble chlorides and sulphates of the heavy metals leach out into the surrounding soil. Attempts have also been made to render the toxic heavy metals safe by forming the toxic waste material into a glass. However when the toxic waste material is incorporated in a glass-forming batch and melted in a furnace a large proportion of the toxic heavy metals present (60% by weight or more) is lost by vaporisation and must be trapped in the furnace flues, recovered and fed again to the furnace. An alternative method which has been used to convert the toxic heavy metals into a glass is to put the material through a plasma arc to form a glass. Losses of the toxic heavy metals by vaporisation in excess of 40% by weight are common in this process and again the vaporized heavy metals must be trapped in a flue and re-circulated.

In both these methods the need to trap substantial quantities of vaporized heavy metals and recirculate them has meant that neither method has been considered to be a viable solution to the problem of rendering toxic waste materials harmless.

The presence of the heavy metals such as zinc, cadmium, mercury, nickel, copper and lead in the toxic waste material has therefore so far proved an insuperable obstacle to rendering the toxic waste material safe. In

consequence those engaged in the refuse disposal business find themselves with accumulating quantities of toxic waste material which they can only store. There is therefore a major problem in the refuse disposal business in knowing what to do to contain this toxic waste material or to render it safe for disposal.

In co-pending UK Patent Application No 2 228 476 there is described and claimed a method of rendering toxic waste material containing heavy metals harmless by feeding a batch comprising toxic waste material and glass-forming materials to a cold-top melter wherein the toxic waste material and the glass-forming materials are heated to form a molten vitreous mass, maintaining a sufficient depth of unmelted feed batch above the molten vitreous mass in the cold-top melter to prevent heavy metal volatiles passing through the unmelted feed batch above the molten vitreous mass, and thereafter cooling the molten vitreous mass to provide a solid vitreous material containing the heavy metals.

In this solid vitreous material, the heavy metal elements are combined in such a way that the heavy metals are not leached significantly from the solid vitreous material by contact with water, and environmental regulations with regard to the release of heavy metals into the environment are not contravened.

In order to ensure that no volatilised heavy metals or heavy metal compounds are contained in the gases which pass through the unmelted feed batch, it is necessary to maintain a batch blanket over the molten vitreous mass substantially thicker than the batch blanket thickness of approximately 150mm which is normally used in cold-top applications. In accordance with the claimed method of UK Patent Application No 2 228 476 a feed batch blanket thickness of at least 500mm of solid feed batch should be maintained to ensure that the heavy metals become incorporated in the solid vitreous material formed in the cold-top melter.

The said co-pending UK Patent Application No 2 228 476

5 further claims a method of rendering toxic waste material
containing heavy metals harmless by feeding a batch
comprising toxic waste material with sufficient glass-
forming materials including silica and lime to form a
vitreous material down a substantially vertical feed
column in which the batch is heated and a molten vitreous
mass is formed, cooling gases emitted during formation of
the molten vitreous mass by passing the emitted gases
10 through a sufficient depth of the unmelted feed batch in
the feed column above the molten vitreous mass for the
gases to be cooled in the unmelted feed batch to a
temperature substantially lower than the condensation
temperatures of the heavy metal constituents of the gases,
and cooling the molten vitreous mass to provide a solid
15 vitreous material containing the heavy metals.

The depth of unmelted feed batch maintained above the
molten glass is advantageously such that gases emerging
from the cold top of the unmelted feed batch are at a
temperature no higher than 100°C. With a 500mm depth of
20 unmelted feed batch, escaping gases were generally at a
temperature below 50°C. Preferably a one metre depth of
unmelted feed batch is maintained over the molten glass.
With such a depth of unmelted feed batch it has been found
that the escaping gases are at a temperature which is
25 substantially ambient temperature, for example 20°C.

Performance of the method claimed in the said co-pending
UK Patent Application No 2 228 476 ensures that no
vaporised heavy metals or heavy metal compounds escape
from the top of the unmelted feed batch, all the heavy
30 metals being incorporated in the molten glass formed. The
mechanism by which this incorporation of the heavy metals
into the molten glass takes place has not been proved, but
it is thought that the pressure developed beneath the
unmelted feed batch forces the majority of the vaporised
35 heavy metals and heavy metal compounds into solution in
the molten glass. Any of the vaporised heavy metals and
heavy metal compounds which are carried away in the waste
gases condense on the unmelted feed batch and are

automatically refed to the melting zone.

The said co-pending UK Patent Application further claims methods in which the feed batch comprising toxic waste material which contains heavy metals is pelletised to provide routes through which gases evolved during melting of the batch may pass thereby avoiding a build-up of pressure in a gas cloud beneath the feed batch blanket to an extent which could be dangerous and lead to an explosion.

Because the feed batch is pelletised, there is no direct route for gases to escape from the melt to the atmosphere above the cold-top melter. The hot gases must pass along a tortuous route between the pellets and in doing so the gases cool and heavy metal volatiles in the gases condense on the pellets which carry the condensed volatiles back into the melting zone.

It is preferred that the feed batch has a pellet size in the range from 8mm diameter to 25mm diameter. If the pellet size is substantially smaller than this range, the gaps between the pellets may be filled by condensates thus providing an impermeable layer below which gas pressure will build up leading to violent eruptions which, as already explained, should be avoided. If the pellet size is substantially larger than the range mentioned, the gaps between the pellets are greater and the escape routes for the gases are too large, with the result that the volatilised heavy metals and heavy metal compounds may not cool sufficiently to condense before escaping into the atmosphere. Alternatively an unacceptable height of feed batch above the molten zone in the cold-top melter may be required.

The density and specific heat of the pellets are also important factors in ensuring condensation of the heavy metal volatiles. The density of the pellet affects the ability of the pellet to absorb heat from the gases and it is also important in connection with the strength and ability of the pellet to hold its shape in mechanical systems before the pellet is charged into the cold-top

melter.

As volatiles in the gases passing through the unmelted feed batch condense on the pellets, there is a tendency for this condensate to act as an adhesive causing the pellets to stick together. Such a tendency for the pellets to adhere can result in pellets adhering together across a whole width of the feed batch above the melting zone so that a sort of bridge is formed which jams within the feeder and prevents the feed batch moving down into the melting zone.

If such a bridge were to form it would, in accordance with conventional practice in the use of cold-top melters, be broken using a mechanical poker. However the use of a mechanical poker pushed through the feed batch in order to break the bridge would inevitably prove a direct route for escape of heavy metal volatiles. The use of a mechanical poker is therefore impracticable when melting a batch including toxic waste.

In accordance with a further feature claimed in the said co-pending UK Patent Application No 2 228 476, the build-up of a bridge in the feed batch is prevented by applying infra-sound energy across the feed batch in the vertical feed column. Preferably the infra-sound is applied at a frequency in a range from 10 to 25 cycles per second at a level of the order of 140 decibels. Such infra-sound has the effect of mechanically vibrating firstly the air and then the volatiles which fill the spaces between the pellets thus breaking the bridges without enabling heavy metal volatiles to escape through the feed batch.

The infra-sound may be applied continuously or intermittently and, if applied intermittently, the intermittent applications of infra-sound would conveniently alternate with the feeding of batch ingredients to the cold-top melter by mechanised devices.

Molten glass from a cold-top melter is normally passed from the bottom of the melter via a throat, a riser and a forehearth from which the glass is poured and quenched. As the molten glass according to the present invention

contains the volatile heavy metal materials, these will readily escape into the atmosphere through the roof of the foreheath of the conventional furnace because the refractory roof expands and contracts during heating of the furnace from cold and during operation. It is virtually impossible to cater for this movement of the refractory as sealing of cracks in the refractory is merely a temporary expedient. Each time a crack or gap appears in the roof of the forehearth, volatiles will be released into the atmosphere.

A possible solution is to suspend water-cooled boxes above the length and width of the forehearth, thus presenting an immediate cold face upon which the volatiles will condense. However that is unsatisfactory, because the underside of the boxes will require constant cleansing, and any dust released into the atmosphere will be highly toxic.

Summary of the Invention

In accordance with the present invention the release of volatiles from the molten glass into the atmosphere on exiting from the furnace is prevented by providing a glass-melting furnace which has an enclosed central cavity within the furnace, the molten vitreous material being caused to exit from the melting zone of the furnace into the enclosed central cavity.

According to the present invention therefore there is provided a glass-melting furnace which comprises a substantially circular wall of refractory material defining a vertical column, a refractory base constituting a floor to the vertical column, means for feeding pelletised batch material to the top of the vertical column, electrode means for heating batch materials at a lower part of the vertical column to form a molten vitreous mass near the floor of the furnace, and a refractory furnace exit construction at a central part of the floor of the furnace within the vertical column and defining, within the vertical column, a space which is closed against upward or sideways movement of gaseous

material from the space, the refractory furnace exit construction having walls with a plurality of exit channels passing therethrough for delivering molten vitreous material from the furnace into an upper part of the enclosed space, and means for heating the walls of the furnace exit construction.

Preferably the refractory furnace exit construction is of a frusto-conical, conical or cylindrical shape or has a semi-circular shape in cross-section.

Preferably the material of the refractory furnace exit construction is electrically conductive and the electrode means preferably comprises a plurality of horizontally disposed electrodes passing through the circular wall of refractory material defining the vertical column.

Preferably the glass-melting furnace further includes means for applying infra-sound energy across pelletised batch material in a part of the vertical column above the electrode means.

The said co-pending UK Patent Application No 2 228 476 includes a claim to a method in which molten vitreous material is delivered through exits into a space which is enclosed on all sides and above by a lower part of the vertical column within which the molten vitreous material is being formed, and the molten vitreous material is immediately quenched in water.

A convenient and cheap source of silica for heating with the toxic waste material is the fly ash obtainable as a waste product from a normal power station. The feed batch for the glass-melting furnace therefore may comprise toxic waste, derived from the precipitators in the flues of refuse incinerators, and a greater quantity of powdered fly ash. Preferably the toxic waste and powdered fly ash are melted together with lime in the form of either calcium oxide or calcium carbonate. Alternatively the calcium compound of the glass may be provided by using the toxic residues from the scrubbers in the flues of refuse incinerators where compounds such as calcium hydroxide or calcium carbonate have absorbed acid gases and heavy metal

volatiles which have passed the initial electrostatic precipitator. In such cases the molten vitreous mass formed may contain as much as 72% by weight of toxic residues derived from precipitators and scrubbers.

5 In a treatment of toxic waste in the glass-melting furnace of the present invention the inclusion of alkali metal oxides among the added glass-forming materials should be avoided. While a limited quantity of alkali metal oxides, such as is found in the toxic waste, may be
10 accepted and a satisfactory harmless glass product obtained, the presence of greater quantities of alkali metal oxides will increase the risk of heavy metals being leached from the glass product.

15 In carrying out a process of treating toxic waste in a glass-melting furnace in accordance with the invention claimed in the said UK Patent Application, the ingredients of the solid vitreous material obtained are preferably selected such that the Basicity Ratio or Basicity Factor, which is defined as the aggregate of the weight
20 percentages of calcium oxide and magnesium oxide divided by the aggregate of the weight percentages of silica and alumina, lies between 0.90 and 1.10.

25 A glass having a Basicity Factor of the order of 1.0 is strong in that it has a high crushing strength, is hard in that it has a high polish factor, and has a high density.

A preferred glass having a Basicity Factor of 1.0 is a glass composition approximating to:

45% CaO

30% SiO₂

30 15% Al₂O₃

the balance being Fe₂O₃, TiO₂, a little alkali etc. The high strength, hardness and high density of this glass will be substantially unchanged by the inclusion of a percentage of MgO provided that there is a corresponding
35 reduction in the percentage of CaO present in the glass. If the toxic waste material is, for example, some kinds of asbestos, as much as 24% MgO may be included, in which case the CaO content is reduced to 21%. However, about 6%

MgO is preferred, because this produces a fairly low viscosity glass which is readily pourable.

5 In carrying out a method according to the co-pending UK Patent Application No 2 228 476, a batch was made up as described therein in Example 1, pelletised and then fed to a glass-melting furnace according to the present invention which is a cold-top melter comprising a substantially vertical feed column down which the batch is fed to a heating zone which is an electric furnace using carbon electrodes. The construction of the cold-top melter used will be described in detail later in the specification. The pelletised batch is melted by heating in the electric furnace at a temperature of 1380°C. The cold-top melter used was constructed to have a column comprising one metre of molten glass with one metre of unmelted feed batch above the molten glass. The gases emitted in the furnace passed up the feed column through the unmelted pelletised feed batch where they were cooled to a temperature substantially below the condensation temperatures of all the vaporized heavy metals and heavy metal compounds. Accordingly the gases emerging at the top of the feed column contained no heavy metals, the heavy metals being incorporated into molten glass formed in the furnace.

25 A pressure drop is created between the surface of the molten glass in the cold-top melter and the atmosphere over the unmelted pelletised feed batch because of the tortuous path which the gases are obliged to follow in passing through the unmelted pelletised feed batch to atmosphere. The back pressure thus created at the surface of the molten glass forces volatile heavy metal compounds into solution in the molten glass.

30 The gases emitted in the furnace and emerging from the top of the feed column were passed through a flame at a temperature of 1300°C which destroyed dioxins given off during heating in the furnace. A continuous sample of the emission was taken, and analysis showed that, prior to the flame treatment, the content of dioxins in the emitted gas was 18 nanograms per cubic metre, but after flame

treatment the dioxins had been substantially entirely destroyed, there being less than 0.1 nanograms of dioxins per cubic metre of gas. There was little evidence either of chlorine gas in the emissions from the furnace.

5 The vitreous melt formed in the electric furnace was poured molten at 1380°C into water, and a solid vitreous mass with an average particle size of 3 cubic mms was obtained.

Brief Description of the Drawings

10 A preferred embodiment of the glass-melting furnace according to the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

15 Figure 1 is a side cross-sectional view of a cold-top melter in accordance with this aspect of the present invention, and

Figure 2 is a diagrammatic plan view of the cold-top melter of Figure 1.

Description of the Preferred Embodiment

20 Referring to Figure 1 of the drawings, pelletised batch 1 is fed vertically to a heating zone of a cold-top melter type of furnace in which a molten vitreous material or glass 2 is formed. The cold-top melter has a conventional circumferential side wall 3 and a base 4 which is
25 substantially modified from the conventional furnace base for incorporating heavy metals into a molten vitreous mass by a method according to the co-pending UK Patent Application No 2 228 476.

30 Within a central part of the base 4 of the cold-top melter, there is created an enclosed space 5 which is surrounded on all sides and above by a refractory furnace exit construction 6. A plurality of exit channels 7 pass through the refractory furnace exit construction 6 from positions near the floor of the furnace to positions near
35 a ceiling 8 of the enclosed space 5. Means is provided for heating the refractory material of the refractory furnace exit construction 6. This refractory material may be electrically conductive, for example carbon, so that

the refractory material of the furnace exit construction 6 may form part of the circuit for heating the batch within the furnace and producing the molten vitreous material. Such an arrangement is illustrated diagrammatically in Figure 2. Alternatively the refractory material of the furnace exit construction 6 may be susceptible to heating by induction.

In Figure 1 the enclosed space within the circle of the furnace construction is of a frusto-conical shape but it could alternatively be of a conical or cylindrical shape or have a semi-circular shape in cross-section.

The heating of the refractory material of the furnace exit construction 6 is necessary to prevent any solidification of the molten vitreous material in the exit channels 7. The molten vitreous material delivered from the channels 7 into the enclosed space 5 is poured directly into a water bath 9 where the material is quenched and a frit is formed.

Because the space 5 is enclosed on all side and above by the furnace construction, the volatiles cannot escape into the surrounding atmosphere. Also the build-up of partial pressure of volatiles in the atmosphere of the enclosed space 5 will tend to limit subsequent volatilisation.

Referring to Figure 2 there is shown diagrammatically the cold-top melter of Figure 1 in which the refractory material of the furnace exit construction 6 is used as one electrode in providing the electrical current for heating and melting the batch materials. The electrical current flows between horizontally disposed electrodes 10 passing through the cylindrical side wall 3 and the furnace exit construction 6. The horizontal mounting of the electrodes 10 ensures that all gases escaping from the melt must pass through the pelletised feed batch and thus follow a tortuous path during which the gases are cooled and volatiles are condensed out. Substantially all, more than 95%, and in most cases as much as 99%, by weight, of the toxic heavy metals are thus incorporated in the glass, and only minimal recovery of toxic heavy metal salts from the

flue is required.

Referring again to Figure 1, there are shown diagrammatically infra-fones 12 and 13 which generate infra-sound waves at a frequency of 15 - 20 cycles per second at a level of 140 decibels. The infra-fones 12 and 13 are bolted to a steel casing 14 on the outside of the circumferential side wall 3 of the cold-top melter so as to pass or receive infra-sound waves through circular apertures positioned opposite one another in the circumferential side wall 3 above the level of the molten glass. The infra-fones 12 and 13 include oscillators 15 and 16 which each act alternately as generator and receiver to pass infra-sound waves through the unmelted pelletised feed batch located between the infra-fones 12 and 13.

Some unmelted pelletised feed batch will fill the entrance to each infra-fone 12 and 13 and provide protection for the oscillators 15 and 16 against the heat from the melting zone of the furnace. The infra-fones 12 and 13 are sealed, and no escape of volatiles can take place through infra-fones 12 and 13.

The application of infra-sound waves by the infra-fones 12 and 13 prevents adherence of adjacent pellets of unmelted pelletised feed batch to one another as a result of condensation forming on the pellets.

In use of the glass-melting furnace of the present invention to render harmless toxic waste material containing heavy metals, it is preferred to form a glass incorporating the toxic waste which has the following properties:-

- (i) Low melting temperature,
about 1,300 to 1,350°C
- (ii) Low viscosity when molten,
about 10 to 50 poise
- (iii) Sufficient content of elements or compounds
which provide nucleating "seeds".

In selecting a melting temperature it is desirable to keep this as low as possible in order to limit the

volatilisation, but the temperature must be high enough to achieve an economical through-put.

5 A low viscosity for the glass improves the mixing of the components within the melt. Thorough mixing during melting is desirable because toxic wastes are very variable in composition and thorough mixing during melting will equalise out some of the variability.

10 It is desirable that as much as possible of the glass formed should be crystallised. To this end it is desirable to use one or more components which provide nucleating seeds. Powdered fly ash, which is exemplified herein as a cheap and convenient source of glass-making materials and particularly of silica, is a compound which is known to provide crystallisation seed.

15 The major components used in the process may be waste products from other manufacturing processes, and therefore the method of rendering toxic waste materials harmless as herein described may be a relatively inexpensive process.

20 Inert solid viscous material of suitable viscosities may be formed into products such as grit, blocks and tiles which may be used without causing environmental pollution.



CLAIMS

1. A glass-melting furnace which comprises a substantially circular wall of refractory material defining a vertical column, a refractory base constituting a floor to the vertical column, means for feeding pelletised batch material to the top of the vertical column, electrode means for heating batch materials at a lower part of the vertical column to form a molten vitreous mass near the floor of the furnace, and a refractory furnace exit construction at a central part of the floor of the furnace within the vertical column and defining, within the vertical column, a space which is closed against upward or sideways movement of gaseous material from the space, the refractory furnace exit construction having walls with a plurality of exit channels passing therethrough for delivering molten vitreous material from the furnace into an upper part of the enclosed space, and means for heating the walls of the furnace exit construction.
2. A glass-melting furnace according to Claim 1 in which the refractory furnace exit construction is of a frusto-conical, conical or cylindrical shape or has a semi-circular shape in cross-section.
3. A glass-melting furnace according to Claim 1 or Claim 2 in which the material of the refractory furnace exit construction is electrically conductive and in which the electrode means comprises a plurality of horizontally disposed electrodes passing through the circular wall of refractory material defining the vertical column.
4. A glass-melting furnace according to any one of Claims 1 to 3 which further comprises means for applying infra-sound energy across pelletised batch material in a part of the vertical column above the electrode means.
5. A glass melting furnace constructed and arranged to



operate substantially as hereinbefore described with reference to the accompanying drawings.

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