



National Pollutant Inventory

Emissions Estimation Technique Manual

for

Glass and Glass Fibre Manufacturing

**EMISSION ESTIMATION TECHNIQUES
FOR
GLASS AND GLASS FIBRE MANUFACTURING**

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GLASS AND GLASS FIBRE MANUFACTURING

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1.0 Introduction

The purpose of all Emission Estimation Techniques (EET) Manuals in this series is to assist Australian manufacturing, industrial, and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in glass manufacturing activities.

The glass and glass product manufacturing activities covered by this Manual includes facilities primarily engaged in the manufacture of:

- Glass containers;
- Motor vehicle glass;
- Domestic glassware;
- Glass and glass products;
- Glass wool and associated insulation products; and
- Industrial glass.

EET MANUAL: Glass and Glass Fibre Manufacturing

HANDBOOK: Glass and Glass Product Industry

ANZSIC CODE : 261 and 264 (the latter code relates to Glass Fibre and Glass Wool Manufacturing)

This Manual was drafted by the Queensland Department of Environment on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key stakeholders, and has been considered by independent reviewers.

2.0 Process Description

The glass industry is characterised by wide variety of manufacturing facilities, from those firms engaged in primary glass manufacturing, to those that create products from purchased glass.

The flat glass sector produces glass using the Float process or Figured Rolled process. This is marketed in its original state, or subjected to further processing to produce toughened (tempered), laminated, decorative, surface coated, double glazed, and mirrored products. Tempered glass is a type of safety glass typically produced using a thermal process, whereby heating and subsequent rapid cooling produce surface and interior stresses, and a stronger than ordinary glass.

Laminated glass consists of two or more layers of glass separated by, and bonded to, thin sheets of plastic that prevent it from shattering when broken. The motor vehicle industry in Australia is the largest market for laminated glass.

Cleaning the glass and coating it on one side with an adhesive, reflective, and binding compound produces glass mirrors. Insulating units consist of two or more parallel and separated panes of glass joined at the edges (by metal seals or by fusion) such that, the space between the panes is either evacuated or filled with dry air or another gas. Insulating units are used to reduce surface condensation, and sound transmission, as well as for thermal insulation.

The glass fibre sector produces two main products and they are, textile glass fibres and insulation glass fibre. Textile glass fibre is used in the production of fireproof cloth, while insulation glass fibre is used in thermal and acoustic insulation, including tank and swimming pool shells.

The processes involved in producing glass include the extraction and/or manufacture of raw materials, followed by weighing, mixing, melting, forming, and controlled cooling. Raw material extraction and manufacture, while integrally related to the manufacture of glass, is outside the scope of this document and is addressed in a separate Manual.

2.1 Mixing Processes

The two principle kinds of mixing are wet mixing and batch agglomeration. Glass with a large silicon dioxide content is wet mixed in a pan-type mixer, then dry-blended and wet-blended by adding small amounts of water. Materials are mixed in a rotating pan or drum. The mixed batch is transferred to holding hoppers above the furnace by

distribution conveyors. These hoppers are situated above the furnace and the material is then fed into the furnace by a pusher-type charger. This process will differ somewhat from facility to facility. Flat glass manufacturers have smaller, more enclosed alcoves (dogboxes) from which the material is fed into the furnace.

2.2 Melting Processes

The type of melting unit employed depends on the quantity and quality of glass to be processed. Flat glass manufacturers commonly have the largest furnaces, followed by container glass manufacturers, and glass fibre manufacturers. The size and depth of the furnaces differs appreciably depending on the process. Generally speaking, container glass furnaces in Australia are cross-fired regenerative. They are between 60 and 100 m² and vary in depth from 1.2 to 1.8 metres in depth and are continuous melting. Fibreglass tanks may rely more on electric melting to enable them to more accurately control the furnace conditions, but container and flat glass manufacturers tend to use gas as the primary fuel. Some facilities will have additional electric melting to assist the gas firing. The electric heating is referred to as boosting, and the electrodes are inserted in to the side walls, or through the bottom of the furnace.

2.3 Forming and Annealing Processes

From the melter, the glass flows (still inside the furnace) into a refining section. At this point, the gas trapped inside the glass body from the melting operation is released. The glass then flows from the main melter/refiner into shallow channels called fore-hearths, and the glass is fired to ensure an equilibrium of temperature through the glass body. The glass flows down the fore hearth into the forming area where the glass stream is cut by water cooled shears into gobs - the lump of glass that will eventually form one container. Forming machines vary in size from six section single gob machines to quad gob ten section machines that can produce containers at a rate in excess of five hundred bottles per minute.

Figure 1 is a process flow diagram for a typical glass manufacturing process. It highlights the likely emission points for particulate matter (PM₁₀). Because every facility in Australia is likely to be unique, you are encouraged to develop a flow diagram for your own operations detailing the input of materials and listed substances, and the waste sources and emissions resulting from the operation of each process.

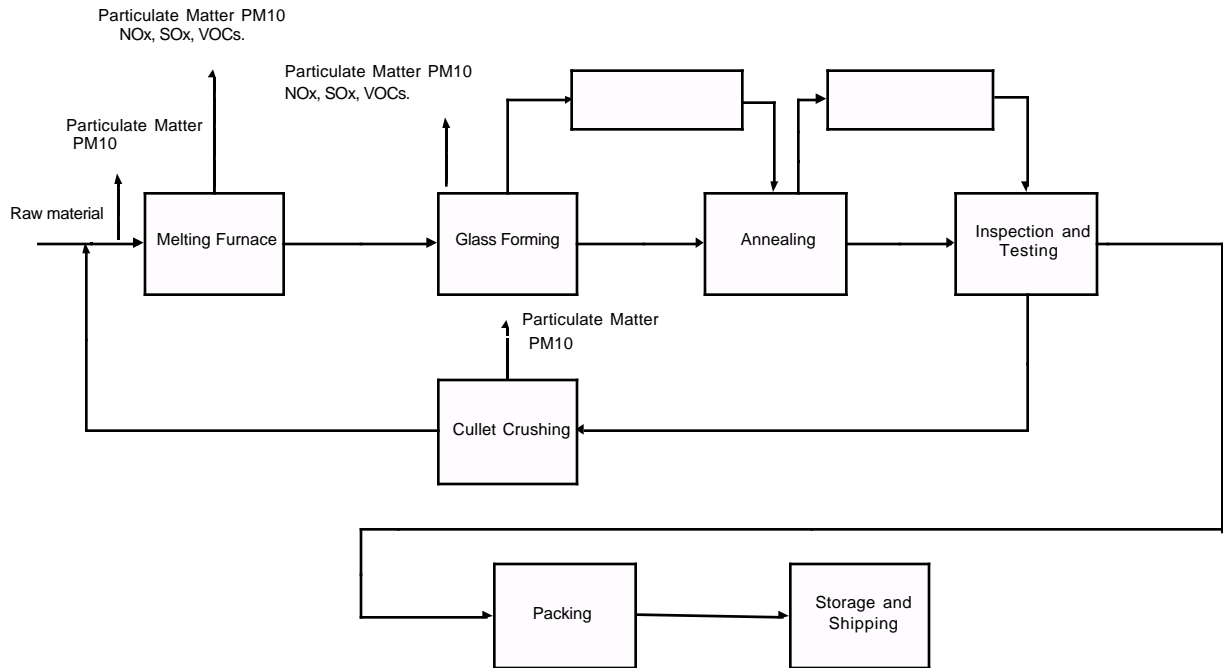


Figure 1. A Typical Glass Manufacturing Process

USEPA 1995 AP42 (S11)

The glass is cut into one to four gobbs at a time and the cut gobbs pass into the forming machine through a series of scoops and troughs. They are delivered into the blank side of the machine where a parison is pressed and blown. This side of the machine makes the top of the bottle, called the *finish*. The parison is then inverted into the mould side of the machine where it is pressed (in the case of pressed ware) or blown (in the case of blown ware), into the final bottle shape. The resultant formed container is placed on a conveyor (using takeouts) and this passes through a hot-end coating hood where a coating of tin is added to the surface of the glass. This is done to ensure efficient adherence of a very thin layer of cold-end coating that gives the glass its lubricity in high speed filling lines.

From the hot-end coating hood, another conveyor takes the glass into a long heated section called a lehr that gradually heats up the glass, lets the temperature soak, and cools the glass slowly. The huge tensile forces that build up in the rapid cooling of the glass are released in this annealing process to achieve the strength requirements of the glass container for the high speed filling lines of pressurised containers.

2.4 Flat Glass Manufacturing

Flat glass is typically made using the Float process. The raw materials used in this process include silica sand, soda ash, limestone, dolomite, scrap glass, and small amounts of other materials. These materials are proportioned to meet certain physical characteristics, and are then mixed

and fed into the melting tank, where temperatures of about 1 600°C reduce the material to glass. Colouring agents can be added at this time to produce differing degrees of translucence. The molten glass is then fed as a continuous ribbon from the furnace into a bath of molten tin where it floats and is fire polished. The ribbon of glass leaves the float bath and enters the annealing lehr where it is gradually cooled to prevent flaw causing stresses. The glass is then cut. At this point, the glass may be packaged and delivered to customers, subjected to further processing, or sent to storage. Additional processing often involves coating glass with thin layers of metal or chemical compounds that absorb infrared, light or improve the reflecting qualities of the glass.

2.5 Glass Fibre Manufacturing

Glass fibre manufacturing involves the high-temperature conversion of raw materials into a homogeneous melt, followed by the fabrication of this melt into glass fibres. The two basic types of glass fibre products, textiles and wool, are created by similar processes. Glass fibre production can be separated into three phases: raw materials handling, glass melting and refining, and glass fibre forming and finishing.

The primary component of glass fibre is sand, but it also includes varying quantities of feldspar, sodium sulphate, boric acid, and other materials. These materials are conveyed to and from storage piles by belts, screws, and bucket elevators. In the glass melting furnace, the raw materials are heated and transformed through a series of chemical reactions into molten glass. Glass fibres are made from the molten glass using one of two methods. In the rotary spin process, which dominates the fibreglass sector, centrifugal force causes molten glass to flow through small holes in the wall of a rapidly rotating cylinder to create fibres that are broken into pieces by an air stream. The flame attenuation process uses gravity to force molten glass through small holes to create threads which are attenuated, (or stretched to the point of breaking) by hot air or flame. After the glass fibres are produced, they are sprayed with a chemical resin to hold them together, collected on a conveyor belt in the form of a mat, cured and packaged.

Figure 2 is a process flow diagram for a typical glass fibre manufacturing process.

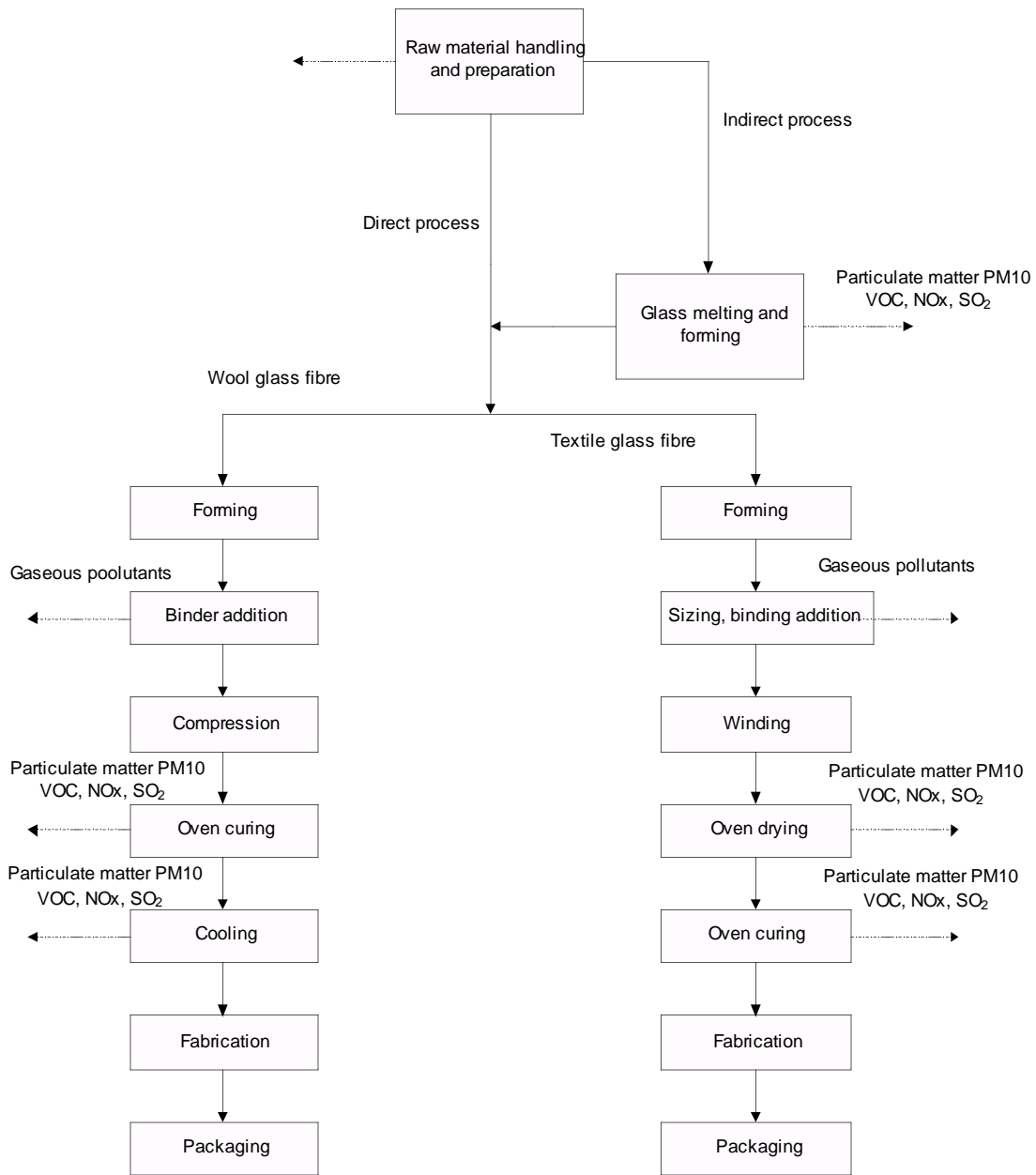


Figure 2. A Typical Glass Fibre Manufacturing Process

USEPA 1995 AP42 (S11)

3.0 Emission Sources

Emissions generated in the glass industry can be categorised into three groups: materials handling emissions; pollution control equipment emissions; and, plant maintenance emissions.

3.1 Materials Handling Emissions

Materials handling emissions are the emissions generated during the receipt and transfer of raw materials at your facility for storage or processing, and include those raw materials that are rendered unusable because of spillage. Particulate matter (PM₁₀) is the dominant emission from this process.

3.2 Control Equipment Emissions

Emissions control equipment at glass manufacturing plants generates emissions and waste residues from NPI listed substances produced and captured during the melting, forming, and finishing steps of the manufacturing process. The melting of raw materials to produce glass generates air emissions consisting of PM₁₀, oxides of nitrogen, sulphur dioxide, and small amounts of carbon monoxide generated by the combustion of fuel and the evaporation or dissociation of raw materials. Emissions are also generated during the forming and finishing of glass products as a result of the thermal decomposition of lubricants at the time that ceramic labelling is undertaken. These emissions include volatile organic compounds (VOCs), ammonia, chlorine, and hydrochloric acid. Emissions may also include NPI listed metals and small quantities of organic pollutants such as polycyclic aromatic hydrocarbons.

Glass facilities are able to diminish emissions using aqueous media, filters, and precipitators. A quench reactor, that combines sulphur dioxide from furnace emissions with water and sodium carbonate, is an example of an aqueous emission control device. When the water evaporates upon contact with flue gases, a solid residue results. The residue may contain NPI listed metals such as selenium, chromium, cadmium, cobalt, lead, and sodium sulphate. Stannic acid, a lubricant used to coat glass bottles to prevent breakage, produces hydrochloric acid when it thermally decomposes. This is usually removed by reaction with aqueous media, or can be physically captured by filters or precipitators.

Glass manufacturers often use baghouse filters to capture particulate emissions. Baghouse dust residue can be recycled back into the manufacturing process. To control oxide of nitrogen emissions, a method called selective noncatalytic reduction (SNCR) has been used. SNCR reduces flue gas nitrogen oxide through a reaction with ammonia in a temperature range of 925 - 1040 °C. The ammonia may be supplied as anhydrous ammonia, aqueous ammonia, or urea. At temperatures above 1040 °C, the oxidation of ammonia and nitrogen oxide increases and SNCR

may actually increase levels of nitrogen oxide. At temperatures below 925 °C, nitrogen oxide reduction falls off and ammonia breakthrough increases, leading to the potential for a visible ammonium-chloride plume.

3.3 Facility Maintenance Emissions

Glass plant maintenance emissions include waste oil and solvents generated in the furnace slag and refractory wastes. During the forming process, oil is used in the forming machines and often contaminates the water that keeps the machines cool. Trichloroethylene, or other NPI listed solvents, might also be used as cleaning agents to remove a thin layer of graphite coating that is applied to the glass forms or moulds. The carryover from the furnace (both particulate and gaseous) is carried to the base of the regenerator where it collects and builds up. The material consists of a high level (85-90 percent) of sodium sulphate and some heavy metals. This material should be removed by a licensed contractor, and be chemically fixated before it is taken to landfill.

3.4 Glass Fibre Emissions

Glass fibre manufacturers also generate materials handling and, pollution control emissions, as well as plant maintenance wastes and emissions. As in other glass manufacturing, the major air emissions associated with glass fibre production relate to the melting and refining furnace operation. The emissions from this operation include PM₁₀, calcium carbonate, sodium fluoride, sodium fluorosilicate, silica, calcium fluoride, aluminium silicate, sodium sulphate, and boron oxides. Gases emitted include fluorides, sulphur dioxide, oxides of nitrogen, boric acid, carbon monoxide, and water vapour.

Table 1 identifies the material inputs and pollutant outputs for glass manufacturing.

Table 1. Glass Manufacturing Material Inputs and Pollutant Outputs

Process	Material Inputs	Air Emissions	Water and Land Emissions	Other Emissions, Wastes, and Transfers
Glass Product Manufacturing	Silica sand, soda ash, limestone, metallic oxides, ammonia.	Particulates, fluorides, sulphur dioxide, oxides of nitrogen, CO, solvents.	Heavy metals, spent solvent wastes.	Materials handling wastes and furnace slag.

QLD Department of Environment, 1998

4.0 Emission Estimation

Estimates of emissions of listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility. These are described in *The NPI Guide*. Select the EET, or mix of EETs, which is most appropriate for your purposes. If you estimate your emission by using any of these EET's, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of emission estimation techniques that are not outlined in this Handbook, your data will also be displayed as being of 'acceptable reliability'.

For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if you already undertake direct measurement, you may use this information for NPI reporting purposes (if you do not undertake direct measurement, the NPI does not require you to do so).

4.1 Emissions to Air

Air emissions may be categorised as:

Fugitive emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats or open vessels, and material handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs is the usual method for determining losses through fugitive emissions.

Point source emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. An air emissions control device such as a carbon adsorption unit, scrubber, baghouse, or afterburner may be added to the stack prior to the atmospheric release.

4.2 Emissions to Water

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI (See also Section 3.0 of *The NPI Guide*). The main source of wastewater from this industry is usually from air pollution control equipment such as wet scrubbers.

The most appropriate method for determining emissions to the environment via wastewater is to use direct measurement, however, you may use other EETs for the purposes of reporting to the NPI.

4.3 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids, and the use of chemicals to control various elements of the environment where these emissions contain listed substances. These emission sources can be broadly categorised as:

- surface impoundment of liquids and slurries
- unintentional leaks and spills.

5.0 Emission Factor Rating

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in the reference section of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows:

A	-	Excellent
B	-	Above Average
C	-	Average
D	-	Below Average
E	-	Poor
U	-	Unrated

Estimating your facility's emissions based on emission factors only, and without taking into account any control measures, may have an uncertainty as high as 100%.

Other EETs, such as release calculations based on mass balance of solvent consumption and without taking into account control measures, may have an uncertainty of 50%.

An EET based on an audit or direct measurement, and taking into account control measures, may have an uncertainty of 20%.

6.0 Emission Factors

An emission factor is a tool that is used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, multiplied by the unit weight, volume, distance, or duration of the activity emitting the substance (eg. kilograms of PM₁₀ emitted per tonne of glass product produced).

Emission factors are used to estimate a facility's emissions by the general equation:

$$E = A \times T \times EF \times [1 - (CE/100)]$$

where :

E = emissions;

A = activity rate;

T = time (or another variable)

EF = uncontrolled emission factor; and

CE = control emission reduction efficiency, %.

To determine PM₁₀ emissions from PM, it may be necessary for facility operators to first undertake a sizing analysis of the stack filter catch. The weight PM₁₀ fraction can then be multiplied by the total PM emission rate to produce a PM₁₀ number.

Emission factors developed from measurements for a specific glass product or manufacturing process may sometimes be used to estimate emissions at other sites. Should a company have several units of similar model and size, and emissions were measured from one process or product line, an emission factor could be developed and applied to similar units and product lines. As previously suggested, it is advisable to have the emission factor reviewed and approved by your local State or Territory environmental authority prior to its use for NPI estimations.

Example 1.

Table 3 shows that 0.1kg of VOCs are emitted for each tonne of decorative glass product produced from a furnace with an electrostatic precipitator control device in place. It is assumed that the glass plant operates for 1 500 hours per year.

EF _{VOC}	=	0.1kg/tonne
Glass production rate	=	20 tonnes/hour
VOC emissions	=	EF _{VOC} x glass production rate x operating time
	=	0.1 x 20
	=	2 kg/hr x (1 tonne ÷ 1 000kg)
	=	x 1 500 hr/yr
	=	3.0 tonnes per year

Table 2. Emission Factors for Glass and Glass Product Manufacturing^{1,a}

Process	PM ₁₀ (kg/tonne)	SO ₂ (kg/tonne)	Oxides of Nitrogen (kg/tonne)
Raw materials handling (all types of glass)	Neg	0	0
Melting furnace Container (uncontrolled)	0.66	1.7	3.1
- with low energy scrubber	0.38	0.9	3.1
- with venturi scrubber	0.095	0.1	3.1
- with baghouse	Neg	1.7	3.1
- with electrostatic precipitator	Neg	1.7	3.1
Melting Furnace Flat (uncontrolled)	0.95	1.5	4.0
-with low energy scrubber	0.475	0.8	4.0
-with venturi scrubber	Neg	0.1	4.0
-with baghouse	Neg	1.5	4.0
-with electrostatic precipitator	Neg	1.5	4.0
Pressed and Blown (uncontrolled)	7.98	2.8	4.3
-with low energy scrubber	3.99	1.3	4.3
-with venturi scrubber	0.475	0.1	4.3
-with baghouse	0.095	2.8	4.3
-with electrostatic precipitator	0.095	2.8	4.3
Forming and finishing -Container	Neg	Neg	Neg
-Flat	Neg	Neg	Neg
-Pressed and blown	Neg	Neg	Neg
Lead glass manufacturing (all processes)	ND	ND	ND

¹ USEPA AP-42 Section 11.15 (1995).

^a Factor units are kg of substance emitted per tonne of glass or glass product manufactured.

All emission factors have an uncertainty rating of B.

Neg = negligible.

ND = no data.

Table 3. Emission Factors for Glass and Glass Product Manufacturing¹

Process	VOCs Total (kg/tonne)	CO (kg/tonne)	Lead (kg/tonne)
Raw materials handling (all types of glass)	0	0	ND
Melting furnace Container (uncontrolled)			
- with low energy scrubber	0.1	0.1	ND
- with venturi scrubber	0.1	0.1	ND
- with baghouse	0.1	0.1	ND
- with electrostatic precipitator	0.1	0.1	ND
Melting Furnace Flat (uncontrolled)			
-with low energy scrubber	0.1	0.1	ND
-with venturi scrubber	0.1	0.1	ND
-with baghouse	0.1	0.1	ND
-with electrostatic precipitator	0.1	0.1	ND
Pressed and Blown (uncontrolled)			
-with low energy scrubber	0.2	0.1	ND
-with venturi scrubber	0.2	0.1	ND
-with baghouse	0.2	0.1	ND
-with electrostatic precipitator	0.2	0.1	ND
Forming and Finishing			
-Container ^{b, c}	4.4	Neg	ND
-Flat	Neg	Neg	ND
-Pressed and blown ^{b, c}	4.5	Neg	ND
Lead Glass Manufacture (all processes)	ND	ND	2.5

¹ USEPA AP-42 Section 11.15 (1995) All emission factors are rated C.

^a Units are kg of substance emitted per tonne of glass or glass product manufactured.

^b VOC emissions occur only from decorating processes using solvents and can be controlled by incineration, absorption or condensation, but efficiencies are not known.

^c For container and pressed and blown glass, tin chloride, hydrated tin chloride, and hydrogen chloride are also emitted during surface treatment process at a rate of <0.1 kg/tonne.

Table 4. Speciation Profile for VOCs in Glass Manufacturing

CASR No.	Substance	Weight % (total = 100%)
71-43-2	Benzene	2.86
110-82-7	Cyclohexane	0.20
50-00-0	Formaldehyde	1.60
110-54-3	<i>n</i> -Hexane	3.14
108-88-3	Toluene	0.78
	Other VOCs ²	91.42

¹USEPA 1992. VOC / PM Speciation Data System - Version 1.50.

²Other VOCs includes all other VOCs not individually listed on the NPI.

To report emissions of the substances in Table 4 above, first determine the emissions of total VOCs from Table 3, and then multiply the weight percent of each individual substance listed above by the total VOC emissions figure.

Table 5. Emission Factors for Metals in Glass Manufacturing

Metal	Emission Factor (g/tonne)
Cadmium	0.15
Chromium(total)	2.4
Copper	0.6
Lead	12
Nickel	0.05
Mercury	1.9
Selenium	18
Zinc	11

¹EMP/CORINAIR (1996).

Factor units are grams of metal emitted per tonne of glass or glass product manufactured.

All emission factors have a rating of U.

Table 6. Particulate Emission Factors for Glass Fibre Manufacturing^{1,a}

Source	PM ₁₀ (kg/tonne)
Unloading and conveying	ND
Storage bins	ND
Mixing and weighing	ND
Crushing and batch charging	ND
Glass furnace - wool	
Electric	ND
Gas - regenerative	ND
Gas - recuperative	ND
Gas - unit melter	ND
Forming - wool	
Flame attenuation	ND
Forming - textile	ND
Oven curing - wool	
Flame attenuation	ND
Rotary spin wool glass manufacturing	
R-19 Building Insulation	ND
R-11 Building Insulation	ND
Ductboard	ND
Heavy density	ND

¹ USEPA AP-42 Section 11.13 (1995).

^a Factors are from uncontrolled sources unless otherwise noted.

ND = no data. Neg = negligible.

All emission factors are rated C.

Table 7. Emission Factors For Glass Fibre Manufacturing ^{1,a}

Source	SO ₂ (kg/tonne)	NO _x (kg/tonne)	CO (kg/tonne)
Glass furnace - wool			
Electric	0.02	0.14	0.025
Gas-regenerative	5	2.5	0.13
Gas-recuperative	5	0.85	0.13
Gas - unit melter	0.3	0.15	0.13
Glass furnace - textile ^b			
Gas-recuperative	1.5 ²	10 ²	0.25 ²
Gas-regenerative	15 ²	10 ²	0.5 ²
Gas - unit melter	ND	10	0.45
Forming - wool			
Flame attenuation	NA	NA	NA
Forming - textile	NA	NA	NA
Oven curing - wool			
Flame attenuation	ND	1	1.8
Oven curing and cooling - textile	NA	1.3	0.75

¹ USEPA AP-42 Section 11.13 (1995)

² Economopoulos (1993).

Factor units are kg of substance emitted / tonne of product produced.

All emission factors are rated C

^a Factors are for uncontrolled sources unless otherwise noted.

ND = no data NA = not applicable

Table 8. Emission Factors For Glass Fibre Manufacturing ^{1,a}

Source	VOCs (kg/tonne)	Phenolics (kg/tonne)	Phenol (kg/tonne)	Formaldehyde (kg/tonne)	Fluorine (kg/tonne)
Glass furnace - wool					
Electric	ND	ND	ND	ND	0.001
Gas-regenerative	ND	ND	ND	ND	0.06
Gas-recuperative	ND	ND	ND	ND	0.06
Gas-unit melter	ND	ND	ND	ND	0.06
Glass furnace - textile ^b					
Gas-recuperative	ND	ND	ND	ND	1
Gas-regenerative	ND	ND	ND	ND	1
Gas-unit melter	ND	ND	ND	ND	1
Forming - wool					
Flame attenuation	0.15	ND	ND	ND	ND
Forming - textile	Neg.	ND	ND	ND	NA
Oven curing - wool					
Flame attenuation	3.5	ND	ND	ND	ND
Oven curing and cooling - textile	Neg	ND	ND	ND	ND
Rotary spin wool glass fibre manufacturing					
R-19	ND	3.21	0.96	0.75	ND
R-11	ND	6.21	0.92	1.23	ND
Ductboard	ND	10.66	3.84	1.80	ND
Heavy density	ND	0.88	0.53	0.43	ND

¹ USEPA AP-42 Section 11.13 (1995)

Units are kg of substance emitted / tonne of product manufactured. To report emissions of phenol, add both the phenolics and phenol emissions together and report the total as phenol.

^a Factors represent uncontrolled emissions unless otherwise noted.

ND = no data. NA = not applicable. Neg. = negligible.

All emission factors rated C.

7.0 Control Technologies

Air emission control technologies traditionally used in glass manufacturing commonly transfer pollutants from one media to another (eg. air to water, or hazardous waste). More recent process improvements have helped to reduce the total emissions generated and improve manufacturing efficiency. One available improvement is a rapid melting system, which involves preheating the batch prior to melting. This practice reduces process time, energy consumption, and air emissions. The substitution of oxygen for combustion air is another process improvement that can reduce nitrogen oxide and particulate emissions. The drawbacks of using pure oxygen rather than air are one high cost, and the emergence of localised hot spots during combustion.

Abatement equipment and control technologies, such as electrostatic precipitators and fabric filters are often used to reduce emissions in glass manufacturing. If you have installed these, or other abatement equipment at your facility, or you have implemented work practices that reduce emissions, you should multiply the control efficiency of the technology, or the practice adopted, by the appropriate emission factors used.

Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of particulates in process off-gases before stack emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been applied in an emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in earlier sections.

In the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 0.9 should be used in the emission factor equation to calculate actual mass emissions.

8.0 References

Eastern Research Group. July 1997. *Introduction To Stationary Point Source Emission Inventory Development Volume II: Chapter 1*. Morrisville, NC, USA.

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