Glass Manufacturing

Industry Description and Practices

This document describes the manufacture of flat glass and pressed and blown glass. Flat glass includes plate and architectural glass, automotive windscreens, and mirrors. Pressed and blown glass includes containers, machine-blown and hand-blown glassware, lamps, and television tubing. In both categories, a glass melt is prepared from silica sand, other raw materials such as lime, dolomite, and soda, and cullet (broken glass). The use of recycled glass is increasing. It reduces the consumption of both raw materials and energy but necessitates extensive sorting and cleaning prior to batch treatment to remove impurities.

For the manufacture of special and technical glass, lead oxide, potash, zinc oxide, and other metal oxides are added. Refining agents include arsenic trioxide, antimony oxide, nitrates, and sulfates. Metal oxides and sulfides are used as coloring or decoloring agents.

The most common furnace used for manufacturing glass melt is the continuous regenerative type, with either the side or the end ports connecting brick checkers to the inside of the melter. Checkers conserve fuel by acting as heat exchangers; the fuel combustion products heat incoming combustion air. The molten glass is refined (heat conditioning) and is then pressed, blown, drawn, rolled, or floated, depending on the final product. Damaged and broken product (cullet) is returned to the process.

The most important fuels for glass-melting furnaces are natural gas, light and heavy fuel oil, and liquefied petroleum gas. Electricity (frequently installed as supplementary heating) is also used. Energy requirements range from 3.7 to 6.0 kilojoules per metric ton (kJ/t) glass produced.

Waste Characteristics

Two types of air emissions are generated: those from the combustion of fuel for operating the glass-melting furnaces, and fine particulates from the vaporization and recrystallization of materials in the melt. The main emissions are sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulates, which can contain heavy metals such as arsenic and lead. Particulates from lead crystal manufacture can have a lead content of 20–60% and an arsenic content of 0.5–2%. Certain specialty glasses can produce releases of hydrogen chloride (HCl), hydrogen fluoride (HF), arsenic, boron, and lead from raw materials. Container, pressing, and blowing operations produce a periodic mist when the hot gob comes into contact with the release agent used on the molds.

Cold-top electric furnaces, in which the melt surface is covered by raw material feed, release very little particulate matter, as the blanket acts as a filter to prevent the release of particulate matter. Some releases of particulates will take place in tapping, but furnace releases should be of the order of 0.1 kilogram per ton (kg/t) when operated this way.

Lead glass manufacture may result in lead emissions of about 2–5 kg/t.

In all cases, the concentration of heavy metals and other pollutants in the raw flue gas mainly depends on the type of fuel used, the composition of the feed material, and the portion of recycled glass. High input of sulfates or potassium nitrate may increase emissions of sulfur dioxide and nitrogen oxides, respectively. Where nitrate is used, more than two thirds of the introduced nitrogen may be emitted as nitrogen oxides. The use of heavy metals as coloring or decoloring agents will increase emissions of these metals.

The grinding and polishing of flat glass to produce plate glass have become obsolete since the development of the float glass process. The chemical makeup of detergents that may be used in float glass manufacturing can vary significantly—some may contain phosphorus. In blowing and pressing, pollutants in effluents are generated by finishing processes such as cutting, grinding, polishing, and etching. The pollutants include suspended solids, fluorides, lead, and variations in pH.

Liquid effluents also result from forming, finishing, coating, and electroplating operations. Heavy metal concentrations in effluents occur where silvering and copperplating processes are in use.

Pollution Prevention and Control

Oxygen-enriched and oxyfuel furnaces are used in specialty glass operations to reduce emissions or to make possible higher production rates with the same size furnace. Although oxyfuel furnaces may produce higher NO_x emissions on a concentration basis, they are expected to yield very low levels of nitrogen oxides on a mass basis (kg / t of product). Low-NO_x furnaces, staged firing, and flue gas recirculation are available to reduce both concentration and the mass of nitrogen oxide emissions. These techniques are also available for air-fuel-fired furnaces. Nitrogen oxide levels can be controlled to 500–800 milligrams per cubic meter (mg/m^3).

The type of combustion fuel used affects the amount of sulfur oxides and nitrogen oxides emitted. Use of natural gas results in negligible sulfur dioxide emissions from the fuel compared with high-sulfur fuel oils. Fuel oil with a low sulfur content is preferable to fuel oil with a high sulfur content if natural gas is not available.

An efficient furnace design will reduce gaseous emissions and energy consumption. Examples of improvements include modifications to the burner design and firing patterns, higher preheater temperatures, preheating of raw material, and electric melting.

Changing the composition of the raw materials can, for example, reduce chlorides, fluorides, and sulfates used in certain specialty glasses. The use of outside-sourced cullet and recycled glass will reduce energy requirements (for an estimated 2% savings for each 10% of cullet used in the manufacture of melt) and thus air emissions (up to 10% for 50% cullet in the mix). Typical recycling rates are 10–20% in the flat glass industry and over 50% for the blown and pressed glass industries.

The amount of heavy metals used as refining and coloring or decoloring agents, as well as use of potassium nitrate, should be minimized to the extent possible.

In the furnace, particulates are formed through the volatilization of materials, leading to formation of condensates and of slag that clogs the furnace checkers. Disposal of the slag requires testing to determine the most suitable disposal method. It is important to inspect the checkers regularly to determine whether cleaning is required.

Particulate matter is also reduced, for example, by enclosing conveyors, pelletizing raw material, reducing melt temperatures, and blanketing the furnace melt with raw material.

Reductions in wastewater volumes are possible through closed cooling water loops and improved blowoff techniques.

Target Pollution Loads

Modern plants using good industrial practices are able to achieve the pollutant loads given here. Because of the lack of nitrogen in the oxidant, using oxyfuel-fired furnaces produces four to five times less flue gas volume than regenerative furnaces. As a result nitrogen oxides are reduced by 80%, and particulates are reduced by 20–80%.

For furnaces that operate with a cover of raw material, a target of 0.1 kg / t for particulates is realistic. Reductions in sulfur dioxide are achieved by choosing natural gas over fuel oil where possible.

Treatment Technologies

ESPs are the preferred choice for removing particulates, although fabric filters are also used. Dry scrubbing using calcium hydroxide is used to reduce sulfur dioxide, hydrogen fluoride, and hydrogen chloride. Secondary measures for NO_x control include selective catalytic reduction

(SCR), selective noncatalytic reduction (SNCR), and certain proprietary processes such as the Pilkington 3R process.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook,* as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The guidelines given below present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

The air emissions presented in Table 1 should be achieved.

Liquid Effluents

The effluent levels presented in Table 2 should be achieved.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

Receptor	Maximum allowable log equivalent (hourly measurements), in dB(A): Day (07:00–22:00)	Night (22:00–07:00)
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Table 1. Air Emissions from Glass Manufacturing

(milligrams per normal cubic meter)

Parameter	*Maximum value*
Nitrogen oxides	1,000 (up to 2,000 may be acceptable, depending on furnace technology and if justified in the EA)
Sulfur oxides	
Gas fired	700
Oil fired	1,800
Particulates	50 (20 where toxic metals are present)
Lead and cadmium (total)	5
Arsenic	1
Total of other heavy metals	5
Fluoride	5
Hydrogen chloride	50

Table 2. Effluents from Glass Manufacturing

(milligrams per liter, except for pH)

Parameter	*Maximum value*
pH	6–9
TSS	50
COD	150
Oil and grease	10
Lead	0.1
Arsenic	0.1
Antimony	0.5
Fluorides	20
Total metals	10

Note: Effluent requirements are for direct discharge to surface waters.

Monitoring and Reporting

Frequent sampling may be required during start-up and upset conditions. Once a record of consistent performance has been established, sampling for the parameters listed in this document should be as described below.

Opacity should be monitored continuously. The maximum opacity level should be set to correspond to 50 mg/Nm^3.Other air emissions parameters should be measured annually. Liquid effluents should be continuously monitored for pH, and other parameters should be tested weekly.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The key production and control practices that will lead to compliance with emissions requirements can be summarized as follows:

- Consider using oxyfuel-fired furnaces for specialty glass manufacturing.
- Use low-NO_x burners, staged firing, and flue gas recirculation.
- Consider natural gas rather than oil as the fuel of choice.
- Select raw materials to minimize emissions of fluorides and other pollutants such as chlorides and sulfates.
- Maximize water reuse.
- For reductions in particulate emissions, pelletize raw materials, enclose conveyors, reduce melt temperatures, and blanket the melt surface with raw material.

Sources

Bounicore, Anthony J., and Wayne T. Davis, eds. 1992. *Air Pollution Engineering Manual.* New York: Van Nostrand Reinhold.

Economopoulos, Alexander P. 1993. *Assessment of Sources of Air, Water, and Land Pollution: A Guide to Rapid Source Inventory Techniques and Their Use in Formulating Environmental Control Strategies.* Part 1: *Rapid Inventory Techniques in Environmental Pollution*. Geneva, World Health Organization.

Sittig, Marshall. 1975. *Pollution Control in the Asbestos, Cement, Glass, and Allied Mineral Industries*. Park Ridge, N.J.: Noyes Data Corporation.

World Bank. 1996. "Pollution Prevention and Abatement: Glass Manufacturing Plants." Draft Technical Background Document. Environment Department, Washington, D.C.