11.15 Glass Manufacturing

11.15.1 General[1-5]

Commercially produced glass can be classified as soda-lime, lead, fused silica, borosilicate, or 96 percent silica. Soda-lime glass, since it constitutes 77 percent of total glass production, is discussed here. Soda-lime glass consists of sand, limestone, soda ash, and cullet (broken glass). The manufacture of such glass is in four phases: (1) preparation of raw material, (2) melting in a furnace, (3) forming and (4) finishing. Figure 11.15-1 is a diagram for typical glass manufacturing.

The products of this industry are flat glass, container glass, and pressed and blown glass. The procedures for manufacturing glass are the same for all products except forming and finishing. Container glass and pressed and blown glass, 51 and 25 percent respectively of total soda-lime glass production, use pressing, blowing or pressing and blowing to form the desired product. Flat glass, which is the remainder, is formed by float, drawing, or rolling processes.

As the sand, limestone, and soda ash raw materials are received, they are crushed and stored in separate elevated bins. These materials are then transferred through a gravity feed system to a weigher and mixer, where the material is mixed with cullet to ensure homogeneous melting. The mixture is conveyed to a batch storage bin where it is held until dropped into the feeder to the melting furnace. All equipment used in handling and preparing the raw material is housed separately from the furnace and is usually referred to as the batch plant. Figure 11.15-2 is a flow diagram of a typical batch plant.

The furnace most commonly used is a continuous regenerative furnace capable of producing between 45 and 272 megagrams (Mg) (50 and 300 tons) of glass per day. A furnace may have either side or end ports that connect brick checkers to the inside of the melter. The purpose of brick checkers (Figure 11.15-3 and Figure 11.15-4) is to conserve fuel by collecting furnace exhaust gas heat that, when the air flow is reversed, is used to preheat the furnace combustion air. As material enters the melting furnace through the feeder, it floats on the top of the molten glass already in the furnace. As it melts, it passes to the front of the melter and eventually flows through a throat leading to the refiner. In the refiner, the molten glass is heat conditioned for delivery to the forming process. Figures 11.15-3 and 11.15-4 show side port and end port regenerative furnaces.

After refining, the molten glass leaves the furnace through forehearths (except in the float process, with molten glass moving directly to the tin bath) and goes to be shaped by pressing, blowing, pressing and blowing, drawing, rolling, or floating to produce the desired product. Pressing and blowing are performed mechanically, using blank molds and glass cut into sections (gobs) by a set of shears. In the drawing process, molten glass is drawn upward in a sheet through rollers, with thickness of the sheet determined by the speed of the draw and the configuration of the draw bar. The rolling process is similar to the drawing process except that the glass is drawn horizontally on plain or patterned rollers and, for plate glass, requires grinding and polishing. The float process is different, having a molten tin bath over which the glass is drawn and formed into a finely finished surface requiring no grinding or polishing. The end product undergoes finishing (decorating or coating) and annealing (removing unwanted stress areas in the glass) as required, and is then inspected and prepared for shipment to market. Any damaged or undesirable glass is transferred back to the batch plant to be used as cullet.

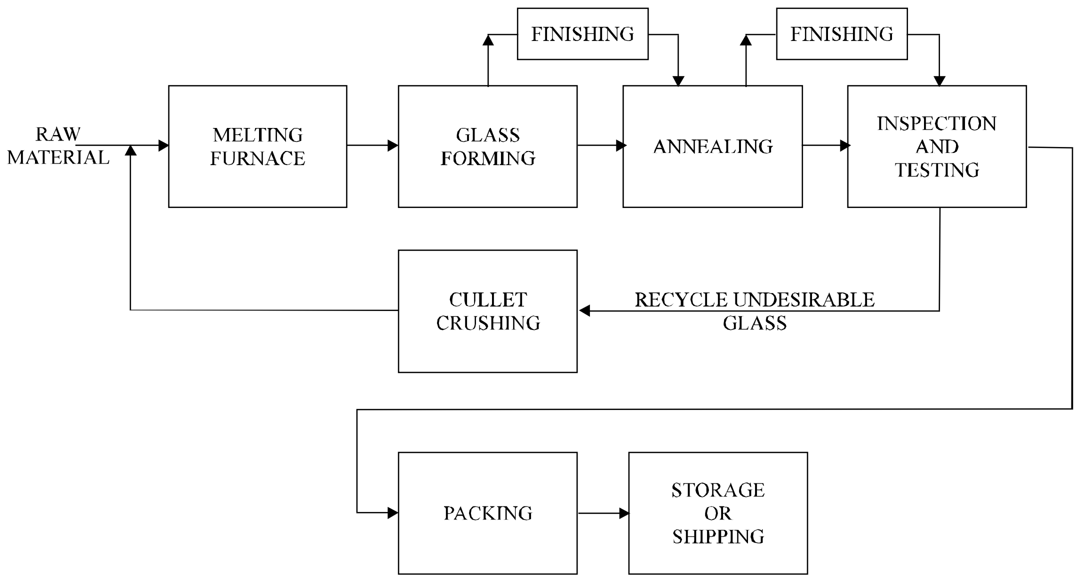

Figure 11.15-1. Typical glass manufacturing process.

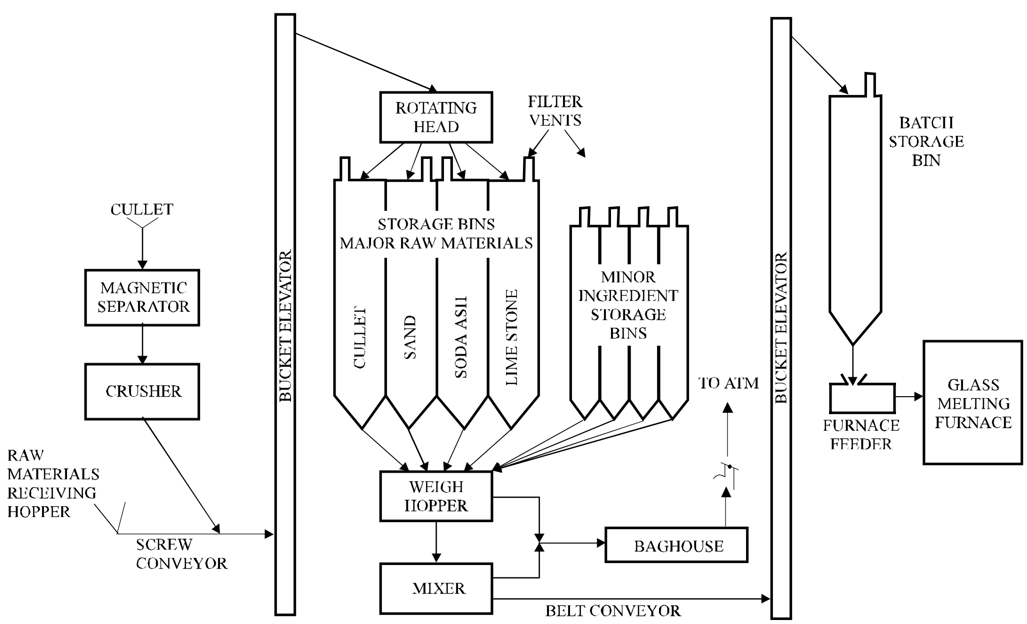

Figure 11.15-2. General diagram of a batch plant.

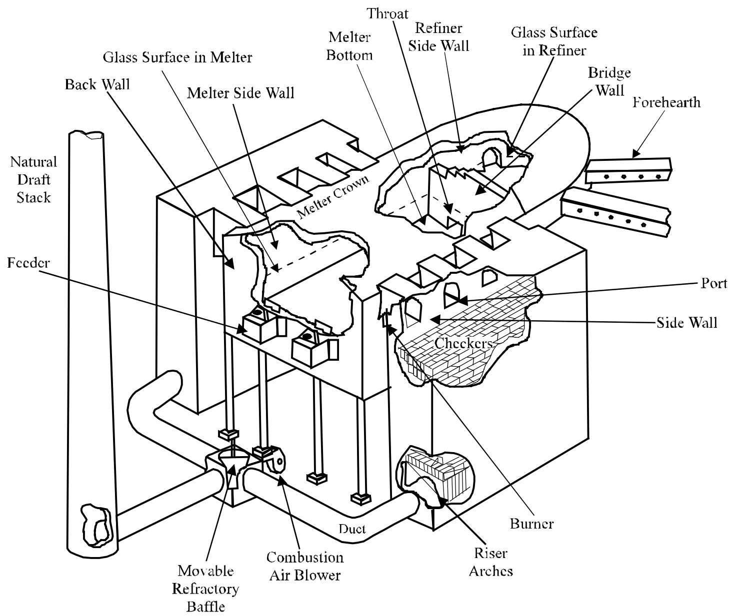

Figure 11.15-3. Side port continuous regenerative furnace.

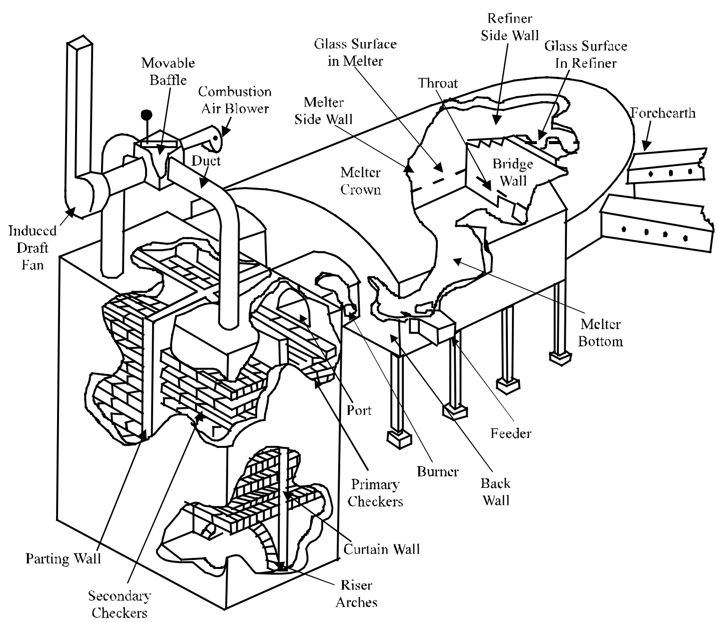

Figure 11.15-4. End port continuous regenerative furnace.

11.15.2 Emissions And Controls[1-5]

The main pollutant emitted by the batch plant is particulates in the form of dust. This can be controlled with 99 to 100 percent efficiency by enclosing all possible dust sources and using baghouses or cloth filters. Another way to control dust emissions, also with an efficiency approaching 100 percent, is to treat the batch to reduce the amount of fine particles present, by presintering, briquetting, pelletizing, or liquid alkali treatment.

The melting furnace contributes over 99 percent of the total emissions from a glass plant, both particulates and gaseous pollutants. Particulates result from volatilization of materials in the melt that combine with gases and form condensates. These either are collected in the checker work and gas passages or are emitted to the atmosphere. Serious problems arise when the checkers are not properly cleaned in that slag can form, clog the passages, and eventually deteriorate the condition and efficiency of the furnace. Nitrogen oxides form when nitrogen and oxygen react in the high temperatures of the furnace. Sulfur oxides result from the decomposition of the sulfates in the batch and sulfur in the fuel. Proper maintenance and firing of the furnace can control emissions and also add to the efficiency of the furnace and reduce operational costs. Low-pressure wet centrifugal scrubbers have been used to control particulate and sulfur oxides, but their inefficiency (approximately 50 percent) indicates their inability to collect particulates of submicrometer size. High-energy venturi scrubbers are approximately 95 percent effective in reducing particulate and sulfur oxide emissions. Their effect on nitrogen oxide emissions is unknown. Baghouses, with up to 99 percent particulate collection efficiency, have been used on small regenerative furnaces, but fabric corrosion requires careful temperature control. Electrostatic precipitators have an efficiency of up to 99 percent in the collection of particulates. Tables 11.15-1 and 11.15-2 list controlled and uncontrolled emission factors for glass manufacturing. Table 11.15-3 presents particle size distributions and corresponding emission factors for uncontrolled and controlled glass melting furnaces, and these are depicted in Figure 11.15-5.

Emissions from the forming and finishing phases depend upon the type of glass being manufactured. For container, press, and blow machines, the majority of emissions results from the gob coming into contact with the machine lubricant. Emissions, in the form of a dense white cloud that can exceed 40 percent opacity, are generated by flash vaporization of hydrocarbon greases and oils. Grease and oil lubricants are being replaced by silicone emulsions and water soluble oils, which may virtually eliminate this smoke. For flat glass, the only contributor to air pollutant emissions is gas combustion in the annealing lehr (oven), which is totally enclosed except for product entry and exit openings. Since emissions are small and operational procedures are efficient, no controls are used on flat glass processes.

Table 11.15-1 (Metric And English Units). PARTICULATE, SULFUR OXIDES, AND NITROGEN OXIDES EMISSION FACTORS FOR GLASS MANUFACTURING[a]

EMISSION FACTOR RATING: B

Process	Particulate		Sulfur Oxides		Nitrogen Oxides	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Raw materials handling[b] (all types of glass)	Neg	Neg	0	0	0	0
Melting furnace[c]						
Container						
Uncontrolled	0.7	1.4	1.7	3.4	3.1	6.2
	(0.4 - 0.9)	(0.9 - 1.9)	(1.0 - 2.4)	(2.0 - 4.8)	(1.6 - 4.5)	(3.3 - 9.1)
w/low-energy scrubber[d]	0.4	0.7	0.9	1.7	3.1	6.2
w/venturi scrubber[e]	<0.1	0.1	0.1	0.2	3.1	6.2
w/baghouse[f]	Neg	Neg	1.7	3.4	3.1	6.2
w/electrostatic precipitator[g]	Neg	Neg	1.7	3.4	3.1	6.2
Flat						
Uncontrolled	1.0	2.0	1.5	3.0	4.0	8.0
	(0.4 - 1.0)	(0.8 - 3.2)	(1.1 - 1.9)	(2.2 - 3.8)	(2.8 - 5.2)	(5.6 - 10.4)
w/low-energy scrubber[d]	0.5	1.0	0.8	1.5	4.0	8.0
w/venturi scrubber[e]	Neg	Neg	0.1	0.2	4.0	8.0
w/baghouse[f]	Neg	Neg	1.5	3.0	4.0	8.0
w/electrostatic precipitator[g]	Neg	Neg	1.5	3.0	4.0	8.0
Pressed and blown						
Uncontrolled	8.4	17.4	2.8	5.6	4.3	8.5
	(0.5 - 12.6)	(1.0 - 25.1)	(0.5 - 5.4)	(1.1 - 10.9)	(0.4 - 10.0)	(0.8 - 20.0)

Table 11.15-1 (cont.).

Process	Particulate		Sulfur Oxides		Nitrogen Oxides	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
w/low-energy scrubber[d]	4.2	8.4	1.3	2.7	4.3	8.5
w/venturi scrubber[e]	0.5	0.9	0.1	0.3	4.3	8.5
w/baghouse[f]	0.1	0.2	2.8	5.6	4.3	8.5
w/electrostatic precipitator[g]	0.1	0.2	2.8	5.6	4.3	8.5
Forming and finishing						
Container[h,j]	Neg	Neg	Neg	Neg	Neg	Neg
Flat	Neg	Neg	Neg	Neg	Neg	Neg
Pressed and blown[h,j]	Neg	Neg	Neg	Neg	Neg	Neg
Lead glass manufacturing, all processes[k]	ND	ND	ND	ND	ND	ND

[a] Reference 2-3,5. ND = no data. Neg = negligible. Ranges in parentheses, where available. Expressed as kg/Mg (lb/ton) of glass produced.
[b] Not separated into types of glass produced, since batch preparation is the same for all types. Particulate emissions are negligible because almost all plants utilize some form of control (i. e., baghouses, scrubbers, centrifugal collectors).
[c] Control efficiencies for the various devices are applied only to the average emission factor.
[d] Approximately 52% efficiency in reducing particulate and sulfur oxides emissions. Effect on nitrogen oxides is unknown.
[e] Approximately 95% efficiency in reducing particulate and sulfur oxide emissions. Effect on nitrogen oxides is unknown.
[f] Approximately 99% efficiency in reducing particulate emissions.
[g] Calculated using data for furnaces melting soda lime and lead glasses. No data available for borosilicate or opal glasses.
[h] Organic emissions are from decorating process. Can be controlled by incineration, absorption, or condensation, but efficiencies are not known.
[j] 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/Mg (0.2 lb/ton) each.
[k] References 6-7. Particulate containing 23% lead.

Table 11.15-2 (Metric And English Units). VOC, CARBON MONOXIDE, AND LEAD EMISSION FACTORS FOR GLASS MANUFACTURING[a]

EMISSION FACTOR RATING: B

Process	VOC		Carbon Monoxide		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Raw materials handling[b] (all types of glass)	0	0	0	0	ND	ND
Melting furnace[c]						
Container						
Uncontrolled	0.1	0.2	0.1	0.2	ND	ND
	(0 - 0.2)	(0 - 0.4)	(0 - 0.2)	(0 - 0.5)		
w/low-energy scrubber[d]	0.1	0.2	0.1	0.2	ND	ND
w/venturi scrubber[e]	0.1	0.2	0.1	0.2	ND	ND
w/baghouse[f]	0.1	0.2	0.1	0.2	ND	ND
w/electrostatic precipitator[g]	0.1	0.2	0.1	0.2	ND	ND
Flat						
Uncontrolled	<0.1	<0.1	<0.1	<0.1	ND	ND
w/low-energy scrubber[d]	<0.1	<0.1	<0.1	<0.1	ND	ND
w/venturi scrubber[e]	<0.1	<0.1	<0.1	<0.1	ND	ND
w/baghouse[f]	<0.1	<0.1	<0.1	<0.1	ND	ND
w/electrostatic precipitator[g]	<0.1	<0.1	<0.1	<0.1	ND	ND
Pressed and blown						
Uncontrolled	0.2	0.3	0.1	0.2	ND	ND
	(0.1 - 0.3)	(0.1 - 1.0)	(0.1 - 0.2)	(0.1 - 0.3)		

Table 11.15-2 (cont.).

Process	VOC		Carbon Monoxide		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
w/low-energy scrubber[d]	0.2	0.3	0.1	0.2	ND	ND
w/venturi scrubber[e]	0.2	0.3	0.1	0.2	ND	ND
w/baghouse[f]	0.2	0.3	0.1	0.2	ND	ND
w/electrostatic precipitator[g]	0.2	0.3	0.1	0.2	ND	ND
Forming and finishing						
Container[h,j]	4.4	8.7	Neg	Neg	ND	ND
Flat	Neg	Neg	Neg	Neg	ND	ND
Pressed and blown[h,j]	4.5	9.0	Neg	Neg	ND	ND
Lead glass manufacturing, all processes[k]	ND	ND	ND	ND	2.5	5

[a] Reference 2-3,5. ND = no data. Neg = negligible. Ranges in parentheses, where available. Expressed as kg/Mg (lb/ton) of glass produced.

[b] Not separated into types of glass produced, since batch preparation is the same for all types. Particulate emissions are negligible because almost all plants utilize some form of control (i. e., baghouses, scrubbers, centrifugal collectors).

[c] Control efficiencies for the various devices are applied only to the average emission factor.

[d] Approximately 52% efficiency in reducing particulate and sulfur oxides emissions. Effect on nitrogen oxides is unknown.

[e] Approximately 95% efficiency in reducing particulate and sulfur oxide emissions. Effect on nitrogen oxides is unknown.

[f] Approximately 99% efficiency in reducing particulate emissions.

[g] Calculated using data for furnaces melting soda lime and lead glasses. No data are available for borosilicate or opal glasses.

[h] Organic emissions are from decorating process. Can be controlled by incineration, absorption or condensation, but efficiencies are not known.

[j] 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/Mg (0.2 lb/ton) each.

[k] References 6-7. Particulate containing 23% lead.

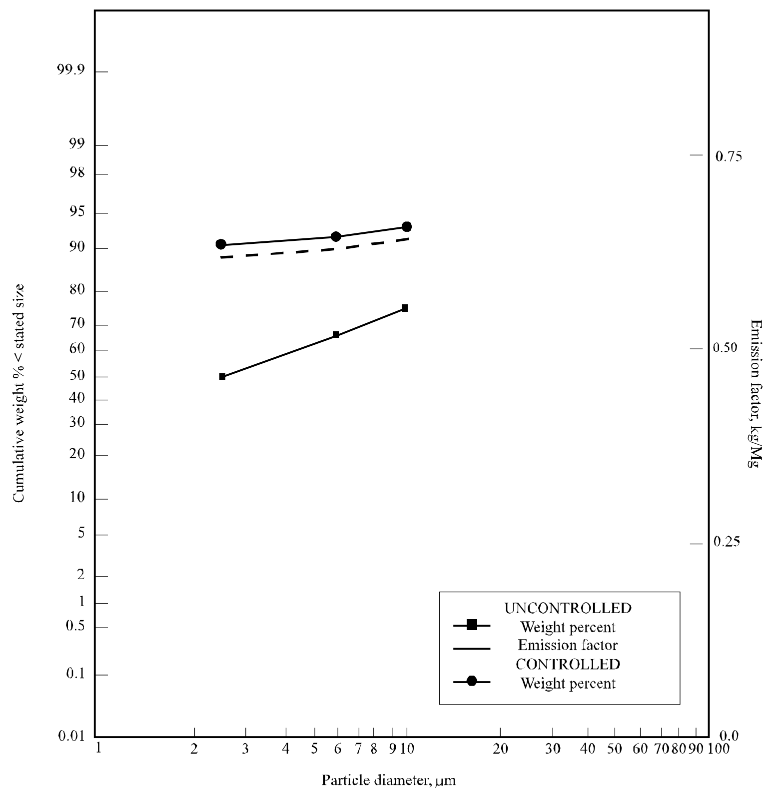

Figure 11.15-5. Particle size distributions and emission factors for glass melting furnace exhaust.

Table 11.15-3 (Metric Units). PARTICLE SIZE DISTRIBUTIONS AND EMISSION FACTORS FOR UNCONTROLLED AND CONTROLLED MELTING FURNACES IN GLASS MANUFACTURING[a]

EMISSION FACTOR RATING: E

Aerodynamic Particle Diameter, μm	Particle Size Distribution[b]		Size-Specific Emission Factor, kg/Mg[c]
	Uncontrolled	ESP Controlled[d]	Uncontrolled
2.5	91	53	0.64
6.0	93	66	0.65
10	95	75	0.66

[a] References 8-11.
[b] Cumulative weight % of particles < corresponding particle size.
[c] Based on mass particulate emission factor of 0.7 kg/Mg glass produced, from Table 11.15-1. Size-specific emission factor = mass particulate emission factor x particle size distribution, %/100. After ESP control, size-specific emission factors are negligible.
[d] References 8-9. Based on a single test.

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