Ⅱ.Glass Manufacturing Industry

1. Glass Manufacturing Process and Air Pollutants

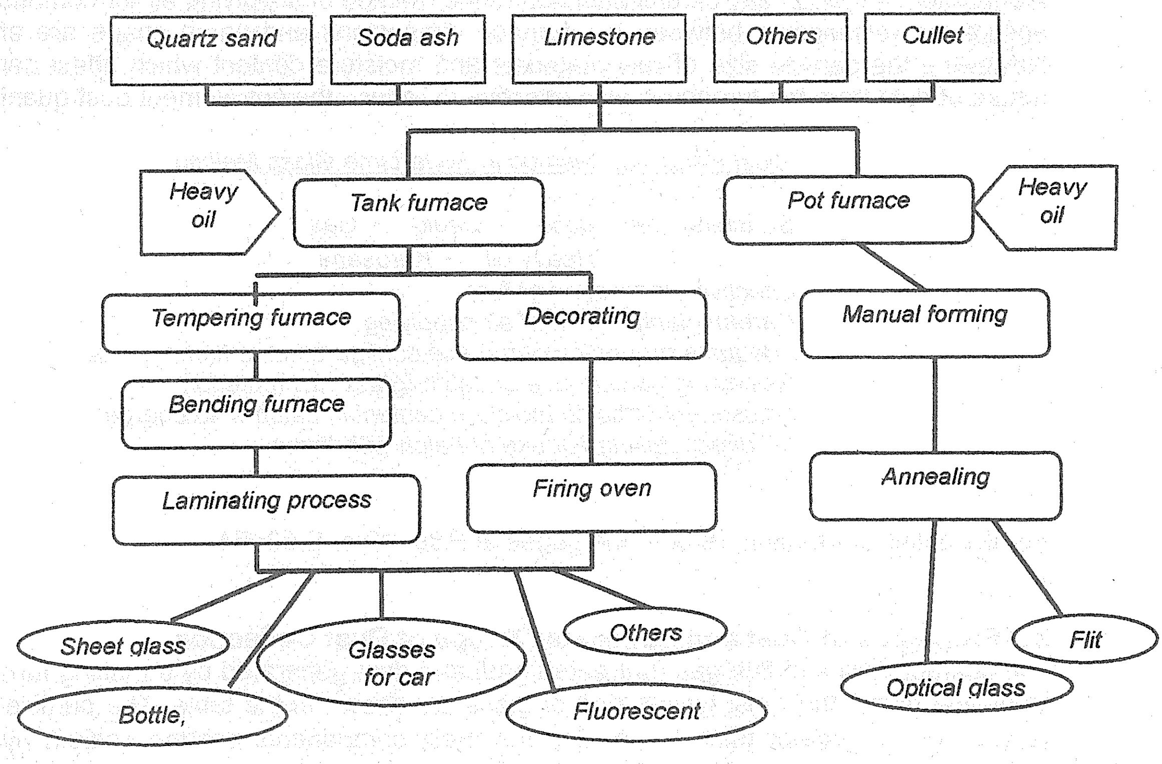
Classifying glass products of according to their composition, the soda-lime glass called "ordinary glass" is the type most generally used. Other than this, special-composition glasses are classified into borosilicate glass (hard glass), lead glass, and alkali-free glass. The main raw materials of glasses are silica (SiO_2), alumina (Al_2O_3), boric acid (B_2O_3)phosphoric acid (P_2O_5), soda (Na_2O), potash (K_2O), lime (CaO), magnesia (MgO), barium oxide (BaO), lead oxide (PbO),zinc oxide (ZnO),etc.

In glass manufacturing process, first raw materials are finely crushed to particle size needed in order to melt glass eventually at high temperature. The crushed materials are melted at very high temperature (melting process) and homogenized (refining process) to remove impurities and bubbles generated in the melted glass.

Glass production methods are classified to 2 combinations of melting and forming;

(1) continuous tank-furnace melting + machine forming, which is suitable for mass production of a few various of product

(2) round pot furnace melting + manual forming, which is suitable for producing small quantities of multiple various of products.



The air pollutants are (1) dust which is generated from crushed materials during the handling, and (2) SOx, NOx and toxic materials which are contained in flue gas from furnace.

For the detail information, refer to the pages at P.3~13 or E.4~18.

2. Soot & Dust Reduction

2-1 Reduction by means of Fuel and Furnace Operation

The dust is generated from combustion of fuel and decomposition of raw materials containing some toxic materials. The particles with 10 ~ 100 μm of large diameter which are scattered from the work processes for storing, mixing, conveying and charging are usually handled separately from the soot and dust in flue gas.

The soot and dust from soda-lime glass melting furnaces consist of (1) the soot generated accompanying the combustion of fuel, (2) ash content, and heavy metals contained in the fuel, (3) scattered substances which are the carry-over from glass materials from the furnace, and (4) fume, which are aggregated evaporated substances.

Causes of Dust

- *Fuel → Dust (soot, ash, heavy metal)*
- *Raw Material → Scattered substances (ash, heavy metal)*
- *Non-uniform mixing fuel and air*

The most easy reduction methods of soot and dust are to change the fuel from solid to gas or from heavy oil to kerosene. Other than these fuels switching, the improvement of furnace operation is practical to deter the generation of dust. For examples, such as (1) effective atomization of fuel (2) pay careful attention to the method of supplying air for combustion (3) ensure the relationship between the furnace dimensions and flame shape are effective. Reviewing the particle size of raw materials and moisture content which affect carry-over nature of dust from the furnace is also effective to reduce the entrainment dust quantities.

Dust Reduction Method in Soda-Lime Glass Melting

- *Switching fuel; Solid → Liquid → Gas*
  Heavy oil → Kerosene
- *Effective atomization of fuel*
- *Careful manipulation of air supplying*
- *Adequate proportion of furnace configuration to flame shape*
- *Reviewing particle size of batch (glass raw material)*
- *Adjustment of batch moisture content in batch wise charge*
- *No direct striking surface of batch with flame*

For the detail information, refer to the pages at P.38~39 or E.53~54.

2-2 Properties of Dust and Applicable Scope of Dust Collection

The characteristics of flue gas (untreated gas) and dust generated by a melting furnace for soda-lime glass, the most typical kind of glass are shown in the table. The particle size is very small, no greater than 1 μm and the main components are the sodium hydrogen sulfate ($NaHSO_4$) and sodium sulfate (Na_2SO_4).

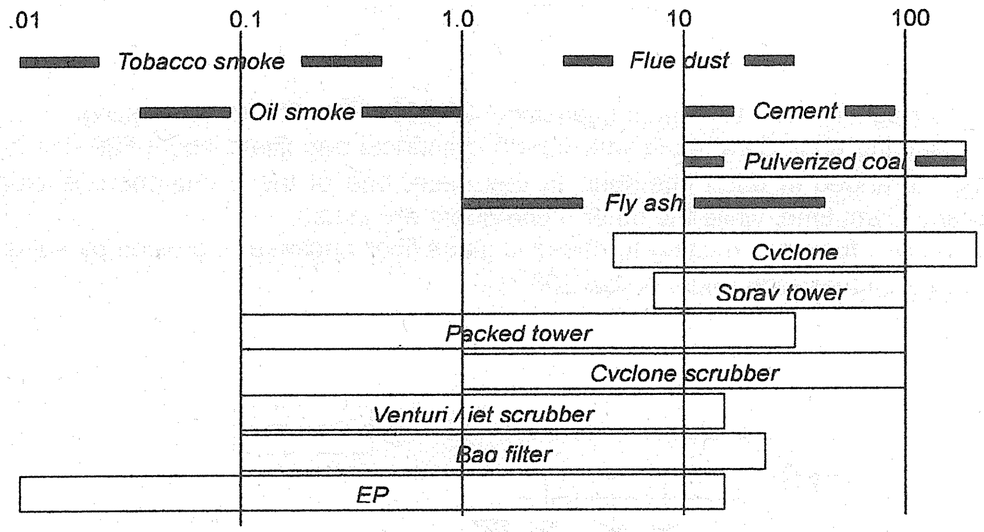
The particle sizes of various dusts and mists, and typical examples of dust collectors applied to them are shown in the figure.

Soda-Lime Glass Melting Furnace Flue Gas

Flue gas (400~600℃)		Dust		
O_2	8~9%	Dust conc.	0.2~0.4 g/Nm3	
CO_2	10%	Particle size	~ 0.5 μm	25%
H_2O	10%		0.5~ 0.3 μm	50%
SOx	500~1,500ppm		0.3~0.1 μm	20%
NOx	400~600ppm		0.1 μm ~	5%

Gravitational dust collectors, inertial dust collectors and centrifugal dust collectors are not suitable for collecting dust with small particle size 1 μm or less, as shown in a figure, and are not used to collect flue gas dust from glass melting furnaces.

Dust Collection



They are most commonly used in glass manufacturing plant to collect raw material particles generated in the processes of storing, mixing and charging of raw materials. Scrubbing dust collectors use large quantity of water and need periodical maintenance; therefore they are not suitable for glass melting furnaces, for which large quantities of flue gas must be continuously treated for long period of time. Therefore, filter dust collectors or electrostatic precipitators are generally used for large tank furnaces.

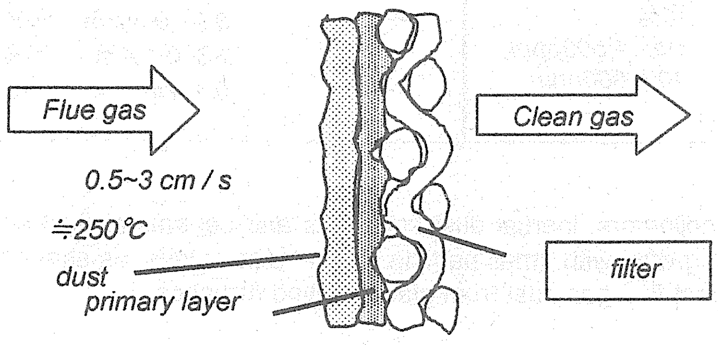
For the detail information, refer to the pages at P.38~41 or E.53~57.

2-3 Filter Dust Collector

Bag filter dust collectors have the widest usage range in all dust collectors. Bag filters can collect fine particles even 0.1 μm in size. When a bag filter is used for the treatment of flue gas from a glass melting furnace, a high dust-collection efficiency rate of 97~99% can be obtained.

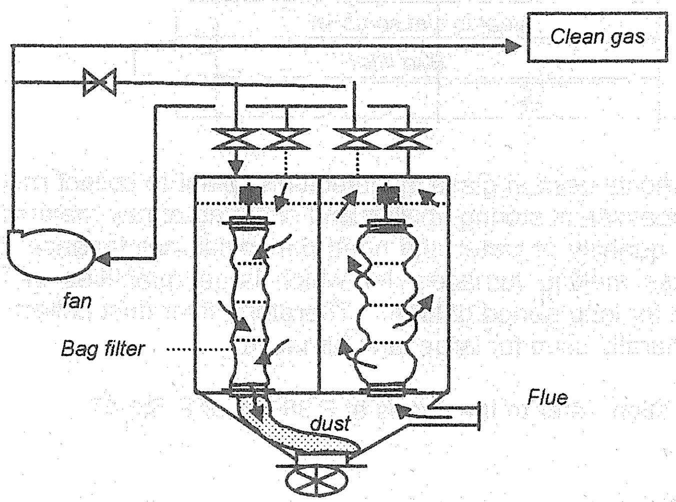
The dust collector mechanism is that the primary layer, which particles have adhered on the surface of the filter cloth, is used as the filtration layer to collect fine particles. The flow rate through the filter is usually around 0.5~3 cm/s. Therefore, when treating a large volume of gas, the dust collector equipment has multiple dust collecting chambers with many bag filters arrangement in parallel.

Filtration Action in Filter Cloth



ΔP≒150 mg Hg → dusting

For example, a bag filter with treatment capacity of 35,000 m^3/h (250℃) for melting furnace has 6 dust collecting chambers, each with 50~60 cylindrical bag filters about 600 cm long and 30 cmϕ, arranged in each chamber. In this case, one of the 6 chambers is being scrubbed at any given time, while the other 5 chambers are in use.
The filter cloth used for glass melting furnaces is glass fiber because of erosion by sulfuric acid due to dew condensation under below 200 ℃.



When the pressure loss has reached about 150 mm Hg after accumulation of dust on the filter, dusting is needed. The dusting method can be either intermittent, most commonly used for glass melting furnaces, or continuous. Dust removal can be done by a method using vibration or a method using reversed air.

Dusting frequency	Dusting drive
- intermittent	- vibration
- continuous	- reverse air

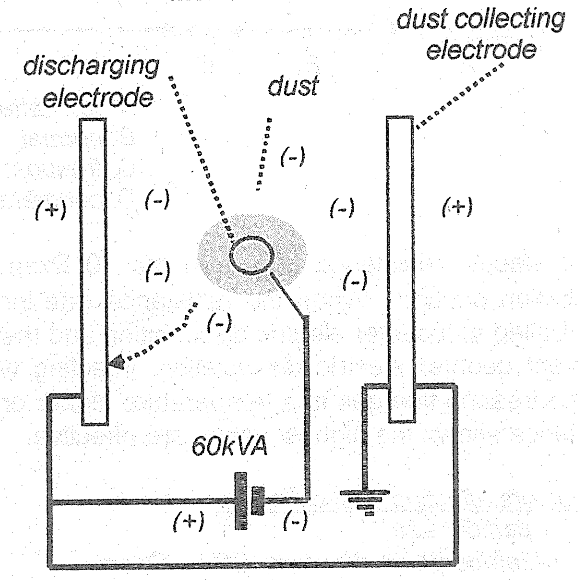
The gas temperature must be kept between 200 and 250 ℃ to avoid over heating for resistance temperature for filter cloth and dew point sulfuric acid.

For the detail information, refer to the pages at P.41~43 or E.57~58.

2-4 Electrostatic Precipitator

The electrostatic precipitator system collects dust by electrifying the dust particles in flue gas by corona discharge. When using an electrostatic precipitator, the influence of properties of flue gas and dust on collection efficiency is less, the collection of fine particles is easy by even when pressure loss is low, and high dust collection efficiency can be obtained. Therefore this system is widely used for the treatment of flue gas from glass melting furnaces.

Principle of EP



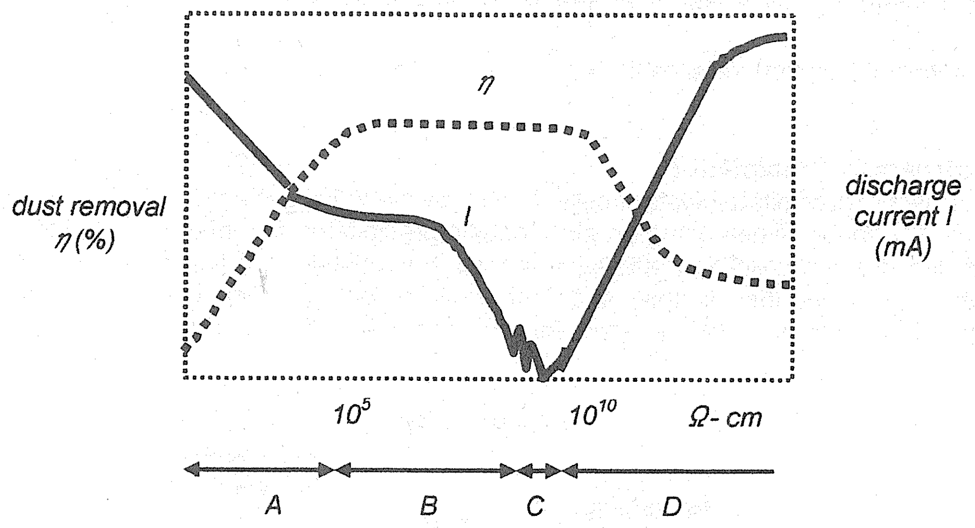
The electrostatic precipitator (EP) is used to remove very small liquid and solid particles from a gas stream. This operates by generating a corona between a high-voltage (60 KVA) electrode, usually a fine wire, and a passive earthed electrode, such as a plate or pipe. Particles passing through such an electric field are ionized by ions migrating from the discharge to collector electrode, with whom they collide. These particles then drift towards the collector electrode to which they are held by electrostatic attraction. The particle are removed from the collector by either a rapping or a water spray periodically.

Feature
- *Less influence of flue gas & dust*
- *Low pressure loss*

Peeling dust from electrode
- *Dry EP : hammering impact*
- *Wet EP: flow down with water film*

As particle size increases, dust collection efficiency is generally higher, although, the apparent electric resistance (Ω-cm) of dust has a great effect on dust collection efficiency. This is affected by gas temperature, moisture and the concentration of SO_3.

<u>Relation between apparent electric resistance and dust removal / discharge current</u>



A: re-scattering
B: normal
C: frequent occurring of sparks
D: counter electric dissociation

When the apparent electric resistance rate is in the $10^5\Omega$cm to $10^{11}\Omega$cm range, ideal electrostatic precipitation occurs. When the resistance rate increases to over $10^{11}\Omega$cm, the phenomenon is called as counter electric dissociation and then dust collection efficiency decreases. To prevent counter electric dissociation, injecting water or steam, or sulfuric anhydride (SO_3), and treating flue gas at a temperature higher or lower than 150~200℃, at which electric resistance shows the highest value, are effective.

<u>Factors affecting dust collection</u>
- *particle size*
- *temperature, moisture, $SO_3 \rightarrow \Omega$- cm*

For the detail information, refer to the pages at P.43~47 or E.60~66.

3. SOx Reduction Method

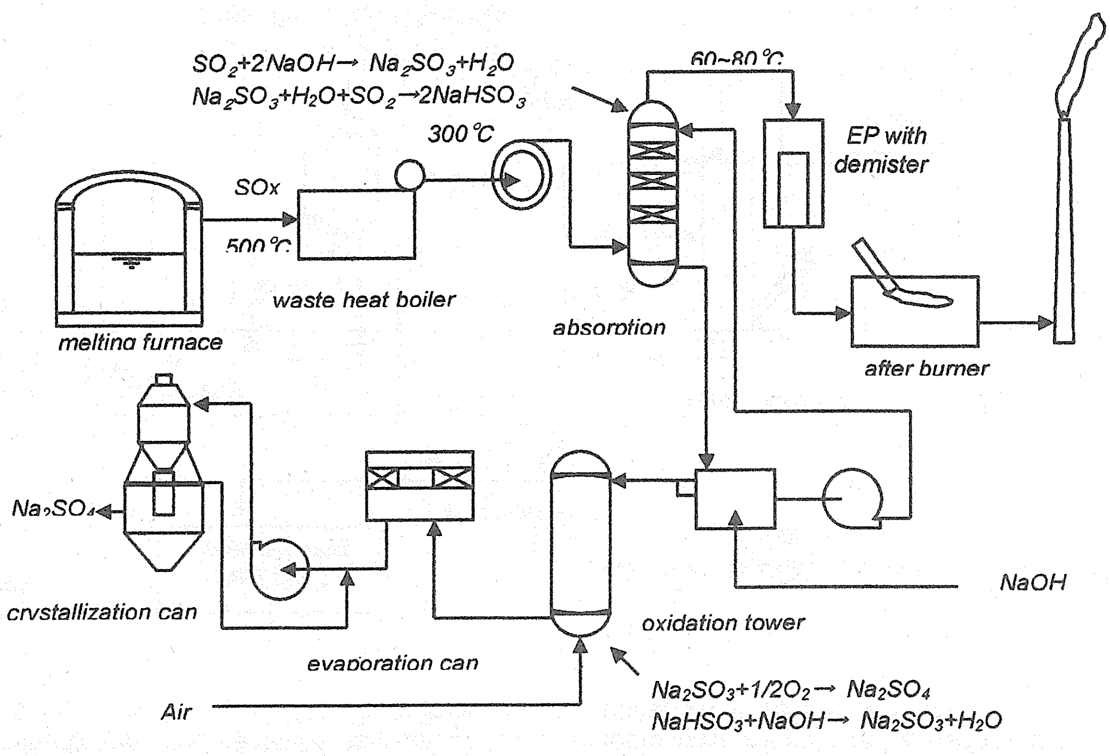
3-1 Desulphurization using Caustic Soda

SOx in flue gas from glass melting furnaces is usually generated by (1) combustion of the sulfur contained in fuel oil, (2) decomposition of sulfates such as sodium sulfate (Na_2SO_4), and gypsum ($CaSO_4$) used in glass raw materials. Flue gas desulphurization systems are generally adopted for glass melting furnaces using high-sulfur heavy oil.

There are many kind of applicable chemical reactions for separating and removing SOx from flue gas. The process of scrubbing using caustic soda and magnesium hydroxide ($Mg(OH)_2$), which is simple from the system view point, is most commonly used for glass melting furnaces.

The typical caustic soda desulphurization process is shown in the figure. Separated SOx is finally recovered as a form of sodium sulfate ($NaSO_4$). This system has achieved a desulphurization rate of over 97% and a dust removal rate of 95% as actual results. After desulphurization and dust removal have been done by this method, it is necessary to raise the temperature of treated gas by doing afterburning using clean gas, in order to eliminate the emission of white smoke containing the steam,: recently, however, concern about energy saving has increased, and since steam does not affect air pollution, there are many cases in which afterburning is not done.

Flow Sheet of Caustic Soda Desulphurization



The wet-type electrostatic precipitator (EP) has become simpler and high efficiency of mist and fumes removal along with dust removal, so wet type electrostatic precipitators with demister has been widely adopted.

For the detail information, refer to the pages at P.48~51 or E.68~72.

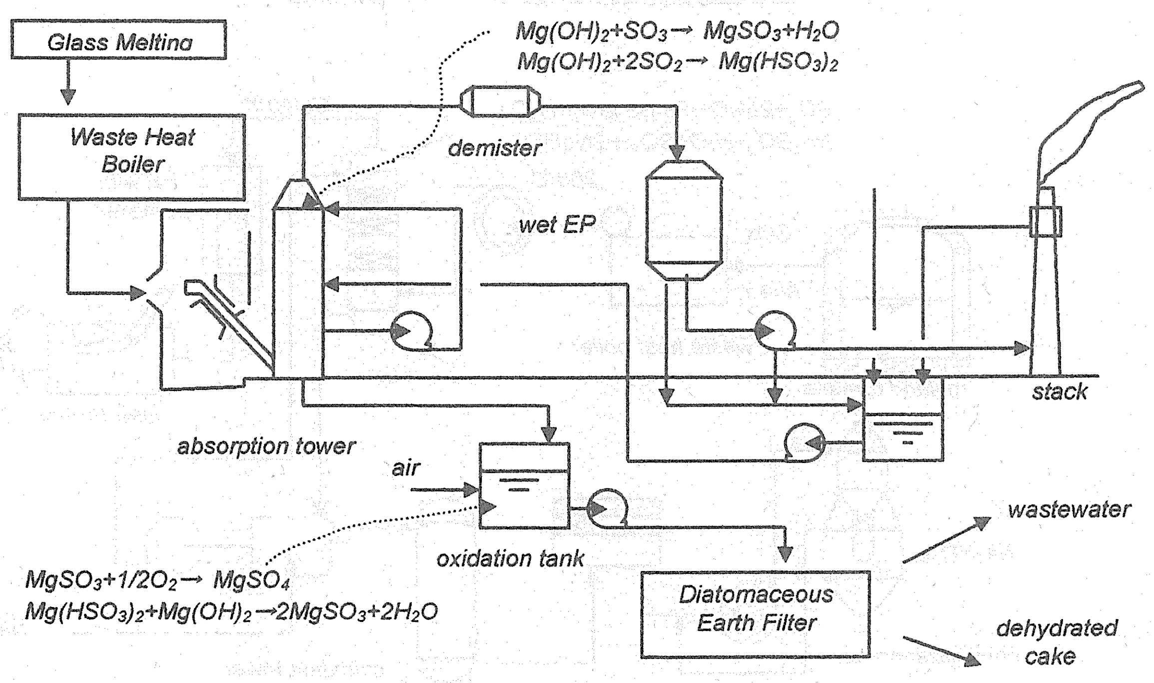
3-2 Desulphurization using Magnesium Hydroxide

When SO_3 is absorbed into magnesium hydroxide ($Mg(OH)_2$) solution, and the solution is oxidized by air, the solution becomes waste liquid containing magnesium sulfate ($MgSO_4$). This method is simple and equipment cost is low; it has been adopted for bottle glass melting furnaces, etc.

Flue gas from the glass melting furnace is cooled to 250 ℃ in a waste heat boiler. Then gas is led to the absorption tower lined with refractory stone and carbon brick. The circulated liquid is sprayed into the gas, adiabatic cooling of the gas occurs, and the flue gas becomes steam saturated gas. The adiabatic cooling action decreases the flue gas temperature to prevent damage to the lining layer of the can body of the tower. Magnesium hydroxide is supplied in the gas scrubber. Flue gas passes through perforated plates, and gradually flows to the upper level. Vigorous gas-liquid contact occurs at this time, and SO_3 is absorbed and removed.

After the greater part of the desulphurized flue gas mist is removed by eliminator, the dust is removed by a wet-type EP, and treated gas is released. Part of the circulating solution which absorbed the gas is drained, aerated and air-oxidized in the oxidation tank, and forms magnesium sulfate($MgSO_4$).

Flow Sheet of Magnesium Hydroxide Desulphurization



The drained solution from oxidation tank is filtrated by the pre-coat filter which uses diatomaceous earth as the filter medium. This system has achieved 98% desulphurization rate. The features of this system are (1) simple system, (2) inexpensive initial and operating cost, (3) using no toxicity and no corrosive of chemicals.

For the detail information, refer to the pages at P.51~52 or E.72~73.

3-3 Dry- type Flue Gas Desulphurization

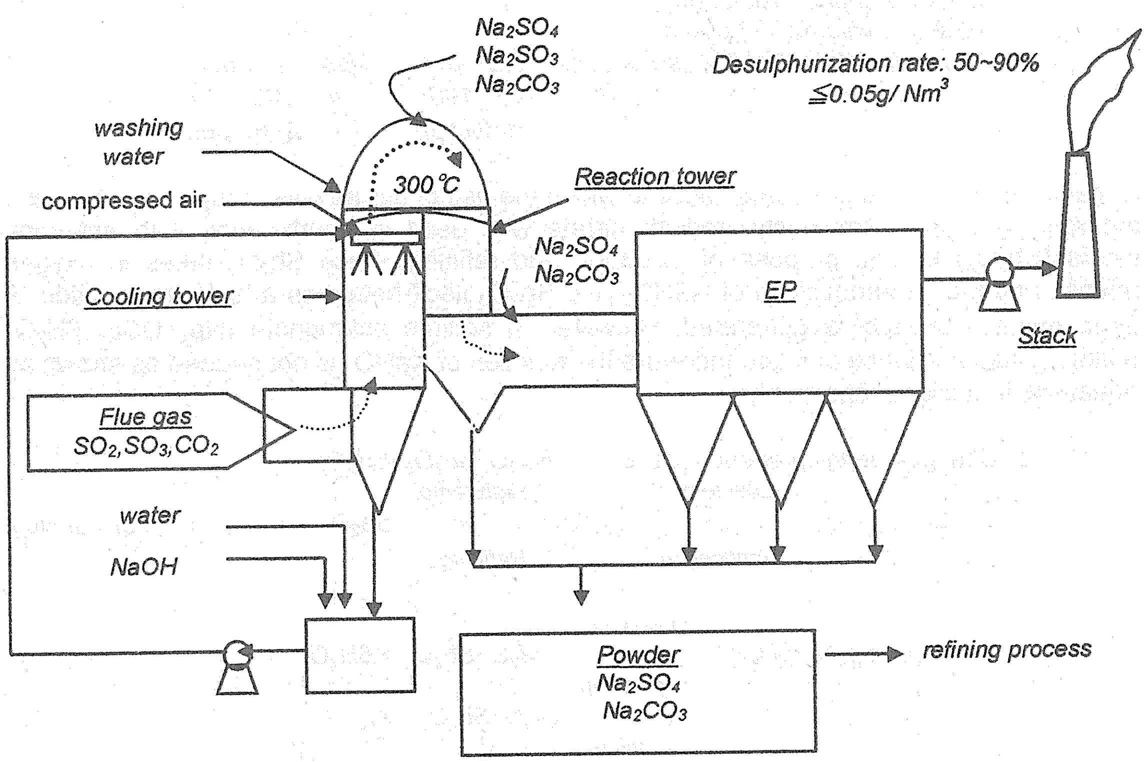
Flue gas led into the cooling tower, where several % of caustic soda solution is sprayed on the flue gas and the temperature is cooled to about 300℃, and at the same time, the SO_2, SO_3, and CO_2 in flue gas are changed to granulated Na_2SO_4, Na_2SO_3, and Na2CO_3.

In the following reaction tower, after Na_2SO_3 has been oxidized to Na_2SO_4, the flue gas is led to the electrostatic precipitator, where Na_2SO_4 and Na_2CO_3 in powder form are removed. The temperature of outlet gas from the electrostatic precipitator is 220~230 ℃, so the flue gas is directly released from the chimney.

This method has achieved desulphurization rate of 50~90% and soot and dust concentration of 0.05 g/Nm^3 or below.

Collected dust at the electrostatic precipitator is dissolved in water to form a solution from which sodium sulfate can be recovered through a refining process. The desulphurization rate of a dry-type desulphurization system is usually lower than that of a wet-type desulphurization system, but the dry-type equipment system is relatively simple and suitable for small and medium-size furnaces.

Flow Sheet of Dry Type Flue Gas Desulphurization



For the detail information, refer to the pages at P.52~53 or E.73~74.

4. NOx Reduction Method

4-1 Reduction of Nitrate in Raw Material

NOx generated from glass melting furnaces by combustion of fuel and also by the decomposition of small quantities of nitrate, used as an oxidizer and refining agent, in the raw materials (nitrates are only used in special furnaces).

NOx generation : $NaNO_3$ (oxidation, refining agent)

Reduction of nitrate dosage can be considered as one method for reducing generation of NOx (called material NOx or batch NOx). When nitrate use is stopped or reduced, obviously the quantity of NOx generation is reduced, but the use of nitrate is sometimes indispensable for maintaining glass quality.

There is one example of a lead glass in which glass quality could not be maintained when the use of sodium nitrate was decreased; therefore, changing the flame to make it more oxidative was unavoidable, and as a result, the quantity of NOx could not be reduced. Concerning the use of nitrate, it is necessary to thoroughly consider the variety of glass and flame condition, then make continuing efforts to reduce the use of nitrate.

As an example of the effect when the use of nitrate is reduced, we compared the trial calculation values and actual measured values for the effect when the quantity of sodium nitrate ($NaNO_3$) used was changed, for an end-port furnace, as shown in the slide. Actual measured values were reduced roughly as indicated in theory.

1. Reducing $NaNO_3$ additives
Quantity of pull : 100 t / day
Flue gas volume : 17,000 m^3 / h
Trial calculation: $NaNO_3$: silica sand = 0.5 : 100   NOx 169 ppm
〃 : 〃 = 0.3 : 100   〃 102 〃
reduction   ▲ 67 ppm

Recently, there have been some cases in which the use of nitrate was stopped by changing the refining agent. Previously, sodium nitrate was used in combination with antimony trioxide(Sb_2O_3) for the purpose of oxidation and refining. Once Sb_2O_3 takes in oxygen released by the decomposition of $NaNO_3$, the Sb_2O_3 itself becomes a high-grade oxide. A large quantity of NOx is generated. However, in sodium antimonate ($Na_2 \cdot OSb_5 \cdot 6H_2O$) antimony has a valence of 5 and therefore the function of $NaNO_3$ is not needed as shown by equations in a slide respectively.

2. Changing refining agent ($Sb_2O_3 \Rightarrow Na_2O \cdot Sb_2O_5 \cdot 6H_2O$)

$$Sb_2O_3 + O_2 \xrightarrow[\text{Vitrification}]{\text{Low temp.}} Sb_2O_5 \xrightarrow[\text{Refining}]{\text{High temp.}} Sb_2O_3 + O_2 \uparrow + \text{thermal NOx} \uparrow$$

$$Na_2O \cdot Sb_2O_5 \cdot 6H_2O \xrightarrow{\text{Low temp.}} Na_2O \cdot Sb_2O_5 + 6H_2O \uparrow$$

$$\xrightarrow[\text{Refining}]{\text{High temp.}} Na_2O \cdot Sb_2O_3 + O_2 \uparrow$$

For the detail information, refer to the pages at P.55~56 or E.77~78.

4-2 NOx Reduction Related to Fuel

Fuel NOx increases as the quantity of nitrogen contained in fuel increases.

N in Fuels

Fuel	Nitrogen (wt %)
Coal	0.7 ~ 2.2
C- heavy oil ※	0.2 ~ 0.4
A- heavy oil ※	0.005 ~ 0.08
Light oil	0.004 ~ 0.006
Kerosene	0.0005 ~ 0.01
LNG	Tr.
LPG	Tr.

※ JIS K2205 kinematic viscosity (cSt, mm2/s) C-heavy oil: 50≦~1,000, A-heavy oil: ≦20

Usually, the quantity of nitrogen in fuel increases in order, from gaseous fuel to light-gravity oil, to heavy-gravity oil. However, because glass-melting furnaces need to be operated at high temperature, 1,500~1,600 ℃, the ratio of thermal NOx in total NOx generated is overwhelmingly greater than the amount of fuel NOx.

Furnace temp. 1,500 ~ 1,600 ℃ ⇒ Thermal NOx ≫ Fuel NOx

In addition, light-gravity oil and gaseous fuel have heating values lower than that of heavy oil, and it is difficult to obtain a bright flame using light-gravity oil and gaseous fuel. Therefore, for a glass furnace which has a heat transfer mechanism almost completely dependent on heat radiation, when the fuel changed from heavy oil to light-gravity oil or gaseous fuel, fuel consumption is certainly to increase. In case of changing to natural gas from the heavy oil, same phenomenon can be seen.

Heating value
Blight flame

Heavy oil > *Light gravity oil*
Gaseous fuel

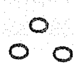
↓

Fuel increasing

↓

NOx increasing

One reliable and effective measure for glass-melting furnaces would be to switch to electric energy, but we cannot yet say that the technology for total electric glass melting in large tank furnaces has been established. Electric boosting is already widely used. Electric glass melting is mainly internal heating (resistance heating by changing of electricity directly into molten glass), and its thermal efficiency is high.



Electric energy

resistance

For the detail information, refer to the pages at P.56~57 or E.78~79.

4-3 NOx Reduction by Furnace Operation Method

There are several methods to decrease the NOx generation by means of maintaining appropriately the operating conditions of furnace.

(1) Lowering the glass melting temperature is a fundamental measure to reduce NOx, but this has the opposite effect on attempts to improve the various characteristics of glass. To solve this problem; ①the adoption for glass of a chemical composition with melting

at low temperature, ②development of method using the largest possible quantities of cullet (scrap glass).

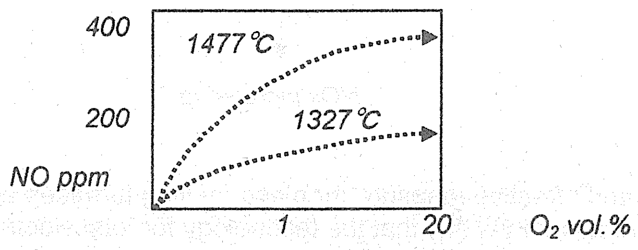
1. Declining Glass Melting Temp.
- chemical composition ----- melting at lower temp.
- using the largest possible quantity of cullet

(2) Lowering the primary air pressure which is used to inject liquid fuel is effective. For example, generation of NOx has been reduced by about 24% by decreasing the pressure from 4 to 3 kg/cm^2. Other than this, mixed gas combustion using fuel gas as the gas for fuel injection, causes no problems in the aspect of maintenance, and is effective for reducing NOx.

2. Lowering Primary Air Pressure
- lowering air pressure for fuel injection
ex. 4 kg /cm2 → 3 kg /cm2 ⇒ NOx ▲24%

(3) When the air ratio (theoretical air ratio: 1) was lowered from 1.2 to 1.1 as shown in the slide, NOx was decreased by 25 %. Therefore, it is desirable to burn fuel using an air ratio as close to the lower limit as permitted.

3. Lowering Secondary Air Volume
- decreasing air ratio ex. 1.2 → 1.1 ⇒ NOx ▲25%



(4) Allotting the fuel distribution to maintain the same average temperature throughout the entire furnace as much as possible is effective to reduce the generation of NOx. Also, combining the direct charging of electricity (electric boosting) with heating by fuel combustion is very effective for decreasing the maximum temperature of the furnace.

4. Lowering Furnace Temp. (Max. Temp.)
- allotting fuel distribution to maintain uniform temp. in furnace
- electric boosting

(5) Work standards for operators are also very important and effective to reduce NOx generation.

5. Combustion Control Work Standards

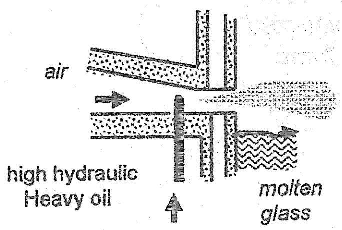
For the detail information, refer to the pages at P.57~58 or E.79~82.

4-4 Using Low NOx Burner

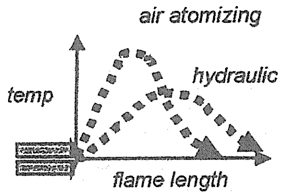
Fuel is usually burned using 10 ~30% excess air (air ratio: 1.1~1.3) in glass melting furnace. While fuel is burned using only the theoretical amount of air, not only it is difficult to maintain furnace temperature due to the formation of soot and unburned substances, but glass quality defects such as coloring of glass can also occur.

1. Hydraulic burner was initially developed for sheet glass melting furnaces for the energy saving and NOx reduction as shown in the table. The method, it uses to atomize heavy oil, is increasing the pressure of heavy oil and injecting it from a spray nozzle, without using air for atomization of the fuel heavy oil.

Hydraulic burner



Burner	Heavy oil use ratio	NOx conc. ratio
Air atomizing	1.00	1.00
Hydraulic	0.88	0.62



2. Supersonic burner is that it utilizes supersonic waves to atomize fuel oil. The amount of atomizing gas (air or steam) needed is said to be about ½ of that for a conventional burner.

- Low O_2 combustion ex. Air 170 → 120 m^3/h ⇒ NOx ▲25~30%

3. Laidlaw Drew burner was developed for bottle glass melting furnaces in England to save the fuel consumption. The amount of primary air required is 30~40% less than for a conventional burner, so it is said that the flame becomes "soft", heat efficiency increases, and fuel consumption decreases, while NOx is also reduced.

- Primary air: 30~40% less than conventional burner ⇒ lower NOx

4. Gas atomizing heavy oil burner uses town gas instead of using primary air and the amount of primary air is decreased. The result of testing done using an end port tank furnace (pull quantity: 100 t/d) for bottle glass were reported that the NOx concentration was decreased by 20~25%, while energy unit requirement is decreased by 3%.

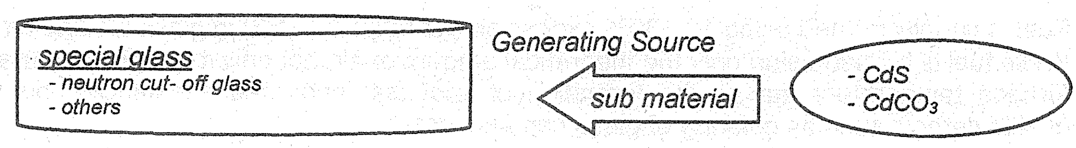
- Town gas is used instead of primary air ⇒ NOx ▲ 20~25%

For the detail information, refer to the pages at P.59~63 or E.83~88.

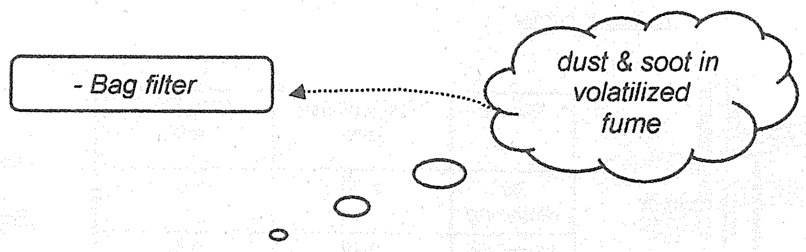
5. Removing Toxic Substances
5-1 Cd & its Compounds

Other than SOx and NOx, the toxic substances discharged from glass melting furnaces are cadmium and its compound, lead and its compounds, and fluorine and its compounds.

Cadmium volatizes and diffuses from the cadmium sulfide (CdS) and cadmium carbonate ($CdCO_3$) used as sub materials for manufacturing of special glass such as neutron cut-off glass or other glass products.



Volatilized and diffused cadmium in the fume state is concentrated in flue gas. Cadmium and its compounds are discharged as a form of particles and are therefore removed by the dust collector.

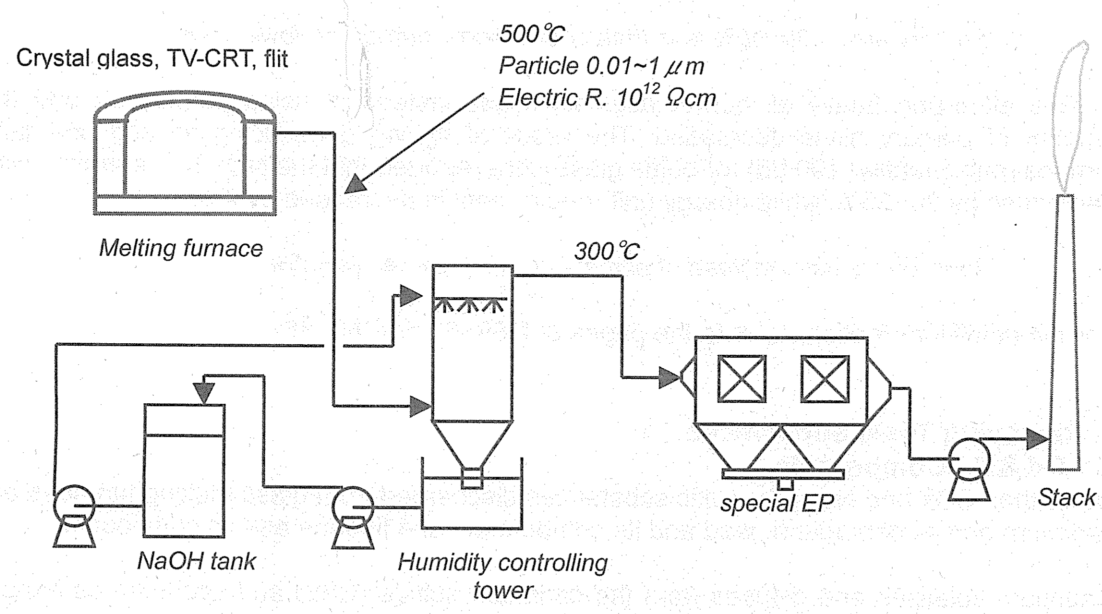


Bag filter and electrostatic precipitator are usually effective.

For the detail information, refer to the pages at P.64 or E.89.

5-2 Pb & its Compounds

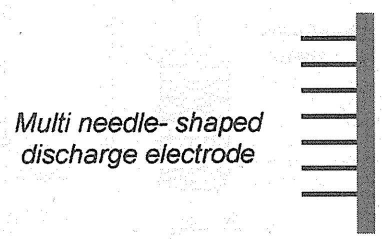
Lead is the main component of crystal glass, and is also used for glass for TV Braun cathode ray tubes (CRT) and frit for glass fusion. The dust in flue gas from the melting furnaces has a lead content of over 50%.



Evaporation of lead becomes vigorous from around 400~500℃, and evaporated lead exists in flue gas as lead fumes. It is necessary to melt raw materials at the lowest temperature possible in order to suppress the evaporation of lead from raw materials. Electric melting is the most desirable, since melting of raw materials can be done while keeping the surface temperature at a low level.

The particle sizes of lead and its compounds are as small as 0.01~ 1 μ m, and their electrical resistance can be as much as 10^{12} Ωcm. Therefore when the bag filter used, plugging of the bag filter mesh occurred, and pressure loss increased. Also, when ordinary electric precipitators were used to collect lead and its compounds, stable collection was difficult due to counter electric dissociation. Since about 28 years ago, the stable collection has become possible using specially designed electrostatic precipitator (EP).

<u>*special EP*</u>



In this system, flue gas is cooled from 500°C to 300°C or below, by the spraying of weak caustic soda solution. This process makes lowering the electric resistance of particles. Also this system designed so that flue gas temperature is kept at around 300°C to prevent the increase of electrical resistance. The flue gas is led into an EP with the distinctive feature that its discharge electrode is not a linear electrode, but a plate with multiple needle-shaped discharge electrodes shown in the slide.

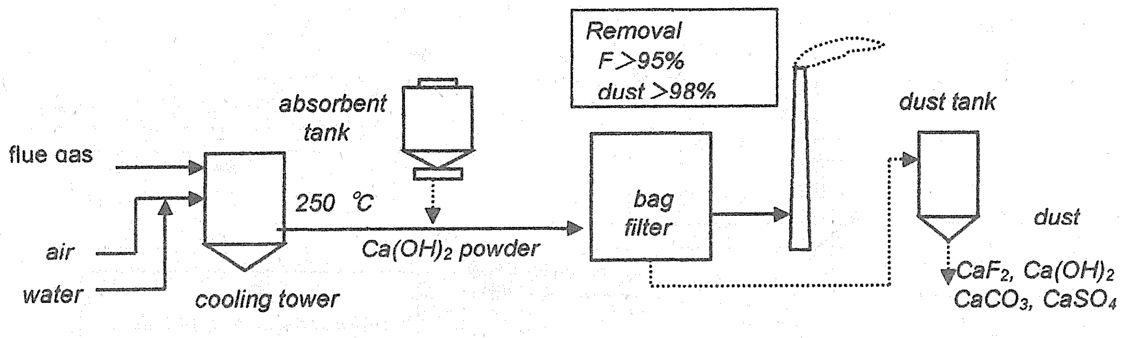
For the detail information, refer to the pages at P. 64~66 or E.89~91.

5-3 F & its Compounds

Fluorine and its compounds are used in many cases as accelerators for melting glass such as electric glass fiber (E-glass-Fiber) and special opaque glass. Fluorite (calcium fluoride) is the fluorine compounds most commonly used in raw materials. Both dry type and wet type methods are used to remove fluorine and its compounds.

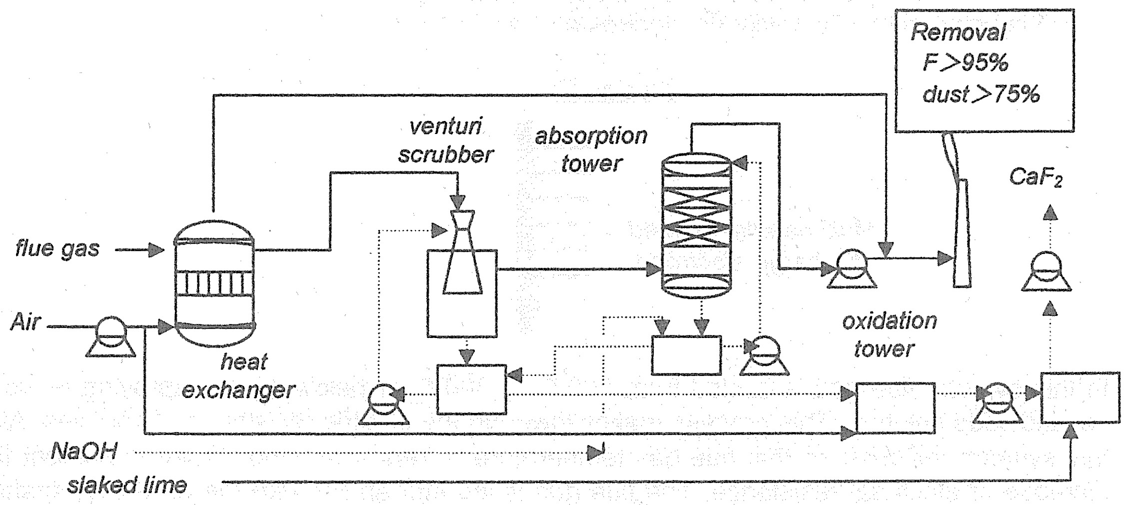
In dry type system, flue gas is cooled to about 250°C by spraying water into the flue gas in the cooling tower. Then, slaked lime powder is supplied to the gas. This operation converts fluorine and its compounds to calcium fluoride (CaF_2), which is collected and removed using a bag filter. $Ca(OH)_2$, $CaCO_3$, $CaSO_4$ coexist in the powder and it is re-used as raw material. This process has achieved fluorine removal rates of over 95% and dust collection rate of over 98%.

<u>*Dry type defluorination*</u>



The distinctive features of this method are its easy maintenance and low running cost, but its equipment size is fairly large.

Wet type defluorination

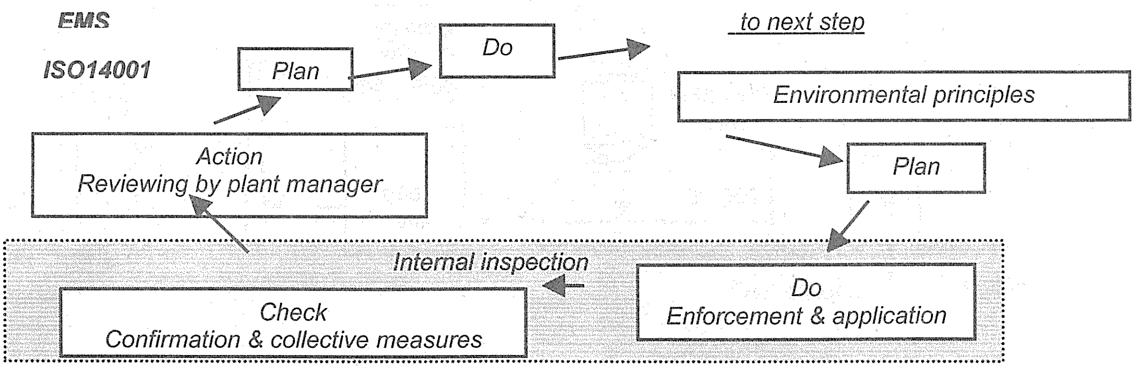


In wet type system, fluorine and its compounds are absorbed by caustic soda solution. This process is constituted of flue gas cooling, flue gas scrubbing, and wastewater treatment. This method removes SOx simultaneously. The fluorine removal rate is over 95%, and the dust removal rate is over 75%. Slaked lime is added to the NaF formed by reaction in the reaction end, to change it to CaF_2, which can be re-used after being separated, concentrated, and dried.

For the detail information, refer to the pages at P.66~67 or E.91~93.

6. Environmental Management System

ISO14001 standards are the basis of the Environmental Management System (EMS). The aims of EMS are to always understand the pollutants discharged by the enterprise itself, to maintain the conditions of a well-managed environment. The ISO 14001 requirements consist of 5 items, ①Environmental principle, ②Plan, ③Enforcement and application, ④Confirmation and collective measures ⑤Reviewing by plant manager.



The items which should be considered at the time of plant construction and operation;

1. Environmental impact assessment is essential to do advance investigation of the natural environmental condition in the area of plant location.

2. To understand the environmental standards and regulations for emission are important.

3. In planning of plant and air pollution control equipment, calculate the allowable value of the pollutants generated by the plant which conform to the emission standards. The most economical treatment methods are determined by selecting from various methods which satisfy the upper limit values for the pollutants emission.

4. Appropriate operation control of entire glass melting furnace system and effective worker training are very important too.
5. The monitor of pollutants emitted from the exhaust ports of glass melting furnaces is important to conform to emission standards.

6. All staff involved with the plant must make their best efforts for its environmental management. The person in charge of the work site where the accident occurred must report the occurrence of accident to related organs, make efforts to minimize damage, and obtain the understandings of local government bodies and local residents.

For the detail information, refer to the pages at P. 14~22 or E. 19~32.

7. Energy Saving Technology

Energy saving as an air pollution control measure is useful for the reduction of production cost, and is effective for reduction of CO_2, which has become a problem; energy saving can support businesses operation for the glass manufacturing industry which consumes large amount of energy.

First, determination of the process how to promote the energy saving including the items of basic policy, recognition for current state, quantitative goal, and measures is useful.

How to promote energy saving
Basic policy→ Understanding current state→ Goal→ Measures

There are various energy saving methods such as ①acceleration of glass melting by increasing cullet use ratio, ②improving combustion condition from the stand points of software and hardware ③minimizing the heat loss ④ waste heat recovery and, ⑤others such as introduction of cogeneration system, etc.

For the detail information, refer to the pages at p.23~37 or E.32~52.