ANNEX

BAT CONCLUSIONS FOR THE MANUFACTURE OF GLASS

AVERAGING PERIODS FOR WASTE WATER DISCHARGES

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for waste water emissions given in these BAT conclusions refer to the average value of a composite sample taken over a period of 2 hours or 24 hours.

1.1. *General BAT conclusions for the manufacture of glass*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all installations.

The process-specific BAT included in Sections 1.2 – 1.9 apply in addition to the general BAT mentioned in this section.

1.1.1. *Environmental management systems*

1. BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features:

(i) commitment of the management, including senior management;

(ii) definition of an environmental policy that includes the continuous improvement for the installation by the management;

(iii) planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;

(iv) implementation of the procedures paying particular attention to:

- (a) structure and responsibility
- (b) training, awareness and competence
- (c) communication
- (d) employee involvement
- (e) documentation
- (f) efficient process control
- (g) maintenance programmes
- (h) emergency preparedness and response
- (i) safeguarding compliance with environmental legislation.

(v) checking performance and taking corrective action, paying particular attention to:

- (a) monitoring and measurement (see also the reference document on the General Principles of Monitoring)
- (b) corrective and preventive action
- (c) maintenance of records

(d) independent (where practicable) internal or external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

(vi) review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;

(vii) following the development of cleaner technologies;

(viii) consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;

(ix) application of sectoral benchmarking on a regular basis.

Applicability

The scope (e.g. level of details) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

1.1.2. *Energy efficiency*

2. BAT is to reduce the specific energy consumption by using one or a combination of the following techniques:

Technique		**Applicability**
(i)	Process optimisation, through the control of the operating parameters	The techniques are generally applicable
(ii)	Regular maintenance of the melting furnace	
(iii)	Optimisation of the furnace design and the selection of the melting technique	Applicable for new plants. For existing plants, the implementation requires a complete rebuild of the furnace
(iv)	Application of combustion control techniques	Applicable to fuel/air and oxy-fuel fired furnaces
(v)	Use of increasing levels of cullet, where available and economically and technically viable	Not applicable to the continuous filament glass fibre, high temperature insulation wool and frits sectors
(vi)	Use of a waste heat boiler for energy recovery, where technically and economically viable	Applicable to fuel/air and oxy-fuel fired furnaces. The applicability and economic viability of the technique is dictated by the overall efficiency that may be obtained, including the effective use of the steam generated
(vii)	Use of batch and cullet preheating, where technically and economically viable	Applicable to fuel/air and oxy-fuel fired furnaces.

	The applicability is normally restricted to batch compositions with more than 50 % cullet

1.1.3. *Materials storage and handling*

3. BAT is to prevent, or where that is not practicable, to reduce diffuse dust emissions from the storage and handling of solid materials by using one or a combination of the following techniques:

I. Storage of raw materials

(i) Store bulk powder materials in enclosed silos equipped with a dust abatement system (e.g. fabric filter)

(ii) Store fine materials in enclosed containers or sealed bags

(iii) Store under cover stockpiles of coarse dusty materials

(iv) Use of road cleaning vehicles and water damping techniques

II. Handling of raw materials

Technique		Applicability
(i)	For materials which are transported by above ground, use enclosed conveyors to prevent material loss	The techniques are generally applicable
(ii)	Where pneumatic conveying is used, apply a sealed system equipped with a filter to clean the transport air before release	
(iii)	Moistening of the batch	The use of this technique is limited by the negative consequences on the furnace energy efficiency. Restrictions may apply to some batch formulations, in particular for borosilicate glass production
(iv)	Application of a slightly negative pressure within the furnace	Applicable only as an inherent aspect of operation (i.e. melting furnaces for frits production) due to a detrimental impact on furnace energy efficiency
(v)	Use of raw materials that do not cause decrepitation phenomena (mainly dolomite and limestone). These phenomena consist of minerals that 'crackle' when exposed to heat, with a consequent	Applicable within the constraints associated with the availability of raw materials

	potential increase of dust emissions	
(vi)	Use of an extraction which vents to a filter system in processes where dust is likely to be generated (e.g. bag opening, frits batch mixing, fabric filter dust disposal, cold-top melters)	The techniques are generally applicable
(vii)	Use of enclosed screw feeders	
(viii)	Enclosure of feed pockets	Generally applicable. Cooling may be necessary to avoid damage to the equipment

4. BAT is to prevent, or where that is not practicable, to reduce diffuse gaseous emissions from the storage and handling of volatile raw materials by using one or a combination of the following techniques:

(i) Use of tank paint with low solar absorbency for bulk storage subject to temperature changes due to solar heating.

(ii) Control of temperature in the storage of volatile raw materials.

(iii) Tank insulation in the storage of volatile raw materials.

(iv) Inventory management

(v) Use of floating roof tanks in the storage of large quantities of volatile petroleum products.

(vi) Use of vapour return transfer systems in the transfer of volatile fluids (e.g. from tank trucks to storage tank).

(vii) Use of bladder roof tanks in the storage of liquid raw materials.

(viii) Use of pressure/vacuum valves in tanks designed to withstand pressure fluctuations.

(ix) Application of a release treatment (e.g. adsorption, absorption, condensation) in the storage of hazardous materials.

(x) Application of subsurface filling in the storage of liquids that tend to foam.

1.1.4. *General primary techniques*

5. BAT is to reduce energy consumption and emissions to air by carrying out a constant monitoring of the operational parameters and a programmed maintenance of the melting furnace.

Technique	Applicability
The technique consists of a series of monitoring and maintenance operations which can be used individually or in combination appropriate to the type of furnace, with the aim of minimising the	Applicable to regenerative, recuperative, and oxy-fuel fired furnaces. The applicability to other types of furnaces requires an installation-specific assessment

ageing effects on the furnace, such as sealing the furnace and burner blocks, keep the maximum insulation, control the stabilised flame conditions, control the fuel/air ratio, etc.	

6. BAT is to carry out a careful selection and control of all substances and raw materials entering the melting furnace in order to reduce or prevent emissions to air by using one or a combination of the following techniques.

Technique		**Applicability**
(i)	Use of raw materials and external cullet with low levels of impurities (e.g. metals, chlorides, fluorides)	Applicable within the constraints of the type of glass produced at the installation and the availability of raw materials and fuels
(ii)	Use of alternative raw materials (e.g. less volatile)	
(iii)	Use of fuels with low metal impurities	

7. BAT is to carry out monitoring of emissions and/or other relevant process parameters on a regular basis, including the following:

Technique		**Applicability**
(i)	Continuous monitoring of critical process parameters to ensure process stability, e.g. temperature, fuel feed and airflow	The techniques are generally applicable
(ii)	Regular monitoring of process parameters to prevent/reduce pollution, e.g. O_2 content of the combustion gases to control the fuel/air ratio.	
(iii)	Continuous measurements of dust, NO_X and SO_2 emissions or discontinuous measurements at least twice per year, associated with the control of surrogate parameters to ensure that the treatment system is working properly between measurements	
(iv)	Continuous or regular periodic measurements of NH_3 emissions, when selective catalytic reduction	The techniques are generally applicable

	(SCR) or selective non-catalytic reduction (SNCR) techniques are applied	
(v)	Continuous or regular periodic measurements of CO emissions when primary techniques or chemical reduction by fuel techniques are applied for NO_X emissions reductions or partial combustion may occur.	
(vi)	Regular periodic measurements of emissions of HCl, HF, CO and metals, in particular when raw materials containing such substances are used or partial combustion may occur	The techniques are generally applicable
(vii)	Continuous monitoring of surrogate parameters to ensure that the waste gas treatment system is working properly and that the emission levels are maintained between discontinuous measurements. The monitoring of surrogate parameters includes: reagent feed, temperature, water feed, voltage, dust removal, fan speed, etc.	

8. BAT is to operate the waste gas treatment systems during normal operating conditions at optimal capacity and availability in order to prevent or reduce emissions

Applicability

Special procedures can be defined for specific operating conditions, in particular:

(i) during start-up and shutdown operations

(ii) during other special operations which could affect the proper functioning of the systems (e.g. regular and extraordinary maintenance work and cleaning operations of the furnace and/or of the waste gas treatment system, or severe production change)

(iii) in the case of insufficient waste gas flow or temperature which prevents the use of the system at full capacity.

9. BAT is to limit carbon monoxide (CO) emissions from the melting furnace, when applying primary techniques or chemical reduction by fuel, for the reduction of NO_X emissions

Technique	Applicability
Primary techniques for the reduction of NO_X emissions are based on combustion	Applicable to conventional air/fuel fired furnaces.

modifications (e.g. reduction of air/fuel ratio, staged combustion low-NO_X burners, etc.). Chemical reduction by fuel consists of the addition of hydrocarbon fuel to the waste gas stream to reduce the NO_X formed in the furnace. The increase in CO emissions due to the application of these techniques can be limited by a careful control of the operational parameters	

TABLE 3

BAT-AELs for carbon monoxide emissions from melting furnaces

Parameter	BAT-AEL
Carbon monoxide, expressed as CO	< 100 mg/Nm^3

10. BAT is to limit ammonia (NH_3) emissions, when applying selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) techniques for a high efficiency NO_X emissions reduction

Technique	Applicability
The technique consists of adopting and maintaining suitable operating conditions of the SCR or SNCR waste gas treatment systems, with the aim of limiting emissions of unreacted ammonia	Applicable to melting furnaces fitted with SCR or SNCR

TABLE 4

BAT-AELs for ammonia emissions, when SCR or SNCR techniques are applied

Parameter	BAT-AELs[a]
Ammonia, expressed as NH_3	< 5 – 30 mg/Nm^3

a The higher levels are associated with higher inlet NO_X concentrations, higher reduction rates and the ageing of the catalyst.

11. BAT is to reduce boron emissions from the melting furnace, when boron compounds are used in the batch formulation, by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Operation of a filtration system at a suitable temperature for enhancing the separation of boron compounds in the solid state, taking into account that some boric acid	The applicability to existing plants may be limited by technical constraints associated with the position and characteristics of the existing filter system

a A description of the techniques is given in Sections 1.10.1, 1.10.4 and 1.10.6.

	species may be present in the flue-gas as gaseous compounds at temperatures below 200 °C, but also as low as 60 °C	
(ii)	Use of dry or semi-dry scrubbing in combination with a filtration system	The applicability may be limited by a decreased removal efficiency of other gaseous pollutants (SO_X, HCl, HF) caused by the deposition of boron compounds on the surface of the dry alkaline reagent
(iii)	Use of wet scrubbing	The applicability to existing plants may be limited by the need of a specific waste water treatment

a A description of the techniques is given in Sections 1.10.1, 1.10.4 and 1.10.6.

Monitoring

The monitoring of boron emissions should be carried out according to a specific methodology which allows measurement of both solid and gaseous forms and to determine the effective removal of these species from the flue gases.

1.1.5. *Emissions to water from glass manufacturing processes*

12. BAT is to reduce water consumption by using one or a combination of the following techniques:

Technique		Applicability
(i)	Minimisation of spillages and leaks	The technique is generally applicable
(ii)	Reuse of cooling and cleaning waters after purging	The technique is generally applicable. Recirculation of scrubbing water is applicable to most scrubbing systems; however, periodic discharge and replacement of the scrubbing medium may be necessary
(iii)	Operate a quasi-closed loop water system as far as technically and economically feasible	The applicability of this technique may be limited by the constraints associated with the safety management of the production process. In particular: — open circuit cooling may be used when safety issues require for it (e.g. incidents when large quantities of glass need to be cooled) — water used in some specific process (e.g. downstream activities in the continuous filament glass fibre sector, acid polishing in the domestic and special glass sectors, etc.) may have to be discharged in total or in part to the waste water treatment system

13. BAT is to reduce the emission load of pollutants in the waste water discharges by using one or a combination of the following waste water treatment systems:

Technique	**Applicability**
(i) Standard pollution control techniques, such as settlement, screening, skimming, neutralisation, filtration, aeration, precipitation, coagulation and flocculation, etc. Standard good practice techniques to control emissions from storage of liquid raw materials and intermediates, such as containments, inspection/testing of tanks, overfill protection, etc.	The techniques are generally applicable
(ii) Biological treatment systems, such as activated sludge, biofiltration to remove/degrade the organic compounds	The applicability is limited to the sectors which use organic substances in the production process (e.g. continuous filament glass fibre and mineral wool sectors)
(iii) Discharge to municipal waste water treatment Plants	Applicable to installations where further reduction of pollutants is necessary
(iv) External reuse of waste waters	The applicability is generally limited to the frits sector (possible reuse in the ceramic industry)

TABLE 5

BAT-AELs for waste water discharges to surface waters from the manufacture of glass

Parameter[a]	**Unit**	**BAT-AEL**[b]**(composite sample)**
pH	—	6,5 – 9
Total suspended solids	mg/l	< 30
Chemical oxygen demand (COD)	mg/l	< 5 – 130[c]
Sulphates, expressed as SO_4^{2-}	mg/l	< 1 000
Fluorides, expressed as F^-	mg/l	< 6[d]

a The relevance of the pollutants listed in the table depends on the sector of the glass industry and on the different activities carried out at the plant.

b The levels refer to a composite sample taken over a time period of 2 hours or 24 hours.

c For the continuous filament glass fibre sector, BAT-AEL is < 200 mg/l.

d The level refers to treated water coming from activities involving acid polishing.

e In general, total hydrocarbons are composed of mineral oils.

f The higher level of the range is associated with downstream processes for the production of lead crystal glass.

Total hydrocarbons	mg/l	< 15[e]
Lead, expressed as Pb	mg/l	< 0,05 – 0,3[f]
Antimony, expressed as Sb	mg/l	< 0,5
Arsenic, expressed as As	mg/l	< 0,3
Barium, expressed as Ba	mg/l	< 3,0
Zinc, expressed as Zn	mg/l	< 0,5
Copper, expressed as Cu	mg/l	< 0,3
Chromium, expressed as Cr	mg/l	< 0,3
Cadmium, expressed as Cd	mg/l	< 0,05
Tin, expressed as Sn	mg/l	< 0,5
Nickel, expressed as Ni	mg/l	< 0,5
Ammonia, expressed as NH_4	mg/l	< 10
Boron, expressed as B	mg/l	< 1 – 3
Phenol	mg/l	< 1

a The relevance of the pollutants listed in the table depends on the sector of the glass industry and on the different activities carried out at the plant.

b The levels refer to a composite sample taken over a time period of 2 hours or 24 hours.

c For the continuous filament glass fibre sector, BAT-AEL is < 200 mg/l.

d The level refers to treated water coming from activities involving acid polishing.

e In general, total hydrocarbons are composed of mineral oils.

f The higher level of the range is associated with downstream processes for the production of lead crystal glass.

1.1.6. *Waste from the glass manufacturing processes*

14. BAT is to reduce the production of solid waste to be disposed of by using one or a combination of the following techniques:

Technique		Applicability
(i)	Recycling of waste batch materials, where quality requirements allow for it	The applicability may be limited by the constraints associated with the quality of the final glass product
(ii)	Minimising material losses during the storage and handling of raw materials	The technique is generally applicable
(iii)	Recycling of internal cullet from rejected production	Generally, not applicable to the continuous filament glass fibre, high temperature insulation wool and frits sectors

(iv)	Recycling of dust in the batch formulation where quality requirements allow for it	The applicability may be limited by different factors: — quality requirements of the final glass product — cullet percentage used in the batch formulation — potential carryover phenomena and corrosion of the refractory materials — sulphur balance constraints
(v)	Valorisation of solid waste and/or sludge through appropriate use on-site (e.g. sludge from water treatment) or in other industries	Generally applicable to the domestic glass sector (for lead crystal cutting sludge) and to the container glass sector (fine particles of glass mixed with oil). Limited applicability to other glass manufacturing sectors due to unpredictable, contaminated composition, low volumes and economic viability
(vi)	Valorisation of end-of-life refractory materials for possible use in other industries	The applicability is limited by the constraints imposed by the refractory manufacturers and potential end-users
(vii)	Applying cement bonded briquetting of waste for recycling into hot blast cupola furnaces where quality requirements allow for it	The applicability of cement bonded briquetting of waste is limited to the stone wool sector. A trade-off approach between air emissions and the generation of solid waste stream should be undertaken

1.1.7. *Noise from the glass manufacturing processes*

15. BAT is to reduce noise emissions by using one or a combination of the following techniques:

(i) Make an environmental noise assessment and formulate a noise management plan as appropriate to the local environment

(ii) Enclose noisy equipment/operation in a separate structure/unit

(iii) Use embankments to screen the source of noise

(iv) Carry out noisy outdoor activities during the day

(v) Use noise protection walls or natural barriers (trees, bushes) between the installation and the protected area, on the basis of local conditions.

1.2. *BAT conclusions for container glass manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all container glass manufacturing installations.

1.2.1. *Dust emissions from melting furnaces*

16. BAT is to reduce dust emissions from the waste gases of the melting furnace by applying a flue-gas cleaning system such as an electrostatic precipitator or a bag filter.

Technique[a]	Applicability
The flue-gas cleaning systems consist of end-of-pipe techniques based on the filtration of all materials that are solid at the point of measurement	The technique is generally applicable

a A description of filtration systems (i.e. electrostatic precipitator, bag filter) is given in Section 1.10.1.

TABLE 6

BAT-AELs for dust emissions from the melting furnace in the container glass sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Dust	< 10 – 20	< 0,015 – 0,06

a The conversion factors of $1,5 \times 10^{-3}$ and 3×10^{-3} have been used for the determination of the lower and higher value of the range respectively.

1.2.2. *Nitrogen oxides (NO_X) from melting furnaces*

17. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

I. primary techniques, such as:

Technique[a]		Applicability
(i) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	Applicable only under installation-specific circumstances due to a lower furnace efficiency and higher fuel demand (i.e. use of recuperative furnaces in place of regenerative furnaces)
(c) — —	Staged combustion: Air staging Fuel staging	Fuel staging is applicable to most conventional air/fuel furnaces. Air staging has very limited applicability due to its technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable.

a A description of the techniques is given in Section 1.10.2.

		The achieved environmental benefits are generally lower for applications to cross-fired, gas-fired furnaces due to technical constraints and a lower degree of flexibility of the furnace. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii)	Special furnace design	The applicability is limited to batch formulations that contain high levels of external cullet (> 70 %). The application requires a complete rebuild of the melting furnace. The shape of the furnace (long and narrow) may pose space restrictions
(iii)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations. The implementation requires a complete furnace rebuild
(iv)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

II. secondary techniques, such as:

Technique[a]		**Applicability**
(i)	Selective catalytic reduction (SCR)	The application may require an upgrade of the dust abatement system in order to guarantee a dust concentration of below 10 – 15 mg/Nm^3 and a desulphurisation system for the removal of SO_X emissions. Due to the optimum operating temperature window, the applicability is limited to the use of electrostatic precipitators. In general, the technique is not used with a bag filter system because the low operating temperature, in the

a A description of the techniques is given in Section 1.10.2.

		range of 180 – 200 °C, would require reheating of the waste gases. The implementation of the technique may require significant space availability
(ii)	Selective non-catalytic reduction(SNCR)	The technique is applicable to recuperative furnaces. Very limited applicability to conventional regenerative furnaces, where the correct temperature window is difficult to access or does not allow a good mixing of the flue-gases with the reagent. It may be applicable to new regenerative furnaces equipped with split regenerators; however, the temperature window is difficult to maintain due to the reversal of fire between the chambers that causes a cyclical temperature change

a A description of the techniques is given in Section 1.10.2.

TABLE 7

BAT-AELs for NO_X emissions from the melting furnace in the container glass sector

Parameter	**BAT**	**BAT-AEL**	
		mg/Nm^3	**kg/tonne melted glass**[a]
NO_X expressed as NO_2	Combustion modifications, special furnace designs[bc]	500 – 800	0,75 – 1,2
	Electric melting	< 100	< 0,3
	Oxy-fuel melting[d]	Not applicable	< 0,5 – 0,8
	Secondary techniques	< 500	< 0,75

a The conversion factor reported in Table 2 for general cases ($1,5 \times 10^{-3}$) has been applied, with the exception of electric melting (specific cases: 3×10^{-3}).

b The lower value refers to the use of special furnace designs, where applicable.

c These values should be reconsidered in the occasion of a normal or complete rebuild of the melting furnace.

d The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

18. When nitrates are used in the batch formulation and/or special oxidising combustion conditions are required in the melting furnace for ensuring the quality of the final product, BAT is to reduce NO_X emissions by minimising the use of these raw materials, in combination with primary or secondary techniques

The BAT-AELs are set out in Table 7.

If nitrates are used in the batch formulation for short campaigns or for melting furnaces with a capacity of < 100 t/day, the BAT-AEL is set out in Table 8.

Technique[a]	**Applicability**
Primary techniques: — Minimising the use of nitrates in the batch formulation The use of nitrates is applied for very high quality products (i.e. flacconage, perfume bottles and cosmetic containers). Effective alternative materials are sulphates, arsenic oxides, cerium oxide. The application of process modifications (e.g. special oxidising combustion conditions) represents an alternative to the use of nitrates	The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials

a A description of the techniques is given in Section 1.10.2.

TABLE 8

BAT-AEL for NO_X emissions from the melting furnace in the container glass sector, when nitrates are used in the batch formulation and/or special oxidising combustion conditions in cases of short campaigns or for melting furnaces with a capacity of < 100 t/day

Parameter	**BAT**	**BAT-AEL**	
		mg/Nm^3	**kg/tonne melted glass**[a]
NO_X expressed as NO_2	Primary techniques	< 1 000	< 3

a The conversion factor reported in Table 2 for specific cases (3×10^{-3}) has been applied.

1.2.3. *Sulphur oxides (SO_X) from melting furnaces*

19. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		**Applicability**
(i)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable
(ii)	Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The minimisation of the sulphur content in the batch formulation is generally applicable within the constraints of quality requirements of the final glass product. The application of sulphur balance optimisation requires a trade-off approach

a A description of the techniques is given in Section 1.10.3.

		between the removal of SO_X emissions and the management of the solid waste (filter dust). The effective reduction of SO_X emissions depends on the retention of sulphur compounds in the glass which may vary significantly depending on the glass type
(iii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State

a A description of the techniques is given in Section 1.10.3.

TABLE 9

BAT-AELs for SO_X emissions from the melting furnace in the container glass sector

Parameter	Fuel	BAT-AEL[ab]	
		mg/Nm^3	kg/tonne melted glass[c]
SO_X expressed as SO_2	Natural gas	< 200 – 500	< 0,3 – 0,75
	Fuel oil[d]	< 500 – 1 200	< 0,75 – 1,8

a For special types of coloured glasses (e.g. reduced green glasses), concerns related to the achievable emission levels may require investigating the sulphur balance. Values reported in the table may be difficult to achieve in combination with filter dust recycling and the rate of recycling of external cullet.

b The lower levels are associated with conditions where the reduction of SO_X is a high priority over a lower production of solid waste corresponding to the sulphate-rich filter dust.

c The conversion factor reported in Table 2 for general cases ($1,5 \times 10^{-3}$) has been applied.

d The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

1.2.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

20. BAT is to reduce HCl and HF emissions from the melting furnace (possibly combined with flue-gases from hot-end coating activities) by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The applicability may be limited by the constraints of the type of glass produced at the installation and the availability of raw materials
(ii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.4.

TABLE 10

BAT-AELs for HCl and HF emissions from the melting furnace in the container glass sector

Parameter	**BAT-AEL**	
	mg/Nm^3	**kg/tonne melted glass**[a]
Hydrogen chloride, expressed as HCl[b]	< 10 – 20	< 0,02 – 0,03
Hydrogen fluoride, expressed as HF	< 1 – 5	< 0,001 – 0,008

a The conversion factor for general cases, reported in Table 2 (1,5 × 10^{-3}) has been applied.

b The higher levels are associated with the simultaneous treatment of flue-gases from hot-end coating operations.

1.2.5. *Metals from melting furnaces*

21. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		**Applicability**
(i)	Selection of raw materials for the batch formulation with a low content of metals	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of the raw materials
(ii)	Minimising the use of metal compounds in the batch formulation, where colouring and decolourising of glass is needed, subject to consumer glass quality requirements	
(iii)	Applying a filtration system (bag filter or electrostatic precipitator)	The techniques are generally applicable
(iv)	Applying a dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the techniques is given in Section 1.10.5.

TABLE 11

BAT-AELs for metal emissions from the melting furnace in the container glass sector

Parameter	BAT-AEL[abc]	
	mg/Nm^3	kg/tonne melted glass[d]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,2 – 1[e]	< 0,3 – 1,5 × 10^{-3}
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 5	< 1,5 – 7,5 × 10^{-3}

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The lower levels are BAT-AELs when metal compounds are not intentionally used in the batch formulation.

c The upper levels are associated with the use of metals for colouring or decolourising the glass, or when the flue-gases from the hot-end coating operations are treated together with the melting furnace emissions.

d The conversion factor for general cases, reported in Table 2 (1,5 × 10^{-3}) has been applied.

e In specific cases, when high quality flint glass is produced requiring higher amounts of selenium for decolourising (depending on the raw materials), higher values are reported, up to 3 mg/Nm^3.

1.2.6. *Emissions from downstream processes*

22. When tin, organotin or titanium compounds are used for hot-end coating operations, BAT is to reduce emissions by using one or a combination of the following techniques:

Technique	Applicability
(i) Minimising the losses of the coating product by ensuring a good sealing of the application system and applying an effective extracting hood. A good construction and sealing of the application system is essential for minimising losses of unreacted product into the air	The technique is generally applicable
(ii) Combining the flue-gas from the coating operations with the waste gas from the melting furnace or with the combustion air of the furnace, when a secondary treatment system is applied (filter and dry or semi-dry scrubber). Based on the chemical compatibility, the waste gases from the coating operations may be combined with other flue-gases before treatment. These two options may be applied: — combination with the flue gases from the melting furnace, upstream of a secondary abatement system (dry or semi-dry scrubbing plus filtration system) — combination with combustion air before entering the regenerator, followed by secondary abatement	The combination with flue gases from the melting furnace is generally applicable. The combination with combustion air may be affected by technical constraints due to some potential effects on the glass chemistry and on the regenerator materials

a A description of the techniques is given in Sections 1.10.4 and 1.10.7.

treatment of the waste gases generated during the melting process (dry or semi-dry scrubbing + filtration system)	
(iii) Applying a secondary technique, e.g. wet scrubbing, dry scrubbing plus filtration[a]	The techniques are generally applicable

a A description of the techniques is given in Sections 1.10.4 and 1.10.7.

TABLE 12

BAT-AELs for air emissions from hot-end coating activities in the container glass sector when the flue-gases from downstream operations are treated separately

Parameter	BAT-AEL
	mg/Nm^3
Dust	< 10
Titanium compounds expressed as Ti	< 5
Tin compounds, including organotin, expressed as Sn	< 5
Hydrogen chloride, expressed as HCl	< 30

23. When SO_3 is used for surface treatment operations, BAT is to reduce SO_X emissions by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Minimising the product losses by ensuring a good sealing of the application system A good construction and maintenance of the application system is essential for minimising the losses of unreacted product into the air	The techniques are generally applicable
(ii) Applying a secondary technique, e.g. wet scrubbing	

a A description of the techniques is given in Section 1.10.6.

TABLE 13

BAT-AEL for SO_X emissions from downstream activities when SO_3 is used for surface treatment operations in the container glass sector, when treated separately

Parameter	BAT-AEL
	mg/Nm^3
SO_x, expressed as SO_2	< 100 – 200

1.3. *BAT conclusions for flat glass manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all flat glass manufacturing installations.

1.3.1. *Dust emissions from melting furnaces*

24. BAT is to reduce dust emissions from the waste gases of the melting furnace by applying an electrostatic precipitator or a bag filter system

A description of the techniques is given in Section 1.10.1.

TABLE 14

BAT-AELs for dust emissions from the melting furnace in the flat glass sector

Parameter	**BAT-AEL**	
	mg/Nm^3	**kg/tonne melted glass**[a]
Dust	< 10 – 20	< 0,025 – 0,05

a The conversion factor reported in Table 2 (2,5 × 10^{-3}) has been applied.

1.3.2. *Nitrogen oxides (NO_X) from melting furnaces*

25. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

I. primary techniques, such as:

Technique[a]		**Applicability**
(i) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	The applicability is restricted to small capacity furnaces for the production of specialty flat glass and under installation-specific circumstances, due to a lower furnace efficiency and higher fuel demand (i.e. use of recuperative furnaces in place of regenerative furnaces)
(c) — —	Staged combustion: Air staging Fuel staging	Fuel staging is applicable to most conventional air/fuel furnaces. Air staging has very limited applicability due to its technical complexity

a A description of the techniques is given in Section 1.10.2.

(d) Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e) Low-NO_X burners	The technique is generally applicable. The achieved environmental benefits are generally lower for applications to cross-fired, gas-fired furnaces due to technical constraints and a lower degree of flexibility of the furnace. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f) Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii) Fenix process Based on the combination of a number of primary techniques for the optimisation of the combustion of cross-fired regenerative float furnaces. The main features are: — reduction of excess air — suppression of hotspots and homogenisation of the flame temperatures — controlled mixing of the fuel and combustion air	The applicability is limited to cross-fired regenerative furnaces. Applicable to new furnaces. For existing furnaces, the technique requires being directly integrated during the design and construction of the furnace, at a complete furnace rebuild
(iii) Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

II. secondary techniques, such as:

Technique[a]	**Applicability**
(i) Chemical reduction by fuel	Applicable to regenerative furnaces. The applicability is limited by an increased fuel consumption and consequent environmental and economic impact
(ii) Selective catalytic reduction (SCR)	The application may require an upgrade of the dust abatement system in order to guarantee a dust concentration of below 10 – 15 mg/Nm^3 and a

a A description of the techniques is given in Section 1.10.2.

	desulphurisation system for the removal of SO_X emissions Due to the optimum operating temperature window, the applicability is limited to the use of electrostatic precipitators. In general, the technique is not used with a bag filter system because the low operating temperature, in the range of 180 – 200 °C, would require reheating of the waste gases. The implementation of the technique may require significant space availability

a A description of the techniques is given in Section 1.10.2.

TABLE 15

BAT-AELs for NO_X emissions from the melting furnace in the flat glass sector

Parameter	**BAT**	**BAT-AEL**[a]	
		mg/Nm^3	**kg/tonne melted glass**[b]
NO_X expressed as NO_2	Combustion modifications, Fenix process[c]	700 – 800	1,75 – 2,0
	Oxy-fuel melting[d]	Not applicable	< 1,25 – 2,0
	Secondary techniques[e]	400 – 700	1,0 – 1,75

a Higher emission levels are expected when nitrates are used occasionally for the production of special glasses.

b The conversion factor reported in Table 2 ($2,5 \times 10^{-3}$) has been applied.

c The lower levels of the range are associated with the application of the Fenix process.

d The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

e The higher levels of the range are associated with existing plants until a normal or complete rebuild of the melting furnace. The lower levels are associated with newer/retrofitted plants.

26. When nitrates are used in the batch formulation, BAT is to reduce NO_X emissions by minimising the use of these raw materials, in combination with primary or secondary techniques. If secondary techniques are applied, the BAT-AELs reported in Table 15 are applicable.

If nitrates are used in the batch formulation for the production of special glasses in a limited number of short campaigns, the BAT-AELs are set out in Table 16.

Technique[a]	**Applicability**
Primary techniques: minimising the use of nitrates in the batch formulation	The substitution of nitrates in the batch formulation may be limited by the high costs

a A description of the technique is given in Section 1.10.2.

	The use of nitrates is applied for special productions (i.e. coloured glass). Effective alternative materials are sulphates, arsenic oxides, cerium oxide	and/or higher environmental impact of the alternative materials

a A description of the technique is given in Section 1.10.2.

TABLE 16

BAT-AEL for NO_X emissions from the melting furnace in the flat glass sector, when nitrates are used in the batch formulation for the production of special glasses in a limited number of short campaigns

Parameter	BAT	BAT-AEL	
		mg/Nm^3	kg/tonne melted glass[a]
NO_X expressed as NO_2	Primary techniques	< 1 200	< 3

a The conversion factor reported in Table 2 for specific cases ($2,5 \times 10^{-3}$) has been applied

1.3.3. *Sulphur oxides (SO_X) from melting furnaces*

27. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable
(ii)	Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The minimisation of the sulphur content in the batch formulation is generally applicable within the constraints of quality requirements of the final glass product. The application of sulphur balance optimisation requires a trade-off approach between the removal of SO_X emissions and the management of the solid waste (filter dust)
(iii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State

a A description of the techniques is given in Section 1.10.3.

TABLE 17

BAT-AELs for SO_X emissions from the melting furnace in the flat glass sector

Parameter	Fuel	BAT-AEL[a]	
		mg/Nm^3	kg/tonne melted glass[b]
SO_X expressedas SO_2	Natural gas	< 300 – 500	< 0,75 – 1,25
	Fuel oil[cd]	500 – 1 300	1,25 – 3,25

a The lower levels are associated with conditions where the reduction of SO_X has a high priority over a lower production of solid waste corresponding to the sulphate-rich filter dust.

b The conversion factor reported in Table 2 ($2,5 \times 10^{-3}$) has been applied.

c The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

d For large flat glass furnaces, concerns related to the achievable emission levels may require investigating the sulphur balance. Values reported in the table may be difficult to achieve in combination with filter dust recycling.

1.3.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

28. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The applicability may be limited by the constraints of the type of glass produced at the installation and the availability of raw materials
(ii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.4.

TABLE 18

BAT-AELs for HCl and HF emissions from the melting furnace in the flat glass sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Hydrogen chloride, expressed as HCl[b]	< 10 – 25	< 0,025 – 0,0625
Hydrogen fluoride, expressed as HF	< 1 – 4	< 0,0025 – 0,010

a The conversion factor reported in Table 2 ($2,5 \times 10^{-3}$) has been applied.

b The higher levels of the range are associated with the recycling of filter dust in the batch formulation

1.3.5. *Metals from melting furnaces*

29. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of metals	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of the raw materials.
(ii)	Applying a filtration system	The technique is generally applicable
(iii)	Applying a dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the techniques is given in Section 1.10.5.

TABLE 19

BAT-AELs for metal emissions from the melting furnace in the flat glass sector, with the exception of selenium coloured glasses

Parameter	BAT-AEL[a]	
	mg/Nm^3	kg/tonne melted glass[b]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,2 – 1	< 0,5 – 2,5 × 10^{-3}
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 5	< 2,5 – 12,5 × 10^{-3}

a The ranges refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factor reported in Table 2 (2,5 × 10^{-3}) has been applied

30. When selenium compounds are used for colouring the glass, BAT is to reduce selenium emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Minimising the evaporation of selenium from the batch composition by selecting raw materials with a higher retention efficiency in the glass and reduced volatilisation	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of the raw materials
(ii)	Applying a filtration system	The technique is generally applicable
(iii)	Applying a dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the techniques is given in Section 1.10.5.

TABLE 20

BAT-AELs for selenium emissions from the melting furnace in the flat glass sector for the production of coloured glass

Parameter	BAT-AEL[ab]	
	mg/Nm^3	kg/tonne melted glass[c]
Selenium compounds, expressed as Se	1 – 3	2,5 – 7,5 × 10^{-3}

a The values refer to the sum of selenium present in the flue-gases in both solid and gaseous phases.

b The lower levels correspond to conditions where the reduction of Se emissions is a priority over a lower production of solid waste from filter dust. In this case, a high stoichiometric ratio (reagent/pollutant) is applied and a significant solid waste stream is generated.

c The conversion factor reported in Table 2 (2,5 × 10^{-3}) has been applied.

1.3.6. *Emissions from downstream processes*

31. BAT is to reduce emissions to air from the downstream processes by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Minimising the losses of coating products applied to the flat glass by ensuring a good sealing of the application system	The techniques are generally applicable
(ii)	Minimising the losses of SO_2 from the annealing lehr, by operating the control system in an optimum manner	
(iii)	Combining the SO_2 emissions from the lehr with the waste gas from the melting furnace, when technically feasible, and where a secondary treatment system is applied (filter and dry or semi-dry scrubber)	
(iv)	Applying a secondary technique, e.g. wet scrubbing, or dry scrubbing and filtration	The techniques are generally applicable. The selection of the technique and its performance will depend on the inlet waste gas composition

a A description of the secondary treatment systems is given in Sections 1.10.3 and 1.10.6.

TABLE 21

BAT-AELs for air emissions from downstream processes in the flat glass sector, when treated separately

Parameter	BAT-AEL

	mg/Nm^3
Dust	< 15 – 20
Hydrogen chloride, expressed as HCl	< 10
Hydrogen fluoride, expressed as HF	< 1 – 5
SO_X, expressed as SO_2	< 200
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 1
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 5

1.4. *BAT conclusions for continuous filament glass fibre manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all continuous filament glass fibre manufacturing installations.

1.4.1. *Dust emissions from melting furnaces*

The BAT-AELs reported in this section for dust refer to all materials that are solid at the point of measurement, including solid boron compounds. Gaseous boron compounds at the point of measurement are not included.

32. BAT is to reduce dust emissions from the waste gases of the melting furnace by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Reduction of the volatile components by raw material modifications The formulation of batch compositions without boron compounds or with low levels of boron is a primary measure for reducing dust emissions which are mainly generated by volatilisation phenomena. Boron is the main constituent of particulate matter emitted from the melting furnace	The application of the technique is limited by proprietary issues, since the boron-free or low-boron batch formulations are covered by a patent
(ii) Filtration system: electrostatic precipitator or bag filter	The technique is generally applicable. The maximum environmental benefits are achieved for applications on new plants where the positioning and characteristics of the filter may be decided without restrictions
(iii) Wet scrubbing system	The application to existing plants may be limited by technical constraints; i.e. need for a specific waste water treatment plant

a A description of the secondary treatment systems is given in Sections 1.10.1 and 1.10.7.

TABLE 22

BAT-AELs for dust emissions from the melting furnace in the continuous filament glass fibre sector

Parameter	BAT-AEL[a]	
	mg/Nm^3	kg/tonne melted glass[b]
Dust	< 10 – 20	< 0,045 – 0,09

a Values at levels of < 30 mg/Nm^3 (< 0,14 kg/tonne melted glass) have been reported for boron-free formulations, with the application of primary techniques.

b The conversion factor reported in Table 2 ($4,5 \times 10^{-3}$) has been applied.

1.4.2. *Nitrogen oxides (NO_X) from melting furnaces*

33. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	Applicable to air/fuel conventional furnaces within the constraints of the furnace energy efficiency and higher fuel demand. Most furnaces are already of the recuperative type.
(c) (d) (e)	Staged combustion: Air staging Fuel staging	Fuel staging is applicable to most air/fuel, oxy-fuel furnaces. Air staging has very limited applicability due to its technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

TABLE 23

BAT-AELs for NO_X emissions from the melting furnace in the continuous filament glass fibre sector

Parameter	BAT	BAT-AEL	
		mg/Nm³	kg/tonne melted glass
NO_X expressed as NO_2	Combustion modifications	< 600 – 1 000	< 2,7 – 4,5[a]
	Oxy-fuel melting[b]	Not applicable	< 0,5 – 1,5

a The conversion factor reported in Table 2 ($4,5 \times 10^{-3}$) has been applied.

b The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

1.4.3. *Sulphur oxides (SO_X) from melting furnaces*

34. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The technique is generally applicable within the constraints of quality requirements of the final glass product. The application of sulphur balance optimisation requires a trade-off approach between the removal of SO_X emissions and the management of the solid waste (filter dust), which needs to be disposed of
(ii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable. The presence of high concentrations of boron compounds in the flue-gases may limit the abatement efficiency of the reagent used in the dry or semi-dry scrubbing systems
(iv)	Use of wet scrubbing	The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant

a A description of the techniques is given in Sections 1.10.3 and 1.10.6.

TABLE 24

BAT-AELs for SO_X emissions from the melting furnace in the continuous filament glass fibre sector

Parameter	Fuel	BAT-AEL[a]	
		mg/Nm^3	kg/tonne melted glass[b]
SO_x expressed as SO_2	Natural gas[c]	< 200 – 800	< 0,9 – 3,6
	Fuel oil[de]	< 500 – 1 000	< 2,25 – 4,5

a The higher levels of the range are associated with the use of sulphates in the batch formulation for refining the glass.

b The conversion factor reported in Table 2 ($4,5 \times 10^{-3}$) has been applied.

c For oxy-fuel furnaces with the application of wet scrubbing, the BAT-AEL is reported to be < 0,1 kg/tonne melted glass of SO_X, expressed as SO_2.

d The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

e The lower levels correspond to conditions where the reduction of SO_X is a priority over a lower production of solid waste corresponding to the sulphate-rich filter dust. In this case, the lower levels are associated with the use of a bag filter.

1.4.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

35. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The technique is generally applicable within the constraints of the batch formulation and the availability of raw materials
(ii) Minimisation of the fluorine content in the batch formulation The minimisation of fluorine emissions from the melting process may be achieved as follows: — minimising/reducing the quantity of fluorine compounds (e.g. fluorspar) used in the batch formulation to the minimum commensurate with the quality of the final product. Fluorine compounds are used to optimise the melting process, help fiberisation and minimise filament breakage — substituting fluorine compounds with alternative materials (e.g. sulphates)	The substitution of fluorine compounds with alternative materials is limited by quality requirements of the product
(iii) dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Sections 1.10.4 and 1.10.6.

(iv)	wet scrubbing	The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant.

a A description of the techniques is given in Sections 1.10.4 and 1.10.6.

TABLE 25

BAT-AELs for HCl and HF emissions from the melting furnace in the continuous filament glass fibre sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Hydrogen chloride, expressed as HCl	< 10	< 0,05
Hydrogen fluoride, expressed as HF[b]	< 5 – 15	< 0,02 – 0,07

a The conversion factor reported in Table 2 ($4,5 \times 10^{-3}$) has been applied.

b The higher levels of the range are associated with the use of fluorine compounds in the batch formulation.

1.4.5. *Metals from melting furnaces*

36. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of metals	The technique is generally applicable within the constraints of the availability of raw materials
(ii)	Applying a dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable
(iii)	Applying wet scrubbing	The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant.

a A description of the techniques is given in Sections 1.10.5 and 1.10.6.

TABLE 26

BAT-AELs for metal emissions from the melting furnace in the continuous filament glass fibre sector

Parameter	BAT-AEL[a]	
	mg/Nm^3	kg/tonne melted glass[b]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,2 – 1	$< 0,9 – 4,5 \times 10^{-3}$

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factor reported in Table 2 ($4,5 \times 10^{-3}$) has been applied.

Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 3	< 4,5 – 13,5 × 10^{-3}

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factor reported in Table 2 (4,5 × 10^{-3}) has been applied.

1.4.6. *Emissions from downstream processes*

37. BAT is to reduce emissions from downstream processes by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Wet scrubbing systems	The techniques are generally applicable for the treatment of waste gases from the forming process (application of the coating to the fibres) or secondary processes which involve the use of binder that must be cured or dried
(ii)	Wet electrostatic precipitator	
(iii)	Filtration system (bag filter)	The technique is generally applicable for the treatment of waste gases from cutting and milling operations of the products

a A description of the techniques is given in Sections 1.10.7 and 1.10.8.

TABLE 27

BAT-AELs for air emissions from downstream processes in the continuous filament glass fibre sector, when treated separately

Parameter	BAT-AEL
	mg/Nm³
Emissions from forming and coating	
Dust	< 5 – 20
Formaldehyde	< 10
Ammonia	< 30
Total volatile organic compounds, expressed as C	< 20
Emissions from cutting and milling	
Dust	< 5 – 20

1.5. *BAT conclusions for domestic glass manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all domestic glass manufacturing installations.

1.5.1. *Dust emissions from melting furnaces*

38. BAT is to reduce dust emissions from the waste gases of the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Reduction of the volatile components by raw material modifications. The formulation of the batch composition may contain very volatile components (e.g. boron, fluorides) which significantly contribute to the formation of dust emissions from the melting furnace	The technique is generally applicable within the constraints of the type of glass produced and the availability of substitute raw materials
(ii) Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations The implementation requires a complete furnace rebuild
(iii) Oxy-fuel melting	The maximum environmental benefits are achieved for applications made at the time of a complete furnace rebuild
(iv) Filtration system: electrostatic precipitator or bag filter	The techniques are generally applicable
(v) Wet scrubbing system	The applicability is limited to specific cases, in particular to electric melting furnaces, where flue-gas volumes and dust emissions are generally low and related to carryover of the batch formulation

a A description of the techniques is given in Sections 1.10.5 and 1.10.7.

TABLE 28

BAT-AELs for dust emissions from the melting furnace in the domestic glass sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Dust	< 10 – 20[b]	< 0,03 – 0,06
	< 1 – 10[c]	< 0,003 – 0,03

a A conversion factor of 3×10^{-3} has been applied (see Table 2). However, a case by case conversion factor may have to be applied for specific productions.

b Considerations concerning the economic viability for achieving the BAT-AELs in the case of furnaces with a capacity of < 80 t/d, producing soda-lime glass, are reported.

c This BAT-AEL applies to batch formulations containing significant amounts of constituents meeting the criteria as dangerous substances, in accordance with Regulation (EC) No 1272/2008 of the European Parliament and of the Council.

1.5.2. *Nitrogen oxides (NO_X) from melting furnaces*

39. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	Applicable only under installation-specific circumstances due to a lower furnace efficiency and higher fuel demand (i.e. use of recuperative furnaces in place of regenerative furnaces)
(c) (f) (g)	Staged combustion: Air staging Fuel staging	Fuel staging is applicable to most conventional air/fuel furnaces. Air staging has very limited applicability due to its technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable. The achieved environmental benefits are generally lower for applications to cross-fired, gas-fired furnaces due to technical constraints and a lower degree of flexibility of the furnace. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii)	Special furnace design	The applicability is limited to batch formulations that contain high levels of external cullet (> 70 %). The application requires a complete rebuild of the melting furnace. The shape of the furnace (long and narrow) may pose space restrictions
(iii)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations. The implementation requires a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

(iv)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

TABLE 29

BAT-AELs for NO_X emissions from the melting furnace in the domestic glass sector

Parameter	BAT	BAT-AEL	
		mg/Nm^3	kg/tonne melted glass[a]
NO_x expressed as NO_2	Combustion modifications, special furnace designs	< 500 – 1 000	< 1,25 – 2,5
	Electric melting	< 100	< 0,3
	Oxy-fuel melting[b]	Not applicable	< 0,5 – 1,5

a A conversion factor of $2{,}5 \times 10^{-3}$ has been applied for combustion modifications and special furnace designs and a conversion factor of 3×10^{-3} has been applied for electric melting (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

b The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

40. When nitrates are used in the batch formulation, BAT is to reduce NO_X emissions by minimising the use of these raw materials, in combination with primary or secondary techniques.

The BAT-AELs are set out in Table 29.

If nitrates are used in the batch formulation for a limited number of short campaigns or for melting furnaces with a capacity < 100 t/day producing special types of soda-lime glasses (clear/ultra-clear glass or coloured glass using selenium) and other special glasses (i.e. borosilicate, glass ceramics, opal glass, crystal and lead crystal), the BAT-AELs are set out in Table 30.

Technique[a]		Applicability
Primary techniques:		
—	Minimising the use of nitrates in the batch formulation The use of nitrates is applied for very high quality products, where a very colourless (clear) glass is required or special glasses are produced. Effective alternative materials are sulphates, arsenic oxides, cerium oxide	The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials

a A description of the technique is given in Section 1.10.2.

TABLE 30

BAT-AELs for NO_X emissions from the melting furnace in the domestic glass sector, when nitrates are used in the batch formulation for a limited number of short campaigns or for melting furnaces with a capacity < 100 t/day producing special types of soda-lime glasses (clear/ultra-clear glass or coloured glass using selenium) and other special glasses (i.e. borosilicate, glass ceramics, opal glass, crystal and lead crystal

Parameter	Type of furnace	BAT-AEL	
		mg/Nm^3	kg/tonne melted glass
NO_X expressed as NO_2	Fuel/air conventional furnaces	< 500 – 1 500	< 1,25 – 3,75[a]
	Electric melting	< 300 – 500	< 8 – 10

a The conversion factor reported in Table 2 for soda-lime glass (2,5 × 10^{-3}) has been applied.

1.5.3. *Sulphur oxides (SO_X) from melting furnaces*

41. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The minimisation of the sulphur content in the batch formulation is generally applicable within the constraints of quality requirements of the final glass product. The application of sulphur balance optimisation requires a trade-off approach between the removal of SO_X emissions and the management of the solid waste (filter dust)
(ii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.3.

TABLE 31

BAT-AELs for SO_X emissions from the melting furnace in the domestic glass sector

Parameter	Fuel/melting technique	BAT-AEL	
		mg/Nm^3	kg/tonne melted glass[a]

a A conversion factor of 2,5 × 10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

b The levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

SO_x expressed as SO_2	Natural gas	< 200 – 300	< 0,5 – 0,75
	Fuel oil[b]	< 1 000	< 2,5
	Electric melting	< 100	< 0,25

a A conversion factor of $2,5 \times 10^{-3}$ has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

b The levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

1.5.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

42. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The applicability may be limited by the constraints of the batch formulation for the type of glass produced at the installation and the availability of raw materials
(ii) Minimisation of the fluorine content in the batch formulation and optimisation of the fluorine mass balance The minimisation of fluorine emissions from the melting process may be achieved by minimising/reducing the quantity of fluorine compounds (e.g. fluorspar) used in the batch formulation to the minimum commensurate with the quality of the final product. Fluorine compounds are added to the batch formulation to give an opaque or cloudy appearance to the glass	The technique is generally applicable within the constraints of the quality requirements for the final product
(iii) Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable
(iv) Wet scrubbing	The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant. High costs, waste water treatment aspects, including restrictions in the recycle of sludge or solid residues from the water treatment, may limit the applicability of this technique

a A description of the techniques is given in Sections 1.10.4 and 1.10.6.

TABLE 32

BAT-AELs for HCl and HF emissions from the melting furnace in the domestic glass sector

Parameter	BAT-AEL	
	mg/Nm³	kg/tonne melted glass[a]
Hydrogen chloride, expressed as HCl[bc]	< 10 – 20	< 0,03 – 0,06
Hydrogen fluoride, expressed as HF[d]	< 1 – 5	< 0,003 – 0,015

a A conversion factor of 3×10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

b The lower levels are associated with the use of electric melting.

c In cases where KCl or NaCl are used as a refining agents, the BAT-AEL is < 30 mg/Nm³ or < 0,09 kg/tonne melted glass.

d The lower levels are associated with the use of electric melting. The higher levels are associated with the production of opal glass, the recycling of filter dust or where high levels of external cullet are used in the batch formulation.

1.5.5. *Metals from melting furnaces*

43. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of metals	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of raw materials
(ii)	Minimising the use of metal compounds in the batch formulation, through a suitable selection of the raw materials where colouring and decolourising of glass is needed or where specific characteristics are conferred to the glass	For the production of crystal and lead crystal glasses the minimisation of metal compounds in the batch formulation is restricted by the limits defined in Directive 69/493/EEC which classifies the chemical composition of the final glass products.
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.5.

TABLE 33

BAT-AELs for metal emissions from the melting furnace in the domestic glass sector with the exception of glasses where selenium is used for decolourising

Parameter	BAT-AEL[a]	
	mg/Nm³	kg/tonne melted glass[b]

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b A conversion factor of 3×10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,2 – 1	< 0,6 – 3 × 10^{-3}
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 5	< 3 – 15 × 10^{-3}

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b A conversion factor of 3 × 10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

44. When selenium compounds are used for decolourising the glass, BAT is to reduce selenium emissions from the melting furnace by using one or a combination of the following techniques

Technique[a]		Applicability
(i)	Minimising the use of selenium compounds in the batch formulation, through a suitable selection of the raw materials	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of raw materials
(ii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.5.

TABLE 34

BAT-AELs for selenium emissions from the melting furnace in the domestic glass sector when selenium compounds are used for decolourising the glass

Parameter	BAT-AEL[a]	
	mg/Nm^3	kg/tonne melted glass[b]
Selenium compounds, as Se	< 1	< 3 × 10^{-3}

a The values refer to the sum of selenium present in the flue-gases in both solid and gaseous phases.

b A conversion factor of 3 × 10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

45. When lead compounds are used for the manufacturing of lead crystal glass, BAT is to reduce lead emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations. The implementation requires a complete furnace rebuild

a A description of the technique is given in Sections 1.10.1 and 1.10.5.

(ii)	Bag filter	The technique is generally applicable
(iii)	Electrostatic precipitator	
(iv)	Dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the technique is given in Sections 1.10.1 and 1.10.5.

TABLE 35

BAT-AELs for lead emissions from the melting furnace in the domestic glass sector when lead compounds are used for manufacturing lead crystal glass

Parameter	**BAT-AEL**[a]	
	mg/Nm^3	**kg/tonne melted glass**[b]
Lead compounds, expressed as Pb	< 0,5 – 1	$< 1 - 3 \times 10^{-3}$

a The values refer to the sum of lead present in the flue-gases in both solid and gaseous phases.

b A conversion factor of 3×10^{-3} has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

1.5.6. *Emissions from downstream processes*

46. For downstream dusty processes, BAT is to reduce emissions of dust and metals by using one or a combination of the following techniques:

Technique[a]		**Applicability**
(i)	Performing dusty operations (e.g. cutting, grinding, polishing) under liquid	The techniques are generally applicable
(ii)	Applying a bag filter system	

a A description of the techniques is given in Section 1.10.8.

TABLE 36

BAT-AELs for air emissions from dusty downstream processes in the domestic glass sector, when treated separately

Parameter	**BAT-AEL**
	mg/Nm^3
Dust	< 1 – 10
Σ (As, Co, Ni, Cd, Se, Cr_{VI})[a]	< 1

a The levels refer to the sum of metals present in the waste gas.

b The levels refer to downstream operations on lead crystal glass.

Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)[a]	< 1 – 5
Lead compounds, expressed as Pb[b]	< 1 – 1,5

a The levels refer to the sum of metals present in the waste gas.

b The levels refer to downstream operations on lead crystal glass.

47. For acid polishing processes, BAT is to reduce HF emissions by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Minimising the losses of polishing product by ensuring a good sealing of the application system	The techniques are generally applicable
(ii) Applying a secondary technique, e.g. wet scrubbing.	

a A description of the techniques is given in Section 1.10.6.

TABLE 37

BAT-AELs for HF emissions from acid polishing processes in the domestic glass sector, when treated separately

Parameter	BAT-AEL
	mg/Nm³
Hydrogen fluoride, expressed as HF	< 5

1.6. *BAT conclusions for special glass manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all special glass manufacturing installations.

1.6.1. *Dust emissions from melting furnaces*

48. BAT is to reduce dust emissions from the waste gases of the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Reduction of the volatile components by raw material modifications The formulation of the batch composition may contain very volatile components (e.g. boron, fluorides) which represent the main constituents of dust emitted from the melting furnace	The technique is generally applicable within the constraints of the quality of the glass produced

a A description of the techniques is given in Section 1.10.1.

(ii)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day) Not applicable for productions requiring large pull variations The implementation requires a complete furnace rebuild
(iii)	Filtration system: electrostatic precipitator or bag filter	The technique is generally applicable

a A description of the techniques is given in Section 1.10.1.

TABLE 38

BAT-AELs for dust emissions from the melting furnace in the special glass sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Dust	< 10 – 20	< 0,03 – 0,13
	< 1 – 10[b]	< 0,003 – 0,065

a The conversions factors of $2,5 \times 10^{-3}$ and $6,5 \times 10^{-3}$ have been used for the determination of the lower and upper value of the BAT-AELs range (see Table 2), with some values being approximated. However, a-case-by-case conversion factor needs to be applied, depending on the type of glass produced (see Table 2).

b The BAT-AELs apply to batch formulations containing significant amounts of constituents meeting the criteria as dangerous substances, in accordance with Regulation (EC) No 1272/2008.

1.6.2. *Nitrogen oxides (NO_X) from melting furnaces*

49. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

I. primary techniques, such as:

Technique[a]		Applicability
(i) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	Applicable only under installation-specific circumstances due to a lower furnace efficiency and higher fuel demand (i.e. use of recuperative furnaces in place of regenerative furnaces)
(c)	Staged combustion:	Fuel staging is applicable to most conventional air/fuel furnaces.

a A description of the techniques is given in Section 1.10.2.

— —	Air staging Fuel staging	Air staging has very limited applicability due to the technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable. The achieved environmental benefits are generally lower for applications to cross-fired, gas-fired furnaces due to technical constraints and a lower degree of flexibility of the furnace. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations. The implementation requires a complete furnace rebuild
(iii)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

II. secondary techniques, such as:

Technique[a]		**Applicability**
(i)	Selective catalytic reduction (SCR)	The application may require an upgrade of the dust abatement system in order to guarantee a dust concentration of below 10 – 15 mg/Nm^3 and a desulphurisation system for the removal of SO_X emissions Due to the optimum operating temperature window, the applicability is limited to the use of electrostatic precipitators. In general, the technique is not used with a bag filter system because the low operating temperature, in the range of 180 – 200 °C, would require reheating of the waste gases.

a A description of the techniques is given in Section 1.10.2.

		The implementation of the technique may require significant space availability
(ii)	Selective non-catalytic reduction (SNCR)	Very limited applicability to conventional regenerative furnaces, where the correct temperature window is difficult to access or does not allow a good mixing of the flue-gases with the reagent It may be applicable to new regenerative furnaces equipped with split regenerators; however, the temperature window is difficult to maintain due to the reversal of fire between the chambers that causes a cyclical temperature change

a A description of the techniques is given in Section 1.10.2.

TABLE 39

BAT-AELs for NO_X emissions from the melting furnace in the special glass sector

Parameter	**BAT**	**BAT-AEL**	
		mg/Nm^3	**kg/tonne melted glass[a]**
NO_X expressed as NO_2	Combustion modifications	600 – 800	1,5 – 3,2
	Electric melting	< 100	< 0,25 – 0,4
	Oxy-fuel melting[bc]	Not applicable	< 1 – 3
	Secondary techniques	< 500	< 1 – 3

a The conversion factors of $2,5 \times 10^{-3}$ and 4×10^{-3} have been used for the determination of the lower and upper value of the BAT-AEL range (see Table 2), with some values being approximated. However, a case-by-case conversion factor needs to be applied based on the type of production (see Table 2).

b The higher values are related to a special production of borosilicate glass tubes for pharmaceutical use.

c The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

50. When nitrates are used in the batch formulation, BAT is to reduce NO_X emissions by minimising the use of these raw materials, in combination with either primary or secondary techniques

Technique[a]		**Applicability**
Primary techniques		
—	minimising the use of nitrates in the batch formulation The use of nitrates is applied for very high quality products, where special characteristics of the glass	The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials

a A description of the technique is given in Section 1.10.2.

are required. Effective alternative materials are sulphates, arsenic oxides, cerium oxide	

a A description of the technique is given in Section 1.10.2.

TABLE 40

BAT-AELs for NO_X emissions from the melting furnace in the special glass sector when nitrates are used in the batch formulation

Parameter	BAT	BAT-AEL[a]	
		mg/Nm^3	kg/tonne melted glass[b]
NO_X expressed as NO_2	Minimisation of nitrate input in the batch formulation combined with primary or secondary techniques	< 500 – 1 000	< 1 – 6

a The lower levels are associated with the use of electric melting.

b The conversion factors of 2,5 × 10^{-3} and 6,5 × 10^{-3} have been used for the determination of the lower and upper value of the BAT-AEL range respectively, with values being approximated. A case-by-case conversion factor may have to be applied based on the type of production (see Table 2).

1.6.3. *Sulphur oxides (SO_X) from melting furnaces*

51. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The technique is generally applicable within the constraints of quality requirements of the final glass product
(ii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.3.

TABLE 41

BAT-AELs for SO_X emissions from the melting furnace in the special glass sector

Parameter	Fuel/melting technique	BAT-AEL[a]	
		mg/Nm^3	kg/tonne melted glass[b]
SO_X expressed as SO_2	Natural gas, electric melting[c]	< 30 – 200	< 0,08 – 0,5
	Fuel oil[d]	500 – 800	1,25 – 2

a The ranges take into account the variable sulphur balances associated with the type of glass produced.

b The conversion factor of $2,5 \times 10^{-3}$ (see Table 2) has been used. However, a case-by-case conversion factor may have to be applied based on the type of production.

c The lower levels are associated with the use of electric melting and batch formulations without sulphates.

d The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

1.6.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

52. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The applicability may be limited by the constraints of the batch formulation for the type of glass produced at the installation and the availability of raw materials
(ii) Minimisation of the fluorine and/or chlorine compounds in the batch formulation and optimisation of the fluorine and/or chlorine mass balance Fluorine compounds are used to confer particular characteristics to special glasses (i.e. opaque lighting glass, optical glass). Chlorine compounds may be used as fining agents for borosilicate glass production	The technique is generally applicable within the constraints of the quality requirements for the final product.
(iii) Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.4.

TABLE 42

BAT-AELs for HCl and HF emissions from the melting furnace in the special glass sector

Parameter	BAT-AEL

a The conversion factor of $2,5 \times 10^{-3}$ (see Table 2) has been used; with some values being approximated. A case-by-case conversion factor may have to be applied based on the type of production.

b The higher levels are associated with the use of materials containing chlorine in the batch formulation.

c The upper value of the range has been derived from specific reported data.

	mg/Nm^3	kg/tonne melted glass[a]
Hydrogen chloride, expressed as HCl[b]	< 10 – 20	< 0,03 – 0,05
Hydrogen fluoride, expressed as HF	< 1 – 5	< 0,003 – 0,04[c]

a The conversion factor of 2,5 × 10^{-3} (see Table 2) has been used; with some values being approximated. A case-by-case conversion factor may have to be applied based on the type of production.

b The higher levels are associated with the use of materials containing chlorine in the batch formulation.

c The upper value of the range has been derived from specific reported data.

1.6.5. *Metals from melting furnaces*

53. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of metals	The applicability may be limited by the constraints imposed by the type of glass produced at the installation and the availability of raw materials
(ii)	Minimising the use of metal compounds in the batch formulation, through a suitable selection of the raw materials where colouring and decolourising of glass is needed or where specific characteristics are conferred to the glass	The techniques are generally applicable
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the techniques is given in Section 1.10.5.

TABLE 43

BAT-AELs for metal emissions from the melting furnace in the special glass sector

Parameter	BAT-AEL[ab]	
	mg/Nm^3	kg/tonne melted glass[c]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,1 – 1	< 0,3 – 3 × 10^{-3}
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 5	< 3 – 15 × 10^{-3}

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The lower levels are BAT-AELs when metal compounds are not intentionally used in the batch formulation.

c The conversion factor of 2,5 × 10^{-3} (see Table 2) has been used, with some values indicated in the table having been approximated. A case-by-case conversion factor may have to be applied based on the type of production.

1.6.6. *Emissions from downstream processes*

54. For downstream dusty processes, BAT is to reduce emissions of dust and metals by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Performing dusty operations (e.g. cutting, grinding, polishing) under liquid	The techniques are generally applicable
(ii)	Applying a bag filter system	

a A description of the techniques is given in Section 1.10.8.

TABLE 44

BAT-AELs for dust and metal emissions from downstream processes in the special glass sector, when treated separately

Parameter	BAT-AEL
	mg/Nm^3
Dust	1 – 10
Σ (As, Co, Ni, Cd, Se, Cr_{VI})[a]	< 1
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)[a]	< 1 – 5

a The levels refer to the sum of metals present in the waste gas.

55. For acid polishing processes, BAT is to reduce HF emissions by using one or a combination of the following techniques:

Technique[a]		Description
(i)	Minimising the losses of polishing product by ensuring a good sealing of the application system	The techniques are generally applicable
(ii)	Applying a secondary technique, e.g. wet scrubbing	

a A description of the techniques is given in Section 1.10.6.

TABLE 45

BAT-AELs for HF emissions from acid polishing processes in the special glass sector, when treated separately

Parameter	BAT-AEL
	mg/Nm^3
Hydrogen fluoride, expressed as HF	< 5

1.7. *BAT conclusions for mineral wool manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all mineral wool manufacturing installations.

1.7.1. *Dust emissions from melting furnaces*

56. BAT is to reduce dust emissions from the waste gases of the melting furnace by applying an electrostatic precipitator or a bag filter system

Technique[a]	Applicability
Filtration system: electrostatic precipitator or bag filter	The technique is generally applicable. Electrostatic precipitators are not applicable to cupola furnaces for stone wool production, due to the risk of explosion from the ignition of carbon monoxide produced within the furnace

a A description of the techniques is given in Section 1.10.1.

TABLE 46

BAT-AELs for dust emissions from the melting furnace in the mineral wool sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Dust	< 10 – 20	< 0,02 – 0,050

a The conversion factors of 2×10^{-3} and $2{,}5 \times 10^{-3}$ have been used for the determination of the lower and upper value of the BAT-AELs range (see Table 2), in order to cover both the production of glass wool and stone wool.

1.7.2. *Nitrogen oxides (NO_X) from melting furnaces*

57. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Combustion modifications	
(a) Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b) Reduced combustion air temperature	Applicable only under installation-specific circumstances due to a lower furnace efficiency and higher fuel demand (i.e. use of recuperative furnaces in place of regenerative furnaces)
(c) Staged combustion: — Air staging — Fuel staging	Fuel staging is applicable to most conventional air/fuel furnaces.

a A description of the techniques is given in Section 1.10.2.

		Air staging has very limited applicability due to the technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable. The achieved environmental benefits are generally lower for applications to cross-fired, gas-fired furnaces due to technical constraints and a lower degree of flexibility of the furnace. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(ii)	Electric melting	Not applicable for large volume glass productions (> 300 tonnes/day). Not applicable for productions requiring large pull variations. The implementation requires a complete furnace rebuild
(iii)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

TABLE 47

BAT-AELs for NO_X emissions from the melting furnace in the mineral wool sector

Parameter	Product	Melting technique	BAT-AEL	
			mg/Nm^3	kg/tonne melted glass[a]
NO_X expressed as NO_2	Glass wool	Fuel/air and electric furnaces	< 200 – 500	< 0,4 – 1,0
		Oxy-fuel melting[b]	Not applicable	< 0,5
	Stone wool	All types of furnaces	< 400 – 500	< 1,0 – 1,25

a The conversion factors of 2×10^{-3} for glass wool and $2,5 \times 10^{-3}$ for stone wool have been used (see Table 2).

b The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

58. When nitrates are used in the batch formulation for glass wool production, BAT is to reduce NO_X emissions by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Minimising the use of nitrates in the batch formulation The use of nitrates is applied as an oxidising agent in batch formulations with high levels of external cullet to compensate for the presence of organic material contained in the cullet	The technique is generally applicable within the constraints of the quality requirements for the final product
(ii) Electric melting	The technique is generally applicable. The implementation of electric melting requires a complete furnace rebuild
(iii) Oxy-fuel melting	The technique is generally applicable. The maximum environmental benefits are achieved for applications made at the time of a complete furnace rebuild

a A description of the techniques is given in Section 1.10.2.

TABLE 48

BAT-AELs for NO_X emissions from the melting furnace in glass wool production when nitrates are used in the batch formulation

Parameter	BAT	BAT-AEL	
		mg/Nm^3	kg/tonne melted glass[a]
NO_X expressed as NO_2	Minimisation of nitrate input in the batch formulation, combined with primary techniques	< 500 – 700	< 1,0 – 1,4[b]

a The conversion factor of 2×10^{-3} has been used (see Table 2).

b The lower levels of the ranges are associated with the application of oxy-fuel melting.

1.7.3. *Sulphur oxides (SO_X) from melting furnaces*

59. BAT is to reduce SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	In glass wool production, the technique is generally applicable within the constraints of the availability of low-sulphur raw materials, in particular external cullet. High levels of external cullet in the batch formulation limit the possibility of optimising the sulphur balance due to a variable sulphur content.

a A description of the techniques is given in Sections 1.10.3 and 1.10.6.

		In the stone wool production, the optimisation of the sulphur balance may require a trade-off approach between the removal of SO_X emissions from the flue-gases and the management of the solid waste, deriving from the treatment of the flue-gases (filter dust) and/or from the fiberising process, which may be recycled into the batch formulation (cement briquettes) or may need to be disposed of
(ii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State
(iii)	Dry or semi-dry scrubbing, in combination with a filtration system	Electrostatic precipitators are not applicable to cupola furnaces for stone wool production (see BAT 56)
(iv)	Use of wet scrubbing	The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant

a A description of the techniques is given in Sections 1.10.3 and 1.10.6.

TABLE 49

BAT-AELs for SO_X emissions from the melting furnace in the mineral wool sector

Parameter	Product/conditions	BAT-AEL	
		mg/Nm³	**kg/tonne melted glass**[a]
SO_X expressed as SO_2	***Glass wool***		
	Gas-fired and electric furnaces[b]	< 50 – 150	< 0,1 – 0,3
	Stone wool		
	Gas-fired and electric furnaces	< 350	< 0,9
	Cupola furnaces, no briquettes or slag recycling[c]	< 400	< 1,0

a The conversion factors of 2×10^{-3} for glass wool and $2,5 \times 10^{-3}$ for stone wool have been used (see Table 2).

b The lower levels of the ranges are associated with the use of electric melting. The higher levels are associated with high levels of cullet recycling.

c The BAT-AEL is associated with conditions where the reduction of SO_X emissions has a high priority over a lower production of solid waste.

d When reduction of waste has a high priority over SO_X emissions, higher emission values may be expected. The achievable levels should be based on a sulphur balance.

	Cupola furnaces, with cement briquettes or slag recycling[d]	< 1 400	< 3,5

a The conversion factors of 2×10^{-3} for glass wool and $2{,}5 \times 10^{-3}$ for stone wool have been used (see Table 2).

b The lower levels of the ranges are associated with the use of electric melting. The higher levels are associated with high levels of cullet recycling.

c The BAT-AEL is associated with conditions where the reduction of SO_X emissions has a high priority over a lower production of solid waste.

d When reduction of waste has a high priority over SO_X emissions, higher emission values may be expected. The achievable levels should be based on a sulphur balance.

1.7.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

60. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Description
(i)	Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The technique is generally applicable within the constraints of the batch formulation and the availability of raw materials
(ii)	Dry or semi-dry scrubbing, in combination with a filtration system	Electrostatic precipitators are not applicable to cupola furnaces for stone wool production (see BAT 56)

a A description of the techniques is given in Section 1.10.4.

TABLE 50

BAT-AELs for HCl and HF emissions from the melting furnace in the mineral wool sector

Parameter	Product	BAT-AEL	
		mg/Nm³	kg/tonne melted glass[a]
Hydrogen chloride, expressed as HCl	Glass wool	< 5 – 10	< 0,01 – 0,02
	Stone wool	< 10 – 30	< 0,025 – 0,075
Hydrogen fluoride, expressed as HF	All products	< 1 – 5	< 0,002 – 0,013[b]

a The conversion factors of 2×10^{-3} for glass wool and $2{,}5 \times 10^{-3}$ for stone wool have been used (see Table 2).

b The conversion factors of 2×10^{-3} and $2{,}5 \times 10^{-3}$ have been used for the determination of the lower and upper values of the BAT-AELs range (see Table 2).

1.7.5. *Hydrogen sulphide (H_2S) from stone wool melting furnaces*

61. BAT is to reduce H_2S emissions from the melting furnace by applying a waste gas incineration system to oxidise hydrogen sulphide to SO_2

Technique[a]	Applicability
Waste gas incinerator system	The technique is generally applicable to stone wool cupola furnaces

a A description of the technique is given in Section 1.10.9.

TABLE 51

BAT-AELs for H_2S emissions from the melting furnace in stone wool production

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Hydrogen sulphide, expressed as H_2S	< 2	< 0,005

a The conversion factor of $2,5 \times 10^{-3}$ for stone wool has been applied (see Table 2).

1.7.6. *Metals from melting furnaces*

62. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of metals	The technique is generally applicable within the constraints of the availability of raw materials. In glass wool production, the use of manganese in the batch formulation as an oxidising agent depends on the quantity and quality of external cullet employed in the batch formulation and may be minimised accordingly
(ii)	Application of a filtration system	Electrostatic precipitators are not applicable to cupola furnaces for stone wool production (see BAT 56)

a A description of the techniques is given in Section 1.10.5.

TABLE 52

BAT-AELs for metal emissions from the melting furnace in the mineral wool sector

Parameter	BAT-AEL[a]	
	mg/Nm^3	kg/tonne melted glass[b]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 0,2 – 1[c]	$< 0,4 – 2,5 \times 10^{-3}$

a The ranges refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factors of 2×10^{-3} and $2,5 \times 10^{-3}$ have been used for the determination of the lower and upper values of the BAT-AELs range (see Table 2).

c Higher values are associated with the use of cupola furnaces for the production of stone wool.

Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 1 – 2[c]	< 2 – 5 × 10^{-3}

a The ranges refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factors of 2 × 10^{-3} and 2,5 × 10^{-3} have been used for the determination of the lower and upper values of the BAT-AELs range (see Table 2).

c Higher values are associated with the use of cupola furnaces for the production of stone wool.

1.7.7. *Emissions from downstream processes*

63. BAT is to reduce emissions from downstream processes by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Impact jets and cyclones The technique is based on the removal of particles and droplets from waste gases by impaction/impingement, as well as gaseous substances by partial absorption with water. Process water is normally used for impact jets. The recycling process water is filtered before it is reapplied	The technique is generally applicable to the mineral wool sector, in particular to glass wool processes for the treatment of emissions from the forming area (application of the coating to the fibres). Limited applicability to stone wool processes since it could adversely affect other abatement techniques being used.
(ii) Wet scrubbers	The technique is generally applicable for the treatment of waste gases from the forming process (application of the coating to the fibres) or for combined waste gases (forming plus curing)
(iii) Wet electrostatic precipitators	The technique is generally applicable for the treatment of waste gases from the forming process (application of the coating to the fibres), from curing ovens or for combined waste gases (forming plus curing)
(iv) Stone wool filters It consists of a steel or concrete structure in which stone wool slabs are mounted and act as a filter medium. The filtering medium needs to be cleaned or exchanged periodically. This filter is suitable for waste gases with a high moisture content and particulate matter with an adhesive nature	The applicability is mainly limited to stone wool processes for waste gases from the forming area and/or curing ovens
(v) Waste gas incineration	The technique is generally applicable for the treatment of waste gases from curing ovens, in particular in the stone wool processes. The application to combined waste gases (forming plus curing) is not economically viable because of the high volume, low

a A description of the techniques is given in Sections 1.10.7 and 1.10.9.

	concentration, low temperature of the waste gases

a A description of the techniques is given in Sections 1.10.7 and 1.10.9.

TABLE 53

BAT-AELs for air emissions from downstream processes in the mineral wool sector, when treated separately

Parameter	**BAT-AEL**	
	mg/Nm^3	**kg/tonne finished product**
Forming area – Combined forming and curing emissions-Combined forming, curing and cooling emissions		
Total particulate matter	< 20 – 50	—
Phenol	< 5 – 10	—
Formaldehyde	< 2 – 5	—
Ammonia	30 – 60	—
Amines	< 3	—
Total volatile organic compounds expressed as C	10 – 30	—
Curing oven emissions[ab]		
Total particulate matter	< 5 – 30	< 0,2
Phenol	< 2 – 5	< 0,03
Formaldehyde	< 2 – 5	< 0,03
Ammonia	< 20 – 60	< 0,4
Amines	< 2	< 0,01
Total volatile organic compounds expressed as C	< 10	< 0,065
NO_X, expressed as NO_2	< 100 – 200	< 1

a Emission levels expressed in kg/tonne of finished product are not affected by the thickness of the mineral wool mat produced nor by extreme concentration or dilution of the flue-gases. A conversion factor of $6{,}5 \times 10^{-3}$ has been used.

b If high density or high binder content mineral wools are produced, the emission levels associated with the techniques listed as BAT for the sector could be significantly higher than these BAT-AELs. If these types of products represent the majority of the production from a given installation, then consideration should be given to other techniques.

1.8. *BAT conclusions for high temperature insulation wools (HTIW) manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all HTIW manufacturing installations.

1.8.1. *Dust emissions from melting and downstream processes*

64. BAT is to reduce dust emissions from the waste gases of the melting furnace by applying a filtration system.

Technique[a]	**Applicability**
The filtration system usually consists of a bag filter	The technique is generally applicable

a A description of the technique is given in Section 1.10.1.

TABLE 54

BAT-AELs for dust emissions from the melting furnace in the HTIW sector

Parameter	**BAT**	**BAT-AEL**
		mg/Nm^3
Dust	Flue-gas cleaning by filtration systems	< 5 – 20[a]

a The values are associated with the use of a bag filter system.

65. For downstream dusty processes, BAT is to reduce emissions using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Minimising the losses of product by ensuring a good sealing of the production line, where technically applicable. The potential sources of dust and fibre emissions are: — fiberisation and collection — mat formation (needling) — lubricant burn-off — cutting, trimming and packaging of the finished product A good construction, sealing and maintenance of the downstream processing systems are essential for minimising the losses of product into the air	The techniques are generally applicable
(ii) Cutting, trimming and packaging under vacuum, by applying an efficient extraction system in conjunction with a fabric filter. A negative pressure is applied to the workstation (i.e. cutting machine, cardboard box for packaging) in order to extract particulate and fibrous releases and convey it to a fabric filter	

a A description of the technique is given in Section 1.10.1.

(iii) Applying a fabric filter system[a] Waste gases from downstream operations (e.g. fiberising, mat formation, lubricant burn-off) are conveyed to a treatment system consisting of a bag filter	

a A description of the technique is given in Section 1.10.1.

TABLE 55

BAT-AELs from dusty downstream processes in the HTIW sector, when treated separately

Parameter	**BAT-AEL**
	mg/Nm^3
Dust[a]	1 – 5

a The lower level of the range is associated with emissions of aluminium silicate glass wool/refractory ceramic fibres (ASW/RCF).

1.8.2. *Nitrogen oxides (NO_X) from melting and downstream processes*

66. BAT is to reduce NO_X emissions from the lubricant burn-off oven by applying combustion control and/or modifications

Technique	**Applicability**
Combustion control and/or modifications Techniques to reduce the formation of thermal NO_X emissions include a control of the main combustion parameters: — air/fuel ratio (oxygen content in the reaction zone) — flame temperature — residence time in the high temperature zone. A good combustion control consists of generating those conditions which are least favourable for NO_X formation	The technique is generally applicable

TABLE 56

BAT-AELs for NO_X from the lubricant burn-off oven in the HTIW sector

Parameter	**BAT**	**BAT-AEL**
		mg/Nm^3
NO_X expressed as NO_2	Combustion control and/or modifications	100 – 200

1.8.3. *Sulphur oxides (SO_X) from melting and downstream processes*

67. BAT is to reduce SO_X emissions from the melting furnaces and downstream processes by using one or a combination of the following techniques:

Technique[a]		Applicability
(i)	Selection of raw materials for the batch formulation with a low content of sulphur	The technique is generally applicable within the constraints of the availability of raw materials
(ii)	Use of low sulphur content fuel	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State

a A description of the technique is given in Section 1.10.3.

TABLE 57

BAT-AELs for SO_X emissions from the melting furnaces and downstream processes in the HTIW sector

Parameter	BAT	BAT-AEL
		mg/Nm^3
SO_x expressed as SO_2	Primary techniques	< 50

1.8.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

68. BAT is to reduce HCl and HF emissions from the melting furnace by selecting raw materials for the batch formulation with a low content of chlorine and fluorine

Technique[a]	Applicability
Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The technique is generally applicable

a A description of the technique is given in Section 1.10.4.

TABLE 58

BAT-AELs for HCl and HF emissions from the melting furnace in the HTIW sector

Parameter	BAT-AEL
	mg/Nm^3
Hydrogen chloride, expressed as HCl	< 10
Hydrogen fluoride, expressed as HF	< 5

1.8.5. *Metals from melting furnaces and downstream processes*

69. BAT is to reduce metal emissions from the melting furnace and/or downstream processes by using one or a combination of the following techniques:

Technique[a]	Applicability

a A description of the technique is given in Section 1.10.5.

(i) Selection of raw materials for the batch formulation with a low content of metals	The techniques are generally applicable
(ii) Applying a filtration system	
a A description of the technique is given in Section 1.10.5.	

TABLE 59

BAT-AELs for metal emissions from the melting furnace and/or downstream processes in the HTIW sector

Parameter	**BAT-AEL**[a]
	mg/Nm^3
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 1
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 5
a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.	

1.8.6. *Volatile organic compounds from downstream processes*

70. BAT is to reduce volatile organic compound (VOC) emissions from the lubricant burn-off oven by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Combustion control, including monitoring the associated emissions of CO. The technique consists of the control of combustion parameters (e.g. oxygen content in the reaction zone, flame temperature) in order to ensure a complete combustion of the organic components (i.e. polyethylene glycol) in the waste gas. The monitoring of carbon monoxide emissions allows for controlling the presence of uncombusted organic materials	The technique is generally applicable
(ii) Waste gas incineration	The economic viability may limit the applicability of these techniques because of low waste gas volumes and VOC concentrations
(iii) Wet scrubbers	
a A description of the techniques is given in Sections 1.10.6 and 1.10.9.	

TABLE 60

BAT-AELs for VOC emissions from the lubricant burn-off oven in the HTIW sector, when treated separately

Parameter	BAT	BAT-AEL
		mg/Nm^3
Volatile organic compounds expressed as C	Primary and/or secondary techniques	10 – 20

1.9. *BAT conclusions for frits manufacturing*

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all frits glass manufacturing installations.

1.9.1. *Dust emissions from melting furnaces*

71. BAT is to reduce dust emissions from the waste gases of the melting furnace by means of an electrostatic precipitator or a bag filter system.

Technique[a]	Applicability
Filtration system: electrostatic precipitator or bag filter	The technique is generally applicable

a A description of the technique is given in Section 1.10.1.

TABLE 61

BAT-AELs for dust emissions from the melting furnace in the frits sector

Parameter	BAT-AEL	
	mg/Nm^3	kg/tonne melted glass[a]
Dust	< 10 – 20	< 0,05 – 0,15

a The conversion factors of 5×10^{-3} and $7{,}5 \times 10^{-3}$ have been used for the determination of the lower and upper value of the BAT-AELs range (see Table 2). However, a case-by-case conversion factor may have to be applied based on the type of combustion.

1.9.2. *Nitrogen oxides (NO_X) from melting furnaces*

72. BAT is to reduce NO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	Applicability
(i) Minimising the use of nitrates in the batch formulation In the frits production, nitrates are used in the batch formulation of many products in order to obtain the required characteristics	The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials and/or the quality requirements of the final product
(ii) Reduction of the parasitic air entering the furnace The technique consists of preventing the ingress of air into the furnace by sealing the	The technique is generally applicable

a A description of the technique is given in Section 1.10.2.

burner blocks, the batch material feeder and any other opening of the melting furnace		
(iii) Combustion modifications		
(a)	Reduction of air/fuel ratio	Applicable to air/fuel conventional furnaces. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(b)	Reduced combustion air temperature	Applicable only under installation-specific circumstances due to a lower furnace efficiency and higher fuel demand
(c) — —	Staged combustion: Air staging Fuel staging	Fuel staging is applicable to most conventional air/fuel furnaces. Air staging has very limited applicability due to its technical complexity
(d)	Flue-gas recirculation	The applicability of this technique is limited to the use of special burners with automatic recirculation of the waste gas
(e)	Low-NO_X burners	The technique is generally applicable. Full benefits are achieved at normal or complete furnace rebuild, when combined with optimum furnace design and geometry
(f)	Fuel choice	The applicability is limited by the constraints associated with the availability of different types of fuel, which may be impacted by the energy policy of the Member State
(iv)	Oxy-fuel melting	The maximum environmental benefits are achieved for applications at the time of a complete furnace rebuild

a A description of the technique is given in Section 1.10.2.

TABLE 62

BAT-AELs for NO_X emissions from the melting furnace in the frits glass sector

Parameter	BAT	Operating conditions	BAT-AEL[a]	
			mg/Nm^3	kg/tonne melted glass[b]
NO_X expressed as NO_2	Primary techniques	Oxy-fuel firing, without nitrates[c]	Not applicable	< 2,5 – 5

a The ranges take into account the combination of flue-gases from furnaces applying different melting techniques and producing a variety of frit types, with or without nitrates in the batch formulations, which may be conveyed to a single stack, precluding the possibility of characterising each applied melting technique and the different products.

b The conversion factors of 5×10^{-3} and $7,5 \times 10^{-3}$ have been used for the determination of the lower and higher values of the range. However, a case-by-case conversion factor may have to be applied based on the type of combustion (see Table 2).

c The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

***Changes to legislation:** There are currently no known outstanding effects for the Commission Implementing Decision of 28 February 2012 establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions for the manufacture of glass (notified under document C(2012) 865) (Text with EEA relevance) (2012/134/EU), AVERAGING PERIODS FOR WASTE WATER DISCHARGES. (See end of Document for details)*

		Oxy-fuel firing, with use of nitrates	Not applicable	5 – 10
		Fuel/air, fuel/oxygen-enriched air combustion, without nitrates	500 – 1 000	2,5 – 7,5
		Fuel/air, fuel/oxygen-enriched air combustion, with use of nitrates	< 1 600	< 12

a The ranges take into account the combination of flue-gases from furnaces applying different melting techniques and producing a variety of frit types, with or without nitrates in the batch formulations, which may be conveyed to a single stack, precluding the possibility of characterising each applied melting technique and the different products.

b The conversion factors of 5×10^{-3} and $7{,}5 \times 10^{-3}$ have been used for the determination of the lower and higher values of the range. However, a case-by-case conversion factor may have to be applied based on the type of combustion (see Table 2).

c The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

1.9.3. *Sulphur oxides (SO_X) from melting furnaces*

73. BAT is to control SO_X emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]		**Applicability**
(i)	Selection of raw materials for the batch formulation with a low content of sulphur	The technique is generally applicable within the constraints of the availability of raw materials
(ii)	Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable
(iii)	Use of low sulphur content fuels	The applicability may be limited by the constraints associated with the availability of low sulphur fuels, which may be impacted by the energy policy of the Member State

a A description of the techniques is given in Section 1.10.3.

TABLE 63

BAT-AELs for SO_X emissions from the melting furnace in the frits sector

Parameter	**BAT-AEL**	
	mg/Nm^3	**kg/tonne melted glass[a]**
SO_X, expressed as SO_2	< 50 – 200	< 0,25 – 1,5

a The conversion factors of 5×10^{-3} and $7{,}5 \times 10^{-3}$ have been used; however, the values indicated in the table may have been approximated. A case-by-case conversion factor may have to be applied based on the type of combustion (see Table 2).

1.9.4. *Hydrogen chloride (HCl) and hydrogen fluoride (HF) from melting furnaces*

74. BAT is to reduce HCl and HF emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The technique is generally applicable within the constraints of the batch formulation and the availability of raw materials
(ii) Minimisation of the fluorine compounds in the batch formulation when used to ensure the quality of the final product Fluorine compounds are used to confer particular characteristics to the frits (i.e. thermal and chemical resistance)	The minimisation or substitution of fluorine compounds with alternative materials is limited by quality requirements of the product
(iii) Dry or semi-dry scrubbing, in combination with a filtration system	The technique is generally applicable

a A description of the techniques is given in Section 1.10.4.

TABLE 64

BAT-AELs for HCl and HF emissions from the melting furnace in the frits sector

Parameter	**BAT-AEL**	
	mg/Nm^3	**kg/tonne melted glass**[a]
Hydrogen chloride, expressed as HCl	< 10	< 0,05
Hydrogen fluoride, expressed as HF	< 5	< 0,03

a The conversion factor of 5×10^{-3} has been used with some values being approximated. A case-by-case conversion factor may have to be applied based on the type of combustion (see Table 2).

1.9.5. *Metals from melting furnaces*

75. BAT is to reduce metal emissions from the melting furnace by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Selection of raw materials for the batch formulation with a low content of metals	The technique is generally applicable within the constraints of the type of frit produced at the installation and the availability of raw materials

a A description of the techniques is given in Section 1.10.5.

(ii) Minimising of the use of metal compounds in the batch formulation, where colouring is required or other specific characteristics are conferred to the frit	The techniques are generally applicable
(iii) Dry or semi-dry scrubbing, in combination with a filtration system	

a A description of the techniques is given in Section 1.10.5.

TABLE 65

BAT-AELs for metal emissions from the melting furnace in the frits sector

Parameter	**BAT-AEL**[a]	
	mg/Nm^3	**kg/tonne melted glass**[b]
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 1	< 7,5 × 10^{-3}
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 5	< 37 × 10^{-3}

a The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

b The conversion factor of 7,5 × 10^{-3} has been used. A case-by-case conversion factor may have to be applied based on the type of combustion (see Table 2).

1.9.6. *Emissions from downstream processes*

76. For downstream dusty processes, BAT is to reduce emissions by using one or a combination of the following techniques:

Technique[a]	**Applicability**
(i) Applying wet milling techniques The technique consists of grinding the frit to the desired particle size distribution with sufficient liquid to form a slurry. The process is generally carried out in alumina ball mills with water	The techniques are generally applicable
(ii) Operating dry milling and dry product packaging under an efficient extraction system in conjunction with a fabric filter A negative pressure is applied to the milling equipment or to the work station where packaging is carried out in order to convey dust emissions to a fabric filter	

a A description of the techniques is given in Section 1.10.1.

(iii) Applying a filtration system	

a A description of the techniques is given in Section 1.10.1.

TABLE 66

BAT-AELs for air emissions from downstream processes in the frits sector, when treated separately

Parameter	**BAT-AEL**
	mg/Nm^3
Dust	5 – 10
Σ (As, Co, Ni, Cd, Se, Cr_{VI})	< 1[a]
Σ (As, Co, Ni, Cd, Se, Cr_{VI}, Sb, Pb, Cr_{III}, Cu, Mn, V, Sn)	< 5[a]

a The levels refer to the sum of metals present in the waste gas.

Glossary

1.10. *Description of techniques*

1.10.1. *Dust emissions*

Technique	**Description**
Electrostatic precipitator	Electrostatic precipitators operate such that particles are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating over a wide range of conditions
Bag filter	Bag filters are constructed from porous woven or felted fabric through which gases are flowed to remove particles. The use of a bag filter requires a fabric material selection adequate to the characteristics of the waste gases and the maximum operating temperature
Reduction of the volatile components by raw material modifications	The formulation of batch compositions might contain very volatile components (e.g. boron compounds) which could be minimised or substituted for reducing dust emissions mainly generated by volatilisation phenomena
Electric melting	The technique consists of a melting furnace where the energy is provided by resistive heating. In the cold-top furnaces (where the electrodes are generally inserted at the bottom of the furnace) the batch blanket covers the surface of the melt with a

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	consequent, significant reduction of the volatilisation of batch components (i.e. lead compounds)

1.10.2. *NO_X emissions*

Technique	Description
Combustion modifications	
(i) Reduction of air/fuel ratio	The technique is mainly based on the following features: — minimisation of air leakages into the furnace — careful control of air used for combustion — modified design of the furnace combustion chamber
(ii) Reduced combustion air temperature	The use of recuperative furnaces, in place of regenerative furnaces, results in a reduced air preheat temperature and, consequently, a lower flame temperature. However, this is associated with a lower furnace efficiency (lower specific pull), lower fuel efficiency and higher fuel demand, resulting in potentially higher emissions (kg/tonne of glass)
(iii) Staged combustion	— Air staging – involves substoichiometric firing and the addition of the remaining air or oxygen into the furnace to complete combustion. — Fuel staging – a low impulse primary flame is developed in the port neck (10 % of total energy); a secondary flame covers the root of the primary flame reducing its core temperature
(iv) Flue-gas recirculation	Implies the reinjection of waste gas from the furnace into the flame to reduce the oxygen content and therefore the temperature of the flame. The use of special burners is based on internal recirculation of combustion gases which cool the root of the flames and reduce the oxygen content in the hottest part of the flames
(v) Low-NO_X burners	The technique is based on the principles of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It may be associated

	with a modified design of the furnace combustion chamber
(vi) Fuel choice	In general, oil-fired furnaces show lower NO_X emissions than gas-fired furnaces due to better thermal emissivity and lower flame temperatures
Special furnace design	Recuperative type furnace that integrates various features, allowing for lower flame temperatures. The main features are: — specific type of burners (number and positioning) — modified geometry of the furnace (height and size) — two-stage raw material preheating with waste gases passing over the raw materials entering the furnace and an external cullet preheater downstream of the recuperator used for preheating the combustion air
Electric melting	The technique consists of a melting furnace where the energy is provided by resistive heating. The main features are: — electrodes are generally inserted at the bottom of the furnace (cold-top) — nitrates are often required in the batch composition of cold-top electric furnaces to provide the necessary oxidising conditions for a stable, safe and efficient manufacturing process
Oxy-fuel melting	The technique involves the replacement of the combustion air with oxygen (> 90 % purity), with consequent elimination/reduction of thermal NO_X formation from nitrogen entering the furnace. The residual nitrogen content in the furnace depends on the purity of the oxygen supplied, on the quality of the fuel (% N_2 in natural gas) and on the potential air inlet
Chemical reduction by fuel	The technique is based on the injection of fossil fuel to the waste gas with chemical reduction of NO_X to N_2 through a series of reactions. In the 3R process, the fuel (natural gas or oil) is injected at the regenerator entrance. The technology is designed for use in regenerative furnaces
Selective catalytic reduction (SCR)	The technique is based on the reduction of NO_X to nitrogen in a catalytic bed by reaction with ammonia (in general

	aqueous solution) at an optimum operating temperature of around 300 – 450 °C. One or two layers of catalyst may be applied. A higher NO_X reduction is achieved with the use of higher amounts of catalyst (two layers)
Selective non-catalytic reduction (SNCR)	The technique is based on the reduction of NO_X to nitrogen by reaction with ammonia or urea at a high temperature. The operating temperature window must be maintained between 900 and 1 050 °C
Minimising the use of nitrates in the batch formulation	The minimisation of nitrates is used to reduce NO_X emissions deriving from the decomposition of these raw materials when applied as an oxidising agent for very high quality products where a very colourless (clear) glass is required or for other glasses to provide the required characteristics. The following options may be applied: — Reduce the presence of nitrates in the batch formulation to the minimum commensurate with the product and melting requirements. — Substitute nitrates with alternative materials. Effective alternatives are sulphates, arsenic oxides, cerium oxide. — Apply process modifications (e.g. special oxidising combustion conditions)

1.10.3. *SO_X emissions*

Technique	Description
Dry or semi-dry scrubbing, in combination with a filtration system	Dry powder or a suspension/solution of alkaline reagent are introduced and dispersed in the waste gas stream. The material reacts with the sulphur gaseous species to form a solid which has to be removed by filtration (bag filter or electrostatic precipitator). In general, the use of a reaction tower improves the removal efficiency of the scrubbing system
Minimisation of the sulphur content in the batch formulation and optimisation of the sulphur balance	The minimisation of sulphur content in the batch formulation is applied to reduce SO_X emissions deriving from the decomposition of sulphur-containing raw materials (in general, sulphates) used as fining agents. The effective reduction of SO_X emissions depends on the retention of sulphur

	compounds in the glass, which may vary significantly depending on the glass type, and on the optimisation of the sulphur balance
Use of low sulphur content fuels	The use of natural gas or low sulphur fuel oil is applied to reduce the amount of SO_X emissions deriving from the oxidation of sulphur contained in the fuel during combustion

1.10.4. *HCl, HF emissions*

Technique	**Description**
Selection of raw materials for the batch formulation with a low content of chlorine and fluorine	The technique consists of a careful selection of raw materials that may contain chlorides and fluorides as impurities (e.g. synthetic soda ash, dolomite, external cullet, recycled filter dust) in order to reduce at source HCl and HF emissions which arise from the decomposition of these materials during the melting process
Minimisation of the fluorine and/or chlorine compounds in the batch formulation and optimisation of the fluorine and/or chlorine mass balance	The minimisation of fluorine and/or chlorine emissions from the melting process may be achieved by minimising/reducing the quantity of these substances used in the batch formulation to the minimum commensurate with the quality of the final product. Fluorine compounds (e.g. fluorspar, cryolite, fluorsilicate) are used to confer particular characteristics to special glasses (e.g. opaque glass, optical glass). Chlorine compounds may be used as fining agents
Dry or semi-dry scrubbing, in combination with a filtration system	Dry powder or a suspension/solution of alkaline reagent are introduced and dispersed in the waste gas stream. The material reacts with the gaseous chlorides and fluorides to form a solid which has to be removed by filtration (electrostatic precipitator or bag filter)

1.10.5. *Metal emissions*

Technique	**Description**
Selection of raw materials for the batch formulation with a low content of metals	The technique consists of a careful selection of batch materials that may contain metals as impurities (e.g. external cullet), in order to reduce at source metal emissions which arise from the decomposition of these materials during the melting process

Minimising the use of metal compounds in the batch formulation, where colouring and decolourising of glass is needed, subject to consumer glass quality requirements	The minimisation of metal emissions from the melting process may be achieved as follows: — minimising the quantity of metal compounds in the batch formulation (e.g. iron, chromium, cobalt, copper, manganese compounds) in the production of coloured glasses — minimising the quantity of selenium compounds and cerium oxide used as decolourising agents for the production of clear glass
Minimising the use of selenium compounds in the batch formulation, through a suitable selection of the raw materials	The minimisation of selenium emissions from the melting process may be achieved by: — minimising/reducing the quantity of selenium in the batch formulation to the minimum commensurate with the product requirements — selecting selenium raw materials with a lower volatility, in order to reduce the volatilisation phenomena during the melting process
Application of a filtration system	Dust abatement systems (bag filter and electrostatic precipitator) can reduce both dust and metal emissions since the emissions to air of metals from glass melting processes are largely contained in particulate form. However, for some metals presenting extremely volatile compounds (e.g. selenium) the removal efficiency may vary significantly with the filtration temperature
Dry or semi-dry scrubbing, in combination with a filtration system	Gaseous metals can be substantially reduced by the use of a dry or semi-dry scrubbing technique with an alkaline reagent. The alkaline reagent reacts with the gaseous species to form a solid which has to be removed by filtration (bag filter or electrostatic precipitator)

1.10.6. *Combined gaseous emissions (e.g. SO_X, HCl, HF, boron compounds)*

Wet scrubbing	In the wet scrubbing process, gaseous compounds are dissolved in a suitable liquid (water or alkaline solution). Downstream of the wet scrubber, the flue-gases are saturated with water and a separation of the droplets is required before discharging the flue-gases. The resulting liquid has to be treated by a

	waste water process and the insoluble matter is collected by sedimentation or filtration

1.10.7. *Combined emissions (solid + gaseous)*

Technique	Description
Wet scrubbing	In a wet scrubbing process (by a suitable liquid: water or alkaline solution), the simultaneous removal of solid and gaseous compounds may be achieved. The design criteria for particulate or gas removal are different; therefore, the design is often a compromise between the two options. The resulting liquid has to be treated by a waste water process and the insoluble matter (solid emissions and products from chemical reactions) is collected by sedimentation or filtration. In the mineral wool and continuous filament glass fibre sector, the most common systems applied are: — packed bed scrubbers with impact jets upstream — venturi scrubbers
Wet electrostatic precipitator	The technique consists of an electrostatic precipitator in which the collected material is removed from the plates of the collectors by flushing with a suitable liquid, usually water. Some mechanism is usually installed to remove water droplets before discharge of the waste gas (demister or a last dry field)

1.10.8. *Emissions from cutting, grinding, polishing operations*

Technique	Description
Performing dusty operations (e.g. cutting, grinding, polishing) under liquid	Water is generally used as a coolant for cutting, grinding and polishing operations and for preventing dust emissions. An extraction system equipped with a mist eliminator may be necessary
Applying a bag filter system	The use of bag filters is suitable for the reduction of both dust and metal emissions since metals from downstream processes are largely contained in particulate form
Minimising the losses of polishing product by ensuring a good sealing of the application system	Acid polishing is performed by immersion of the glass articles in a polishing bath of hydrofluoric and sulphuric acids. The release of fumes may be minimised by a good design

	and maintenance of the application system in order to minimise losses
Applying a secondary technique, e.g. wet scrubbing	Wet scrubbing with water is used for the treatment of waste gases, due to the acidic nature of the emissions and the high solubility of the gaseous pollutants to be removed

1.10.9. *H_2S, VOC emissions*

Waste gas incineration	The technique consists of an afterburner system which oxidises the hydrogen sulphide (generated by strong reducing conditions in the melting furnace) to sulphur dioxide and carbon monoxide to carbon dioxide. Volatile organic compounds are thermally incinerated with consequent oxidation to carbon dioxide, water and other combustion products (e.g. NO_X, SO_X)

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