

## II

*(Non-legislative acts)*

## DECISIONS

## 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)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) <sup>(1)</sup> and in particular Article 13(5) thereof,

Whereas:

- (3) 'BAT conclusions' as defined in Article 3(12) of Directive 2010/75/EU are the key element of BAT reference documents and lay down the conclusions on best available techniques, their description, information to assess their applicability, the emission levels associated with the best available techniques, associated monitoring, associated consumption levels and, where appropriate, relevant site remediation measures.
- (4) In accordance with Article 14(3) of Directive 2010/75/EU, BAT conclusions are to be the reference for setting permit conditions for installations covered by Chapter 2 of that Directive.
- (1) Article 13(1) of Directive 2010/75/EU requires the Commission to organise an exchange of information on industrial emissions between it and Member States, the industries concerned and non-governmental organisations promoting environmental protection in order to facilitate the drawing up of best available techniques (BAT) reference documents as defined in Article 3(11) of that Directive.
- (5) Article 15(3) of Directive 2010/75/EU requires the competent authority to set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the decisions on BAT conclusions referred to in Article 13(5) of Directive 2010/75/EU.
- (2) In accordance with Article 13(2) of Directive 2010/75/EU, the exchange of information is to address the performance of installations and techniques in terms of emissions, expressed as short- and long-term averages, where appropriate, and the associated reference conditions, consumption and nature of raw materials, water consumption, use of energy and generation of waste and the techniques used, associated monitoring, cross-media effects, economic and technical viability and developments therein and best available techniques and emerging techniques identified after considering the issues mentioned in points (a) and (b) of Article 13(2) of that Directive.
- (6) Article 15(4) of Directive 2010/75/EU provides for derogations from the requirement laid down in Article 15(3) only where the costs associated with the achievement of emissions levels disproportionately outweigh the environmental benefits due to the geographical location, the local environmental conditions or the technical characteristics of the installation concerned.
- (7) Article 16(1) of Directive 2010/75/EU provides that the monitoring requirements in the permit referred to in point (c) of Article 14(1) of the Directive are to be based on the conclusions on monitoring as described in the BAT conclusions.

<sup>(1)</sup> OJ L 334, 17.12.2010, p. 17.

- (8) In accordance with Article 21(3) of Directive 2010/75/EU, within 4 years of publication of decisions on BAT conclusions, the competent authority is to reconsider and, if necessary, update all the permit conditions and ensure that the installation complies with those permit conditions.
- (9) Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of Directive 2010/75/EU on industrial emissions <sup>(1)</sup> established a forum composed of representatives of Member States, the industries concerned and non-governmental organisations promoting environmental protection.
- (10) In accordance with Article 13(4) of Directive 2010/75/EU, the Commission obtained the opinion <sup>(2)</sup> of that forum on the proposed content of the BAT reference document for the manufacture of glass on 13 September 2011 and made it publicly available.

- (11) The measures provided for in this Decision are in accordance with the opinion of the Committee established by Article 75(1) of Directive 2010/75/EU,

HAS ADOPTED THIS DECISION:

*Article 1*

The BAT conclusions for the manufacture of glass are set out in the Annex to this Decision.

*Article 2*

This Decision is addressed to the Member States.

Done at Brussels, 28 February 2012.

*For the Commission*

Janez POTOČNIK

*Member of the Commission*

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<sup>(1)</sup> OJ C 146, 17.5.2011, p. 3.

<sup>(2)</sup> [http://circa.europa.eu/Public/irc/env/ied/library?l=/ied\\_art\\_13\\_forum/opinions\\_article](http://circa.europa.eu/Public/irc/env/ied/library?l=/ied_art_13_forum/opinions_article)

## ANNEX

**BAT CONCLUSIONS FOR THE MANUFACTURE OF GLASS**

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## SCOPE

These BAT conclusions concern the industrial activities specified in Annex I to Directive 2010/75/EU, namely:

- 3.3. Manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day;
- 3.4. Melting mineral substances including the production of mineral fibres with a melting capacity exceeding 20 tonnes per day.

These BAT conclusions do not address the following activities:

- Production of water glass, covered by the reference document Large Volume Inorganic Chemicals – Solids and Other Industry (LVIC-S)
- Production of polycrystalline wool
- Production of mirrors, covered by the reference document Surface Treatment Using Organic Solvents (STS)

Other reference documents which are of relevance for the activities covered by these BAT conclusions are the following:

| Reference documents                    | Activity                                        |
|----------------------------------------|-------------------------------------------------|
| Emissions from Storage (EFS)           | Storage and handling of raw materials           |
| Energy Efficiency (ENE)                | General energy efficiency                       |
| Economic and Cross-Media Effects (ECM) | Economics and cross-media effects of techniques |
| General Principles of Monitoring (MON) | Emissions and consumption monitoring            |

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

## DEFINITIONS

For the purposes of these BAT conclusions, the following definitions apply:

| Term used                | Definition                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| New plant                | A plant introduced on the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant on the existing foundations of the installation following the publication of these BAT conclusions                                                                                                              |
| Existing plant           | A plant which is not a new plant                                                                                                                                                                                                                                                                                                                           |
| New furnace              | A furnace introduced on the site of the installation following the publication of these BAT conclusions or a complete rebuild of a furnace following the publication of these BAT conclusions                                                                                                                                                              |
| Normal furnace rebuild   | A rebuild between campaigns without a significant change in furnace requirements or technology and in which the furnace frame is not significantly adjusted and the furnace dimensions remain basically unchanged. The refractory of the furnace and, where appropriate, the regenerators are repaired by the full or partial replacement of the material. |
| Complete furnace rebuild | A rebuild involving a major change in the furnace requirements or technology and with major adjustment or replacement of the furnace and associated equipments.                                                                                                                                                                                            |

## GENERAL CONSIDERATIONS

**Averaging periods and reference conditions for air emissions**

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for air emissions given in these BAT conclusions apply under the reference conditions shown in Table 1. All values for concentrations in waste gases refer to standard conditions: dry gas, temperature 273,15 K, pressure 101,3 kPa.

|                                |                                                                                                                                                                                                                  |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| For discontinuous measurements | BAT-AELs refer to the average value of three spot samples of at least 30 minutes each; for regenerative furnaces the measuring period should cover a minimum of two firing reversals of the regenerator chambers |
| For continuous measurements    | BAT-AELs refer to daily average values                                                                                                                                                                           |

Table 1

**Reference conditions for BAT-AELs concerning air emissions**

| Activities                                                    |                                                       | Unit                                              | Reference conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|---------------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Melting activities</b>                                     | Conventional melting furnace in continuous melters    | mg/Nm <sup>3</sup>                                | 8 % oxygen by volume                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                                               | Conventional melting furnace in discontinuous melters | mg/Nm <sup>3</sup>                                | 13 % oxygen by volume                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                                               | Oxy-fuel-fired furnaces                               | kg/tonne melted glass                             | The expression of emission levels measured as mg/Nm <sup>3</sup> to a reference oxygen concentration is not applicable                                                                                                                                                                                                                                                                                                                                                           |
|                                                               | Electric furnaces                                     | mg/Nm <sup>3</sup><br>or<br>kg/tonne melted glass | The expression of emission levels measured as mg/Nm <sup>3</sup> to a reference oxygen concentration is not applicable                                                                                                                                                                                                                                                                                                                                                           |
|                                                               | Frit melting furnaces                                 | mg/Nm <sup>3</sup><br>or<br>kg/tonne melted frit  | Concentrations refer to 15 % oxygen by volume.<br><br>When air-gas firing is used, BAT AELs expressed as emission concentration (mg/Nm <sup>3</sup> ) apply.<br><br>When only oxy-fuel firing is employed, BAT AELs expressed as specific mass emissions (kg/tonne melted frit) apply.<br><br>When oxygen-enriched air-fuel firing is used, BAT AELs expressed as either emission concentration (mg/Nm <sup>3</sup> ) or as specific mass emissions (kg/tonne melted frit) apply |
|                                                               | All type of furnaces                                  | kg/tonne melted glass                             | The specific mass emissions refer to 1 tonne of melted glass                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Non-melting activities, including downstream processes</b> | All processes                                         | mg/Nm <sup>3</sup>                                | No correction for oxygen                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                                               | All processes                                         | kg/tonne glass                                    | The specific mass emissions refer to 1 tonne of produced glass                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Conversion to reference oxygen concentration**

The formula for calculating the emissions concentration at a reference oxygen level (see Table 1) is shown below.

$$E_R = \frac{21 - O_R}{21 - O_M} \times E_M$$

Where:

$E_R$  (mg/Nm<sup>3</sup>): emissions concentration corrected to the reference oxygen level  $O_R$

$O_R$  (vol %): reference oxygen level

$E_M$  (mg/Nm<sup>3</sup>): emissions concentration referred to the measured oxygen level  $O_M$

$O_M$  (vol %): measured oxygen level.

### Conversion from concentrations to specific mass emissions

BAT-AELs given in Sections 1.2 to 1.9 as specific mass emissions (kg/tonne melted glass) are based on the calculation reported below except for oxy-fuel fired furnaces and, in a limited number of cases, for electric melting where BAT-AELs given in kg/tonne melted glass were derived from specific reported data.

The calculation procedure used for the conversion from concentrations to specific mass emissions is shown below.

$$\text{Specific mass emission (kg/tonne of melted glass)} = \text{conversion factor} \times \text{emissions concentration (mg/Nm}^3\text{)}$$

Where: conversion factor =  $(Q/P) \times 10^{-6}$

with Q = waste gas volume in Nm<sup>3</sup>/h

P = pull rate in tonnes of melted glass/h.

The waste gas volume (Q) is determined by the specific energy consumption, type of fuel, and the oxidant (air, air enriched by oxygen and oxygen with purity depending on the production process). The energy consumption is a complex function of (predominantly) the type of furnace, the type of glass and the cullet percentage.

However, a range of factors can influence the relationship between concentration and specific mass flow, including:

- type of furnace (air preheating temperature, melting technique)
- type of glass produced (energy requirement for melting)
- energy mix (fossil fuel/electric boosting)
- type of fossil fuel (oil, gas)
- type of oxidant (oxygen, air, oxygen-enriched air)
- cullet percentage
- batch composition
- age of the furnace
- furnace size.

The conversion factors given in Table 2 have been used for converting BAT-AELs from concentrations into specific mass emissions.

The conversion factors have been determined on the basis of energy efficient furnaces and relate only to full air/fuel-fired furnaces.

Table 2

### Indicative factors used for converting mg/Nm<sup>3</sup> into kg/tonne of melted glass based on energy efficient fuel-air furnaces

| Sectors                         |                               | Factors to convert<br>mg/Nm <sup>3</sup> into kg/tonne of melted glass |
|---------------------------------|-------------------------------|------------------------------------------------------------------------|
| Flat glass                      |                               | $2,5 \times 10^{-3}$                                                   |
| Container glass                 | General case                  | $1,5 \times 10^{-3}$                                                   |
|                                 | Specific cases <sup>(1)</sup> | Case-by-case study<br>(often $3,0 \times 10^{-3}$ )                    |
| Continuous filament glass fibre |                               | $4,5 \times 10^{-3}$                                                   |

| Sectors        |                               | Factors to convert<br>mg/Nm <sup>3</sup> into kg/tonne of melted glass                        |
|----------------|-------------------------------|-----------------------------------------------------------------------------------------------|
| Domestic glass | Soda lime                     | $2,5 \times 10^{-3}$                                                                          |
|                | Specific cases <sup>(2)</sup> | Case-by-case study<br>(between $2,5$ and $> 10 \times 10^{-3}$ ; often $3,0 \times 10^{-3}$ ) |
| Mineral wool   | Glass wool                    | $2 \times 10^{-3}$                                                                            |
|                | Stone wool cupola             | $2,5 \times 10^{-3}$                                                                          |
| Special glass  | TV glass (panels)             | $3 \times 10^{-3}$                                                                            |
|                | TV glass (funnel)             | $2,5 \times 10^{-3}$                                                                          |
|                | Borosilicate (tube)           | $4 \times 10^{-3}$                                                                            |
|                | Glass ceramics                | $6,5 \times 10^{-3}$                                                                          |
|                | Lighting glass (soda-lime)    | $2,5 \times 10^{-3}$                                                                          |
| Frits          |                               | Case-by-case study<br>(between $5 - 7,5 \times 10^{-3}$ )                                     |

<sup>(1)</sup> Specific cases correspond to less favourable cases (i.e. small special furnaces with a production of generally below 100 tonnes/day and a cullet rate of below 30 %). This category represents only 1 or 2 % of the container glass production.

<sup>(2)</sup> Specific cases corresponding to less favourable cases and/or non-soda-lime glasses: borosilicates, glass ceramic, crystal glass and, less frequently, lead crystal glass.

#### DEFINITIONS FOR CERTAIN AIR POLLUTANTS

For the purpose of these BAT conclusions and for the BAT-AELs reported in Sections 1.2 to 1.9, the following definitions apply:

|                                              |                                                                                                                    |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| NO <sub>x</sub> expressed as NO <sub>2</sub> | The sum of nitrogen oxide (NO) and nitrogen dioxide (NO <sub>2</sub> ) expressed as NO <sub>2</sub>                |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | The sum of sulphur dioxide (SO <sub>2</sub> ) and sulphur trioxide (SO <sub>3</sub> ) expressed as SO <sub>2</sub> |
| Hydrogen chloride expressed as HCl           | All gaseous chlorides expressed as HCl                                                                             |
| Hydrogen fluoride expressed as HF            | All gaseous fluorides expressed as HF                                                                              |

#### 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.<br>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                                                               |

| Technique                                                                                       | Applicability                                                                                                                                                                                                                       |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (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.<br><br>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.<br><br>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 potential increase of dust emissions | Applicable within the constraints associated with the availability of raw materials                                                                                                                    |
| (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 absorptency 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 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. | Applicable to regenerative, recuperative, and oxy-fuel fired furnaces.<br><br>The applicability to other types of furnaces requires an installation-specific assessment |

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 <sub>2</sub> content of the combustion gases to control the fuel/air ratio.                                                                                                                                                                        |                                         |
| (iii) Continuous measurements of dust, NO <sub>x</sub> and SO <sub>2</sub> 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 <sub>3</sub> emissions, when selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) techniques are applied                                                                                                                                           | The techniques are generally applicable |
| (v) Continuous or regular periodic measurements of CO emissions when primary techniques or chemical reduction by fuel techniques are applied for NO <sub>x</sub> 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<sub>x</sub> emissions

| Technique                                                                                                                                                                                                                                                                                                                                             | Applicability                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Primary techniques for the reduction of NO <sub>x</sub> emissions are based on combustion modifications (e.g. reduction of air/fuel ratio, staged combustion low-NO <sub>x</sub> burners, etc.). Chemical reduction by fuel consists of the addition of hydrocarbon fuel to the waste gas stream to reduce the NO <sub>x</sub> formed in the furnace. | Applicable to conventional air/fuel fired furnaces. |
| 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 <sup>3</sup> |

10. BAT is to limit ammonia (NH<sub>3</sub>) emissions, when applying selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) techniques for a high efficiency NO<sub>x</sub> 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 (1)                |
|---------------------------------------|-----------------------------|
| Ammonia, expressed as NH <sub>3</sub> | < 5 – 30 mg/Nm <sup>3</sup> |

(1) The higher levels are associated with higher inlet NO<sub>x</sub> 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 (1)                                                                                                                                                                                                                                                                                  | 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 species may be present in the flue-gas as gaseous compounds at temperatures below 200 °C, but also as low as 60 °C | The applicability to existing plants may be limited by technical constraints associated with the position and characteristics of the existing filter system                                                       |
| (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 <sub>x</sub> , 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                                                                                                               |

(1) 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.<br>Recirculation of scrubbing water is applicable to most scrubbing systems; however, periodic discharge and replacement of the scrubbing medium may be necessary |

| Technique                                                                                      | Applicability                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (iii) Operate a quasi-closed loop water system as far as technically and economically feasible | <p>The applicability of this technique may be limited by the constraints associated with the safety management of the production process. In particular:</p> <ul style="list-style-type: none"> <li>— open circuit cooling may be used when safety issues require for it (e.g. incidents when large quantities of glass need to be cooled)</li> <li>— 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</li> </ul> |

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                                                                                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(i) Standard pollution control techniques, such as settlement, screening, skimming, neutralisation, filtration, aeration, precipitation, coagulation and flocculation, etc.</p> <p>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.</p> | 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 <sup>(1)</sup>                              | Unit | BAT-AEL <sup>(2)</sup><br>(composite sample) |
|-------------------------------------------------------|------|----------------------------------------------|
| pH                                                    | —    | 6,5 – 9                                      |
| Total suspended solids                                | mg/l | < 30                                         |
| Chemical oxygen demand (COD)                          | mg/l | < 5 – 130 <sup>(3)</sup>                     |
| Sulphates, expressed as SO <sub>4</sub> <sup>2-</sup> | mg/l | < 1 000                                      |
| Fluorides, expressed as F <sup>-</sup>                | mg/l | < 6 <sup>(4)</sup>                           |
| Total hydrocarbons                                    | mg/l | < 15 <sup>(5)</sup>                          |
| Lead, expressed as Pb                                 | mg/l | < 0,05 – 0,3 <sup>(6)</sup>                  |
| Antimony, expressed as Sb                             | mg/l | < 0,5                                        |
| Arsenic, expressed as As                              | mg/l | < 0,3                                        |
| Barium, expressed as Ba                               | mg/l | < 3,0                                        |

| Parameter <sup>(1)</sup>              | Unit | BAT-AEL <sup>(2)</sup><br>(composite sample) |
|---------------------------------------|------|----------------------------------------------|
| 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 <sub>4</sub> | mg/l | < 10                                         |
| Boron, expressed as B                 | mg/l | < 1 – 3                                      |
| Phenol                                | mg/l | < 1                                          |

<sup>(1)</sup> 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.

<sup>(2)</sup> The levels refer to a composite sample taken over a time period of 2 hours or 24 hours.

<sup>(3)</sup> For the continuous filament glass fibre sector, BAT-AEL is < 200 mg/l.

<sup>(4)</sup> The level refers to treated water coming from activities involving acid polishing.

<sup>(5)</sup> In general, total hydrocarbons are composed of mineral oils.

<sup>(6)</sup> 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: <ul style="list-style-type: none"> <li>— quality requirements of the final glass product</li> <li>— cullet percentage used in the batch formulation</li> <li>— potential carryover phenomena and corrosion of the refractory materials</li> <li>— sulphur balance constraints</li> </ul> |
| (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).<br><br>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.<br><br>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 <sup>(1)</sup>                                                                                                                            | 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 |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20          | < 0,015 – 0,06                       |

<sup>(1)</sup> The conversion factors of  $1,5 \times 10^{-3}$  and  $3 \times 10^{-3}$  have been used for the determination of the lower and higher value of the range respectively.

#### 1.2.2. Nitrogen oxides (NO<sub>x</sub>) from melting furnaces

17. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

I. primary techniques, such as:

| Technique <sup>(1)</sup>               | Applicability                                                                                                                                                                            |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications           |                                                                                                                                                                                          |
| (a) Reduction of air/fuel ratio        | Applicable to air/fuel conventional furnaces.<br>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) |

| Technique <sup>(1)</sup>                                                   | Applicability                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (c) Staged combustion:<br>— Air staging<br>— Fuel staging                  | Fuel staging is applicable to most conventional air/fuel furnaces.<br>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 <sub>x</sub> burners                                            | The technique is generally applicable.<br>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.<br>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 %).<br>The application requires a complete rebuild of the melting furnace.<br>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).<br>Not applicable for productions requiring large pull variations.<br>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                                                                                                                                                                                                                                                       |
| <sup>(1)</sup> A description of the techniques is given in Section 1.10.2. |                                                                                                                                                                                                                                                                                                                                                                  |

II. secondary techniques, such as:

| Technique <sup>(1)</sup>                     | 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 <sup>3</sup> and a desulphurisation system for the removal of SO <sub>x</sub> emissions.<br>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.<br>The implementation of the technique may require significant space availability |
| (ii) Selective non-catalytic reduction(SNCR) | The technique is applicable to recuperative furnaces.<br>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.<br>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                                                                                                                        |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 7

**BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the container glass sector**

| Parameter                                    | BAT                                                                             | BAT-AEL            |                                      |
|----------------------------------------------|---------------------------------------------------------------------------------|--------------------|--------------------------------------|
|                                              |                                                                                 | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion modifications, special furnace designs <sup>(2)</sup> <sup>(3)</sup> | 500 – 800          | 0,75 – 1,2                           |
|                                              | Electric melting                                                                | < 100              | < 0,3                                |
|                                              | Oxy-fuel melting <sup>(4)</sup>                                                 | Not applicable     | < 0,5 – 0,8                          |
|                                              | Secondary techniques                                                            | < 500              | < 0,75                               |

<sup>(1)</sup> 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:  $3 \times 10^{-3}$ ).

<sup>(2)</sup> The lower value refers to the use of special furnace designs, where applicable.

<sup>(3)</sup> These values should be reconsidered in the occasion of a normal or complete rebuild of the melting furnace.

<sup>(4)</sup> 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<sub>x</sub> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                        | Applicability                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Primary techniques:</p> <p>— Minimising the use of nitrates in the batch formulation</p> <p>The use of nitrates is applied for very high quality products (i.e. flaconage, perfume bottles and cosmetic containers).</p> <p>Effective alternative materials are sulphates, arsenic oxides, cerium oxide.</p> <p>The application of process modifications (e.g. special oxidising combustion conditions) represents an alternative to the use of nitrates</p> | <p>The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials</p> |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 8

**BAT-AEL for NO<sub>x</sub> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Primary techniques | < 1 000            | < 3                                  |

<sup>(1)</sup> The conversion factor reported in Table 2 for specific cases ( $3 \times 10^{-3}$ ) has been applied.

### 1.2.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces

19. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                  | 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 | <p>The minimisation of the sulphur content in the batch formulation is generally applicable within the constraints of quality requirements of the final glass product.</p> <p>The application of sulphur balance optimisation requires a trade-off approach between the removal of SO<sub>x</sub> emissions and the management of the solid waste (filter dust).</p> <p>The effective reduction of SO<sub>x</sub> emissions depends on the retention of sulphur compounds in the glass which may vary significantly depending on the glass type</p> |
| (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                                                                                                                                                                                                                                                                                                                                                                           |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.3.

Table 9

### BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the container glass sector

| Parameter                                    | Fuel                    | BAT-AEL <sup>(1)</sup> <sup>(2)</sup> |                                      |
|----------------------------------------------|-------------------------|---------------------------------------|--------------------------------------|
|                                              |                         | mg/Nm <sup>3</sup>                    | kg/tonne melted glass <sup>(3)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | Natural gas             | < 200 – 500                           | < 0,3 – 0,75                         |
|                                              | Fuel oil <sup>(4)</sup> | < 500 – 1 200                         | < 0,75 – 1,8                         |

<sup>(1)</sup> 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.

<sup>(2)</sup> The lower levels are associated with conditions where the reduction of SO<sub>x</sub> is a high priority over a lower production of solid waste corresponding to the sulphate-rich filter dust.

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

<sup>(4)</sup> 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 <sup>(1)</sup>                                                                             | 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                                                                                                       |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl <sup>(2)</sup> | < 10 – 20          | < 0,02 – 0,03                        |
| Hydrogen fluoride, expressed as HF                 | < 1 – 5            | < 0,001 – 0,008                      |

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

<sup>(2)</sup> 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 <sup>(1)</sup>                                                                                                                                                  | 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                                                                                        |                                                                                                                                                         |

<sup>(1)</sup> 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 <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup> |                                      |
|--------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------|
|                                                                                      | mg/Nm <sup>3</sup>                                   | kg/tonne melted glass <sup>(4)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,2 – 1 <sup>(5)</sup>                             | < 0,3 – $1,5 \times 10^{-3}$         |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 5                                              | < 1,5 – $7,5 \times 10^{-3}$         |

<sup>(1)</sup> The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The lower levels are BAT-AELs when metal compounds are not intentionally used in the batch formulation.

<sup>(3)</sup> 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.

<sup>(4)</sup> The conversion factor for general cases, reported in Table 2 ( $1,5 \times 10^{-3}$ ) has been applied.

<sup>(5)</sup> 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<sup>3</sup>.

**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.<br><br>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 |

| Technique                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Applicability                                                                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(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).</p> <p>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:</p> <ul style="list-style-type: none"> <li>— combination with the flue gases from the melting furnace, upstream of a secondary abatement system (dry or semi-dry scrubbing plus filtration system)</li> <li>— combination with combustion air before entering the regenerator, followed by secondary abatement treatment of the waste gases generated during the melting process (dry or semi-dry scrubbing + filtration system)</li> </ul> | <p>The combination with flue gases from the melting furnace is generally applicable.</p> <p>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</p> |
| (iii) Applying a secondary technique, e.g. wet scrubbing, dry scrubbing plus filtration <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | The techniques are generally applicable                                                                                                                                                                                                                            |
| <sup>(1)</sup> 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 <sup>3</sup> |
| 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<sub>3</sub> is used for surface treatment operations, BAT is to reduce SO<sub>x</sub> emissions by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                                                                                                                                                    | Applicability                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| <p>(i) Minimising the product losses by ensuring a good sealing of the application system</p> <p>A good construction and maintenance of the application system is essential for minimising the losses of unreacted product into the air</p> | The techniques are generally applicable |
| (ii) Applying a secondary technique, e.g. wet scrubbing                                                                                                                                                                                     |                                         |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.6.

Table 13

**BAT-AEL for SO<sub>x</sub> emissions from downstream activities when SO<sub>3</sub> is used for surface treatment operations in the container glass sector, when treated separately**

| Parameter                                      | BAT-AEL            |
|------------------------------------------------|--------------------|
|                                                | mg/Nm <sup>3</sup> |
| SO <sub>x</sub> , expressed as SO <sub>2</sub> | < 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20          | < 0,025 – 0,05                       |

<sup>(1)</sup> The conversion factor reported in Table 2 ( $2,5 \times 10^{-3}$ ) has been applied.

#### 1.3.2. Nitrogen oxides (NO<sub>x</sub>) from melting furnaces

25. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

I. primary techniques, such as:

| Technique <sup>(1)</sup>                                  | Applicability                                                                                                                                                                                                                                                                                                                                                    |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications                              |                                                                                                                                                                                                                                                                                                                                                                  |
| (a) Reduction of air/fuel ratio                           | Applicable to air/fuel conventional furnaces.<br>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:<br>— Air staging<br>— Fuel staging | Fuel staging is applicable to most conventional air/fuel furnaces.<br>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 <sub>x</sub> burners                           | The technique is generally applicable.<br>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.<br>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                                                                                                                                                                                      |

| Technique <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                           | Applicability                                                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (ii) Fenix process<br>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: <ul style="list-style-type: none"> <li>— reduction of excess air</li> <li>— suppression of hotspots and homogenisation of the flame temperatures</li> <li>— controlled mixing of the fuel and combustion air</li> </ul> | The applicability is limited to cross-fired regenerative furnaces.<br>Applicable to new furnaces.<br>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                                                                                                                                                    |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

II. secondary techniques, such as:

| Technique <sup>(1)</sup>                 | Applicability                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Chemical reduction by fuel           | Applicable to regenerative furnaces.<br>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 <sup>3</sup> and a desulphurisation system for the removal of SO <sub>x</sub> emissions<br>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.<br>The implementation of the technique may require significant space availability |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 15

**BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the flat glass sector**

| Parameter                                    | BAT                                                    | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|--------------------------------------------------------|------------------------|--------------------------------------|
|                                              |                                                        | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion modifications, Fenix process <sup>(3)</sup> | 700 – 800              | 1,75 – 2,0                           |
|                                              | Oxy-fuel melting <sup>(4)</sup>                        | Not applicable         | < 1,25 – 2,0                         |
|                                              | Secondary techniques <sup>(5)</sup>                    | 400 – 700              | 1,0 – 1,75                           |

<sup>(1)</sup> Higher emission levels are expected when nitrates are used occasionally for the production of special glasses.

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

<sup>(3)</sup> The lower levels of the range are associated with the application of the Fenix process.

<sup>(4)</sup> The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

<sup>(5)</sup> 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<sub>x</sub> 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 <sup>(1)</sup>                                                                                                                                                                                                                       | Applicability                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Primary techniques:<br>minimising the use of nitrates in the batch formulation<br>The use of nitrates is applied for special productions (i.e. coloured glass).<br>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 |

<sup>(1)</sup> A description of the technique is given in Section 1.10.2.

Table 16

**BAT-AEL for NO<sub>x</sub> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Primary techniques | < 1 200            | < 3                                  |

<sup>(1)</sup> The conversion factor reported in Table 2 for specific cases ( $2,5 \times 10^{-3}$ ) has been applied

### 1.3.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces

27. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                  | 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.<br><br>The application of sulphur balance optimisation requires a trade-off approach between the removal of SO <sub>x</sub> 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                                                                                                                                                                                     |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.3.

Table 17

**BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the flat glass sector**

| Parameter                                    | Fuel                                   | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|----------------------------------------|------------------------|--------------------------------------|
|                                              |                                        | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | Natural gas                            | < 300 – 500            | < 0,75 – 1,25                        |
|                                              | Fuel oil <sup>(3)</sup> <sup>(4)</sup> | 500 – 1 300            | 1,25 – 3,25                          |

<sup>(1)</sup> The lower levels are associated with conditions where the reduction of SO<sub>x</sub> has a high priority over a lower production of solid waste corresponding to the sulphate-rich filter dust.

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

<sup>(3)</sup> The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

<sup>(4)</sup> 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 <sup>(1)</sup>                                                                             | 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                                                                                                       |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl <sup>(2)</sup> | < 10 – 25          | < 0,025 – 0,0625                     |
| Hydrogen fluoride, expressed as HF                 | < 1 – 4            | < 0,0025 – 0,010                     |

<sup>(1)</sup> The conversion factor reported in Table 2 ( $2,5 \times 10^{-3}$ ) has been applied.

<sup>(2)</sup> 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 <sup>(1)</sup>                                                              | 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   |                                                                                                                                                          |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|---------------------------------------------------------------------------------------------|------------------------|--------------------------------------|
|                                                                                             | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| $\Sigma$ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,2 – 1              | < 0,5 – $2,5 \times 10^{-3}$         |
| $\Sigma$ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 5                | < 2,5 – $12,5 \times 10^{-3}$        |

<sup>(1)</sup> The ranges refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The conversion factor reported in Table 2 ( $2,5 \times 10^{-3}$ ) 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 <sup>(1)</sup>                                                                                                                                                    | 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                                                                                                                                           |                                                                                                                                                         |
| (iii) Applying a dry or semi-dry scrubbing, in combination with a filtration system                                                                                         |                                                                                                                                                         |

<sup>(1)</sup> 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 <sup>(1)</sup> <sup>(2)</sup> |                                      |
|-------------------------------------|---------------------------------------|--------------------------------------|
|                                     | mg/Nm <sup>3</sup>                    | kg/tonne melted glass <sup>(3)</sup> |
| Selenium compounds, expressed as Se | 1 – 3                                 | 2,5 – 7,5 × 10 <sup>-3</sup>         |

<sup>(1)</sup> The values refer to the sum of selenium present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> 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.

<sup>(3)</sup> The conversion factor reported in Table 2 (2,5 × 10<sup>-3</sup>) 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 <sup>(1)</sup>                                                                                                                                                                                                    | 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 <sub>2</sub> from the annealing lehr, by operating the control system in an optimum manner                                                                                                 |                                                                                                                                               |
| (iii) Combining the SO <sub>2</sub> 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.<br>The selection of the technique and its performance will depend on the inlet waste gas composition |

<sup>(1)</sup> 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 <sup>3</sup> |
| Dust      | < 15 – 20          |

| Parameter                                                                            | BAT-AEL            |
|--------------------------------------------------------------------------------------|--------------------|
|                                                                                      | mg/Nm <sup>3</sup> |
| Hydrogen chloride, expressed as HCl                                                  | < 10               |
| Hydrogen fluoride, expressed as HF                                                   | < 1 – 5            |
| SO <sub>x</sub> , expressed as SO <sub>2</sub>                                       | < 200              |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 1                |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                              | Applicability                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Reduction of the volatile components by raw material modifications<br><br>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.<br><br>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                                                                                         |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|-----------|------------------------|--------------------------------------|
|           | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| Dust      | < 10 – 20              | < 0,045 – 0,09                       |

<sup>(1)</sup> Values at levels of < 30 mg/Nm<sup>3</sup> (< 0,14 kg/tonne melted glass) have been reported for boron-free formulations, with the application of primary techniques.

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

1.4.2. Nitrogen oxides (NO<sub>x</sub>) from melting furnaces

33. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                      | Applicability                                                                                                                                                                    |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications                                  |                                                                                                                                                                                  |
| (a) Reduction of air/fuel ratio                               | Applicable to air/fuel conventional furnaces.<br>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) Staged combustion:<br>(d) Air staging<br>(e) Fuel staging | Fuel staging is applicable to most air/fuel, oxy-fuel furnaces.<br>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 <sub>x</sub> burners                               | The technique is generally applicable.<br>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                                                                       |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 23

**BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the continuous filament glass fibre sector**

| Parameter                                    | BAT                             | BAT-AEL            |                            |
|----------------------------------------------|---------------------------------|--------------------|----------------------------|
|                                              |                                 | mg/Nm <sup>3</sup> | kg/tonne melted glass      |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion modifications        | < 600 – 1 000      | < 2,7 – 4,5 <sup>(1)</sup> |
|                                              | Oxy-fuel melting <sup>(2)</sup> | Not applicable     | < 0,5 – 1,5                |

<sup>(1)</sup> The conversion factor reported in Table 2 ( $4,5 \times 10^{-3}$ ) has been applied.

<sup>(2)</sup> The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

1.4.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces

34. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                 | 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.<br><br>The application of sulphur balance optimisation requires a trade-off approach between the removal of SO <sub>x</sub> emissions and the management of the solid waste (filter dust), which needs to be disposed of |

| Technique <sup>(1)</sup>                                                 | Applicability                                                                                                                                                                                                      |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (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.<br>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                                                                                           |

<sup>(1)</sup> A description of the techniques is given in Sections 1.10.3 and 1.10.6.

Table 24

#### BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the continuous filament glass fibre sector

| Parameter                                    | Fuel                                   | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|----------------------------------------|------------------------|--------------------------------------|
|                                              |                                        | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | Natural gas <sup>(3)</sup>             | < 200 – 800            | < 0,9 – 3,6                          |
|                                              | Fuel oil <sup>(4)</sup> <sup>(5)</sup> | < 500 – 1 000          | < 2,25 – 4,5                         |

<sup>(1)</sup> The higher levels of the range are associated with the use of sulphates in the batch formulation for refining the glass.

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

<sup>(3)</sup> 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<sub>x</sub>, expressed as SO<sub>2</sub>.

<sup>(4)</sup> The associated emission levels are related to the use of 1 % sulphur fuel oil in combination with secondary abatement techniques.

<sup>(5)</sup> The lower levels correspond to conditions where the reduction of SO<sub>x</sub> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 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<br><br>The minimisation of fluorine emissions from the melting process may be achieved as follows:<br><br>— 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<br><br>— 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                                                                                       |
| (iv) wet scrubbing                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | The technique is generally applicable within technical constraints; i.e. need for a specific waste water treatment plant.   |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl               | < 10               | < 0,05                               |
| Hydrogen fluoride, expressed as HF <sup>(2)</sup> | < 5 – 15           | < 0,02 – 0,07                        |

<sup>(1)</sup> The conversion factor reported in Table 2 ( $4,5 \times 10^{-3}$ ) has been applied.

<sup>(2)</sup> 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 <sup>(1)</sup>                                                              | 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. |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|---------------------------------------------------------------------------------------------|------------------------|--------------------------------------|
|                                                                                             | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| $\Sigma$ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,2 – 1              | < 0,9 – $4,5 \times 10^{-3}$         |
| $\Sigma$ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 3                | < 4,5 – $13,5 \times 10^{-3}$        |

<sup>(1)</sup> The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The conversion factor reported in Table 2 ( $4,5 \times 10^{-3}$ ) 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 <sup>(1)</sup>             | 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                                                                                                      |

<sup>(1)</sup> 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/Nm <sup>3</sup> |
| <b>Emissions from forming and coating</b>        |                    |
| Dust                                             | < 5 – 20           |
| Formaldehyde                                     | < 10               |
| Ammonia                                          | < 30               |
| Total volatile organic compounds, expressed as C | < 20               |
| <b>Emissions from cutting and milling</b>        |                    |
| 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 <sup>(1)</sup>                                                                                                                                                                                                                                                        | Applicability                                                                                                                                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Reduction of the volatile components by raw material modifications.<br><br>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).<br><br>Not applicable for productions requiring large pull variations<br><br>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 |

<sup>(1)</sup> 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 <sup>3</sup>       | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20 <sup>(2)</sup> | < 0,03 – 0,06                        |
|           | < 1 – 10 <sup>(3)</sup>  | < 0,003 – 0,03                       |

<sup>(1)</sup> A conversion factor of  $3 \times 10^{-3}$  has been applied (see Table 2). However, a case by case conversion factor may have to be applied for specific productions.

<sup>(2)</sup> 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.

<sup>(3)</sup> 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<sub>x</sub>) from melting furnaces

39. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>               | Applicability                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications           |                                                                                                                                                                                                                                                                                                                                                                  |
| (a) Reduction of air/fuel ratio        | Applicable to air/fuel conventional furnaces.<br>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.                                                                                                                                                                                                                                                                                               |
| (f) Air staging                        | Air staging has very limited applicability due to its technical complexity                                                                                                                                                                                                                                                                                       |
| (g) Fuel staging                       |                                                                                                                                                                                                                                                                                                                                                                  |
| (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 <sub>x</sub> burners        | The technique is generally applicable.<br>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.<br>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 %).<br>The application requires a complete rebuild of the melting furnace.<br>The shape of the furnace (long and narrow) may pose space restrictions                                                                                                        |

| Technique <sup>(1)</sup> | Applicability                                                                                                                                                                                              |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (iii) Electric melting   | Not applicable for large volume glass productions (> 300 tonnes/day).<br><br>Not applicable for productions requiring large pull variations.<br><br>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                                                                                                 |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 29

#### BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the domestic glass sector

| Parameter                                    | BAT                                               | BAT-AEL            |                                      |
|----------------------------------------------|---------------------------------------------------|--------------------|--------------------------------------|
|                                              |                                                   | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion modifications, special furnace designs | < 500 – 1 000      | < 1,25 – 2,5                         |
|                                              | Electric melting                                  | < 100              | < 0,3                                |
|                                              | Oxy-fuel melting <sup>(2)</sup>                   | Not applicable     | < 0,5 – 1,5                          |

<sup>(1)</sup> A conversion factor of  $2,5 \times 10^{-3}$  has been applied for combustion modifications and special furnace designs and a conversion factor of  $3 \times 10^{-3}$  has been applied for electric melting (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

<sup>(2)</sup> 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<sub>x</sub> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                       | Applicability                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Primary techniques:                                                                                                                                                                                                                                                                            |                                                                                                                                                        |
| — Minimising the use of nitrates in the batch formulation<br><br>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 |

<sup>(1)</sup> A description of the technique is given in Section 1.10.2.

Table 30

**BAT-AELs for NO<sub>x</sub> 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 <sup>3</sup> | kg/tonne melted glass        |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Fuel/air conventional furnaces | < 500 – 1 500      | < 1,25 – 3,75 <sup>(1)</sup> |
|                                              | Electric melting               | < 300 – 500        | < 8 – 10                     |

<sup>(1)</sup> The conversion factor reported in Table 2 for soda-lime glass ( $2,5 \times 10^{-3}$ ) has been applied.

### 1.5.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces

41. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                 | 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.<br><br>The application of sulphur balance optimisation requires a trade-off approach between the removal of SO <sub>x</sub> 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                                                                                                                                                                                                                                                                                                                         |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.3.

Table 31

### BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the domestic glass sector

| Parameter                                    | Fuel/melting technique  | BAT-AEL            |                                      |
|----------------------------------------------|-------------------------|--------------------|--------------------------------------|
|                                              |                         | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | Natural gas             | < 200 – 300        | < 0,5 – 0,75                         |
|                                              | Fuel oil <sup>(2)</sup> | < 1 000            | < 2,5                                |
|                                              | Electric melting        | < 100              | < 0,25                               |

<sup>(1)</sup> 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.

<sup>(2)</sup> 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 <sup>(1)</sup>                                                                             | 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 |

| Technique <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Applicability                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (ii) Minimisation of the fluorine content in the batch formulation and optimisation of the fluorine mass balance<br><br>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.<br><br>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 |

<sup>(1)</sup> 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/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl <sup>(2)</sup> <sup>(3)</sup> | < 10 – 20          | < 0,03 – 0,06                        |
| Hydrogen fluoride, expressed as HF <sup>(4)</sup>                 | < 1 – 5            | < 0,003 – 0,015                      |

<sup>(1)</sup> A conversion factor of  $3 \times 10^{-3}$  has been applied (see Table 2). However, a case-by-case conversion factor may have to be applied for specific productions.

<sup>(2)</sup> The lower levels are associated with the use of electric melting.

<sup>(3)</sup> In cases where KCl or NaCl are used as a refining agents, the BAT-AEL is < 30 mg/Nm<sup>3</sup> or < 0,09 kg/tonne melted glass.

<sup>(4)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                 | 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                                                                                                                                                                                                                  |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|--------------------------------------------------------------------------------------|------------------------|--------------------------------------|
|                                                                                      | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,2 – 1              | < 0,6 – 3 × 10 <sup>-3</sup>         |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 5                | < 3 – 15 × 10 <sup>-3</sup>          |

<sup>(1)</sup> The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> A conversion factor of 3 × 10<sup>-3</sup> 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 <sup>(1)</sup>                                                                                                 | 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                                                                                                               |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|---------------------------|------------------------|--------------------------------------|
|                           | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| Selenium compounds, as Se | < 1                    | < 3 × 10 <sup>-3</sup>               |

<sup>(1)</sup> The values refer to the sum of selenium present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> A conversion factor of 3 × 10<sup>-3</sup> 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 <sup>(1)</sup>                                                | Applicability                                                                                                                                                                                      |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Electric melting                                                    | Not applicable for large volume glass productions (> 300 tonnes/day).<br>Not applicable for productions requiring large pull variations.<br>The implementation requires a complete furnace rebuild |
| (ii) Bag filter                                                         | The technique is generally applicable                                                                                                                                                              |
| (iii) Electrostatic precipitator                                        |                                                                                                                                                                                                    |
| (iv) Dry or semi-dry scrubbing, in combination with a filtration system |                                                                                                                                                                                                    |

<sup>(1)</sup> 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 <sup>(1)</sup> |                                      |
|---------------------------------|------------------------|--------------------------------------|
|                                 | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| Lead compounds, expressed as Pb | < 0,5 – 1              | < 1 – 3 × 10 <sup>-3</sup>           |

<sup>(1)</sup> The values refer to the sum of lead present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> A conversion factor of 3 × 10<sup>-3</sup> 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 <sup>(1)</sup>                                                         | Applicability                           |
|----------------------------------------------------------------------------------|-----------------------------------------|
| (i) Performing dusty operations (e.g. cutting, grinding, polishing) under liquid | The techniques are generally applicable |
| (ii) Applying a bag filter system                                                |                                         |

<sup>(1)</sup> 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 <sup>3</sup> |
| Dust                                                                                                | < 1 – 10           |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> ) <sup>(1)</sup>                                            | < 1                |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) <sup>(1)</sup> | < 1 – 5            |
| Lead compounds, expressed as Pb <sup>(2)</sup>                                                      | < 1 – 1,5          |

<sup>(1)</sup> The levels refer to the sum of metals present in the waste gas.

<sup>(2)</sup> 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 <sup>(1)</sup>                                                                            | 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.                                            |                                         |

<sup>(1)</sup> 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/Nm <sup>3</sup> |
| 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 <sup>(1)</sup>                                                                                                                                                                                                                                           | Applicability                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Reduction of the volatile components by raw material modifications<br><br>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                                                                                                        |
| (ii) Electric melting                                                                                                                                                                                                                                              | Not applicable for large volume glass productions (> 300 tonnes/day)<br><br>Not applicable for productions requiring large pull variations<br><br>The implementation requires a complete furnace rebuild |
| (iii) Filtration system: electrostatic precipitator or bag filter                                                                                                                                                                                                  | The technique is generally applicable                                                                                                                                                                    |

<sup>(1)</sup> 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 <sup>3</sup>      | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20               | < 0,03 – 0,13                        |
|           | < 1 – 10 <sup>(2)</sup> | < 0,003 – 0,065                      |

<sup>(1)</sup> 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).

<sup>(2)</sup> 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<sub>x</sub>) from melting furnaces**

49. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

## I. primary techniques, such as:

| Technique <sup>(1)</sup>                                  | Applicability                                                                                                                                                                                                                                                                                                                                                    |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications                              |                                                                                                                                                                                                                                                                                                                                                                  |
| (a) Reduction of air/fuel ratio                           | Applicable to air/fuel conventional furnaces.<br>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:<br>— Air staging<br>— Fuel staging | Fuel staging is applicable to most conventional air/fuel furnaces.<br>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 <sub>x</sub> burners                           | The technique is generally applicable.<br>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.<br>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).<br>Not applicable for productions requiring large pull variations.<br>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                                                                                                                                                                                                                                                       |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

## II. secondary techniques, such as:

| Technique <sup>(1)</sup>                | 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 <sup>3</sup> and a desulphurisation system for the removal of SO <sub>x</sub> emissions<br><br>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.<br><br>The implementation of the technique may require significant space availability |

| Technique <sup>(1)</sup>                      | Applicability                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (ii) Selective non-catalytic reduction (SNCR) | <p>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</p> <p>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</p> |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 39

#### BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the special glass sector

| Parameter                                    | BAT                                            | BAT-AEL            |                                      |
|----------------------------------------------|------------------------------------------------|--------------------|--------------------------------------|
|                                              |                                                | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion modifications                       | 600 – 800          | 1,5 – 3,2                            |
|                                              | Electric melting                               | < 100              | < 0,25 – 0,4                         |
|                                              | Oxy-fuel melting <sup>(2)</sup> <sup>(3)</sup> | Not applicable     | < 1 – 3                              |
|                                              | Secondary techniques                           | < 500              | < 1 – 3                              |

<sup>(1)</sup> The conversion factors of  $2,5 \times 10^{-3}$  and  $4 \times 10^{-3}$  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).

<sup>(2)</sup> The higher values are related to a special production of borosilicate glass tubes for pharmaceutical use.

<sup>(3)</sup> 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<sub>x</sub> emissions by minimising the use of these raw materials, in combination with either primary or secondary techniques

| Technique <sup>(1)</sup>                                                                                                                                                                                                                                                                              | Applicability                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Primary techniques</p> <p>— minimising the use of nitrates in the batch formulation</p> <p>The use of nitrates is applied for very high quality products, where special characteristics of the glass are required. Effective alternative materials are sulphates, arsenic oxides, cerium oxide</p> | The substitution of nitrates in the batch formulation may be limited by the high costs and/or higher environmental impact of the alternative materials |

<sup>(1)</sup> A description of the technique is given in Section 1.10.2.

Table 40

#### BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the special glass sector when nitrates are used in the batch formulation

| Parameter                                    | BAT                                                                                                  | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------|--------------------------------------|
|                                              |                                                                                                      | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Minimisation of nitrate input in the batch formulation combined with primary or secondary techniques | < 500 – 1 000          | < 1 – 6                              |

<sup>(1)</sup> The lower levels are associated with the use of electric melting.

<sup>(2)</sup> The conversion 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-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<sub>x</sub>) from melting furnaces

51. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                 | 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                                                                                                                                     |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.3.

Table 41

#### BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the special glass sector

| Parameter                                    | Fuel/melting technique                       | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|----------------------------------------------|------------------------|--------------------------------------|
|                                              |                                              | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | Natural gas, electric melting <sup>(3)</sup> | < 30 – 200             | < 0,08 – 0,5                         |
|                                              | Fuel oil <sup>(4)</sup>                      | 500 – 800              | 1,25 – 2                             |

<sup>(1)</sup> The ranges take into account the variable sulphur balances associated with the type of glass produced.

<sup>(2)</sup> 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.

<sup>(3)</sup> The lower levels are associated with the use of electric melting and batch formulations without sulphates.

<sup>(4)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                            | 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<br><br>Fluorine compounds are used to confer particular characteristics to special glasses (i.e. opaque lighting glass, optical glass).<br><br>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                                                                                                                                 |

<sup>(1)</sup> 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            |                                      |
|----------------------------------------------------|--------------------|--------------------------------------|
|                                                    | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl <sup>(2)</sup> | < 10 – 20          | < 0,03 – 0,05                        |
| Hydrogen fluoride, expressed as HF                 | < 1 – 5            | < 0,003 – 0,04 <sup>(3)</sup>        |

<sup>(1)</sup> 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.

<sup>(2)</sup> The higher levels are associated with the use of materials containing chlorine in the batch formulation.

<sup>(3)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                 | 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 |                                                                                                                                                     |
| (iii) Dry or semi-dry scrubbing, in combination with a filtration system                                                                                                                                                                 |                                                                                                                                                     |

<sup>(1)</sup> 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 <sup>(1)</sup> <sup>(2)</sup> |                                      |
|--------------------------------------------------------------------------------------|---------------------------------------|--------------------------------------|
|                                                                                      | mg/Nm <sup>3</sup>                    | kg/tonne melted glass <sup>(3)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,1 – 1                             | < 0,3 – $3 \times 10^{-3}$           |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 5                               | < 3 – $15 \times 10^{-3}$            |

<sup>(1)</sup> The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The lower levels are BAT-AELs when metal compounds are not intentionally used in the batch formulation.

<sup>(3)</sup> The conversion factor of  $2,5 \times 10^{-3}$  (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 <sup>(1)</sup>                                                         | Applicability                           |
|----------------------------------------------------------------------------------|-----------------------------------------|
| (i) Performing dusty operations (e.g. cutting, grinding, polishing) under liquid | The techniques are generally applicable |
| (ii) Applying a bag filter system                                                |                                         |

<sup>(1)</sup> 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 <sup>3</sup> |
| Dust                                                                                                | 1 – 10             |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> ) <sup>(1)</sup>                                            | < 1                |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) <sup>(1)</sup> | < 1 – 5            |

<sup>(1)</sup> 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 <sup>(1)</sup>                                                                            | 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                                             |                                         |

<sup>(1)</sup> 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 <sup>3</sup> |
| 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 <sup>(1)</sup>                                    | Applicability                                                                                                                                                                                                                            |
|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Filtration system: electrostatic precipitator or bag filter | The technique is generally applicable.<br><br>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 |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20          | < 0,02 – 0,050                       |

<sup>(1)</sup> The conversion factors of  $2 \times 10^{-3}$  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<sub>x</sub>) from melting furnaces

57. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                  | Applicability                                                                                                                                                                                                                                                                                                                                                    |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion modifications                              |                                                                                                                                                                                                                                                                                                                                                                  |
| (a) Reduction of air/fuel ratio                           | Applicable to air/fuel conventional furnaces.<br>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:<br>— Air staging<br>— Fuel staging | Fuel staging is applicable to most conventional air/fuel furnaces.<br>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 <sub>x</sub> burners                           | The technique is generally applicable.<br>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.<br>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).<br>Not applicable for productions requiring large pull variations.<br>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                                                                                                                                                                                                                                                       |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 47

BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the mineral wool sector

| Parameter                                    | Product    | Melting technique               | BAT-AEL            |                                      |
|----------------------------------------------|------------|---------------------------------|--------------------|--------------------------------------|
|                                              |            |                                 | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Glass wool | Fuel/air and electric furnaces  | < 200 – 500        | < 0,4 – 1,0                          |
|                                              |            | Oxy-fuel melting <sup>(2)</sup> | Not applicable     | < 0,5                                |
|                                              | Stone wool | All types of furnaces           | < 400 – 500        | < 1,0 – 1,25                         |

<sup>(1)</sup> The conversion factors of  $2 \times 10^{-3}$  for glass wool and  $2,5 \times 10^{-3}$  for stone wool have been used (see Table 2).

<sup>(2)</sup> 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<sub>x</sub> emissions by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                                                                                                                                                                 | Applicability                                                                                                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Minimising the use of nitrates in the batch formulation<br>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.<br>The implementation of electric melting requires a complete furnace rebuild                                      |
| (iii) Oxy-fuel melting                                                                                                                                                                                                                                   | The technique is generally applicable.<br>The maximum environmental benefits are achieved for applications made at the time of a complete furnace rebuild |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.2.

Table 48

**BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in glass wool production when nitrates are used in the batch formulation**

| Parameter                                    | BAT                                                                                      | BAT-AEL            |                                      |
|----------------------------------------------|------------------------------------------------------------------------------------------|--------------------|--------------------------------------|
|                                              |                                                                                          | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Minimisation of nitrate input in the batch formulation, combined with primary techniques | < 500 – 700        | < 1,0 – 1,4 <sup>(2)</sup>           |

<sup>(1)</sup> The conversion factor of  $2 \times 10^{-3}$  has been used (see Table 2).

<sup>(2)</sup> The lower levels of the ranges are associated with the application of oxy-fuel melting.

**1.7.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces**

59. BAT is to reduce SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                 | 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.<br><br>In the stone wool production, the optimisation of the sulphur balance may require a trade-off approach between the removal of SO <sub>x</sub> 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

<sup>(1)</sup> A description of the techniques is given in Sections 1.10.3 and 1.10.6.

Table 49

**BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the mineral wool sector**

| Parameter                                    | Product/conditions                                                       | BAT-AEL            |                                      |
|----------------------------------------------|--------------------------------------------------------------------------|--------------------|--------------------------------------|
|                                              |                                                                          | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | <b>Glass wool</b>                                                        |                    |                                      |
|                                              | Gas-fired and electric furnaces <sup>(2)</sup>                           | < 50 – 150         | < 0,1 – 0,3                          |
|                                              | <b>Stone wool</b>                                                        |                    |                                      |
|                                              | Gas-fired and electric furnaces                                          | < 350              | < 0,9                                |
|                                              | Cupola furnaces, no briquettes or slag recycling <sup>(3)</sup>          | < 400              | < 1,0                                |
|                                              | Cupola furnaces, with cement briquettes or slag recycling <sup>(4)</sup> | < 1 400            | < 3,5                                |

<sup>(1)</sup> The conversion factors of  $2 \times 10^{-3}$  for glass wool and  $2,5 \times 10^{-3}$  for stone wool have been used (see Table 2).

<sup>(2)</sup> 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.

<sup>(3)</sup> The BAT-AEL is associated with conditions where the reduction of SO<sub>x</sub> emissions has a high priority over a lower production of solid waste.

<sup>(4)</sup> When reduction of waste has a high priority over SO<sub>x</sub> 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 <sup>(1)</sup>                                                                             | 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)                    |

<sup>(1)</sup> 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/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| 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 <sup>(2)</sup>       |

<sup>(1)</sup> The conversion factors of  $2 \times 10^{-3}$  for glass wool and  $2,5 \times 10^{-3}$  for stone wool have been used (see Table 2).

<sup>(2)</sup> The conversion factors of  $2 \times 10^{-3}$  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<sub>2</sub>S) from stone wool melting furnaces

61. BAT is to reduce H<sub>2</sub>S emissions from the melting furnace by applying a waste gas incineration system to oxidise hydrogen sulphide to SO<sub>2</sub>

| Technique <sup>(1)</sup>     | Applicability                                                       |
|------------------------------|---------------------------------------------------------------------|
| Waste gas incinerator system | The technique is generally applicable to stone wool cupola furnaces |

<sup>(1)</sup> A description of the technique is given in Section 1.10.9.

Table 51

#### BAT-AELs for H<sub>2</sub>S emissions from the melting furnace in stone wool production

| Parameter                                        | BAT-AEL            |                                      |
|--------------------------------------------------|--------------------|--------------------------------------|
|                                                  | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen sulphide, expressed as H <sub>2</sub> S | < 2                | < 0,005                              |

<sup>(1)</sup> 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 <sup>(1)</sup>                                                              | 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.<br><br>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)                                                                                                                                                                                                                          |

<sup>(1)</sup> 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 <sup>(1)</sup>   |                                      |
|--------------------------------------------------------------------------------------|--------------------------|--------------------------------------|
|                                                                                      | mg/Nm <sup>3</sup>       | kg/tonne melted glass <sup>(2)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 0,2 – 1 <sup>(3)</sup> | < 0,4 – $2,5 \times 10^{-3}$         |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 1 – 2 <sup>(3)</sup>   | < 2 – $5 \times 10^{-3}$             |

<sup>(1)</sup> The ranges refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The conversion factors of  $2 \times 10^{-3}$  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).

<sup>(3)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                     | Applicability                                                                                                                                                                                                                                                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(i) Impact jets and cyclones</p> <p>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</p>         | <p>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).</p> <p>Limited applicability to stone wool processes since it could adversely affect other abatement techniques being used.</p> |
| (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)                                                                                                                             |
| <p>(iv) Stone wool filters</p> <p>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</p> | The applicability is mainly limited to stone wool processes for waste gases from the forming area and/or curing ovens                                                                                                                                                                                                                       |
| (v) Waste gas incineration                                                                                                                                                                                                                                                                                                                   | <p>The technique is generally applicable for the treatment of waste gases from curing ovens, in particular in the stone wool processes.</p> <p>The application to combined waste gases (forming plus curing) is not economically viable because of the high volume, low concentration, low temperature of the waste gases</p>               |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne finished product |
| <b>Forming area – Combined forming and curing emissions-Combined forming, curing and cooling emissions</b> |                    |                           |
| Total particulate matter                                                                                   | < 20 – 50          | —                         |
| Phenol                                                                                                     | < 5 – 10           | —                         |
| Formaldehyde                                                                                               | < 2 – 5            | —                         |
| Ammonia                                                                                                    | 30 – 60            | —                         |

| Parameter                                                  | BAT-AEL            |                           |
|------------------------------------------------------------|--------------------|---------------------------|
|                                                            | mg/Nm <sup>3</sup> | kg/tonne finished product |
| Amines                                                     | < 3                | —                         |
| Total volatile organic compounds expressed as C            | 10 – 30            | —                         |
| <b>Curing oven emissions</b> <sup>(1)</sup> <sup>(2)</sup> |                    |                           |
| 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 <sub>x</sub> , expressed as NO <sub>2</sub>             | < 100 – 200        | < 1                       |

<sup>(1)</sup> 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.

<sup>(2)</sup> 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 <sup>(1)</sup>                               | Applicability                         |
|--------------------------------------------------------|---------------------------------------|
| The filtration system usually consists of a bag filter | The technique is generally applicable |

<sup>(1)</sup> 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 <sup>3</sup>      |
| Dust      | Flue-gas cleaning by filtration systems | < 5 – 20 <sup>(1)</sup> |

<sup>(1)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Applicability                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| <p>(i) Minimising the losses of product by ensuring a good sealing of the production line, where technically applicable.</p> <p>The potential sources of dust and fibre emissions are:</p> <ul style="list-style-type: none"> <li>— fiberisation and collection</li> <li>— mat formation (needling)</li> <li>— lubricant burn-off</li> <li>— cutting, trimming and packaging of the finished product</li> </ul> <p>A good construction, sealing and maintenance of the downstream processing systems are essential for minimising the losses of product into the air</p> | The techniques are generally applicable |
| <p>(ii) Cutting, trimming and packaging under vacuum, by applying an efficient extraction system in conjunction with a fabric filter.</p> <p>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</p>                                                                                                                                                                                                                             |                                         |
| <p>(iii) Applying a fabric filter system <sup>(1)</sup></p> <p>Waste gases from downstream operations (e.g. fiberising, mat formation, lubricant burn-off) are conveyed to a treatment system consisting of a bag filter</p>                                                                                                                                                                                                                                                                                                                                             |                                         |

<sup>(1)</sup> 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 <sup>3</sup> |
| Dust <sup>(1)</sup> | 1 – 5              |

<sup>(1)</sup> 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<sub>x</sub>) from melting and downstream processes**

66. BAT is to reduce NO<sub>x</sub> emissions from the lubricant burn-off oven by applying combustion control and/or modifications

| Technique                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Applicability                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| <p>Combustion control and/or modifications</p> <p>Techniques to reduce the formation of thermal NO<sub>x</sub> emissions include a control of the main combustion parameters:</p> <ul style="list-style-type: none"> <li>— air/fuel ratio (oxygen content in the reaction zone)</li> <li>— flame temperature</li> <li>— residence time in the high temperature zone.</li> </ul> <p>A good combustion control consists of generating those conditions which are least favourable for NO<sub>x</sub> formation</p> | The technique is generally applicable |

Table 56

**BAT-AELs for NO<sub>x</sub> from the lubricant burn-off oven in the HTIW sector**

| Parameter                                    | BAT                                     | BAT-AEL            |
|----------------------------------------------|-----------------------------------------|--------------------|
|                                              |                                         | mg/Nm <sup>3</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Combustion control and/or modifications | 100 – 200          |

1.8.3. Sulphur oxides (SO<sub>x</sub>) from melting and downstream processes

67. BAT is to reduce SO<sub>x</sub> emissions from the melting furnaces and downstream processes by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                               | 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 |

<sup>(1)</sup> A description of the technique is given in Section 1.10.3.

Table 57

**BAT-AELs for SO<sub>x</sub> emissions from the melting furnaces and downstream processes in the HTIW sector**

| Parameter                                    | BAT                | BAT-AEL            |
|----------------------------------------------|--------------------|--------------------|
|                                              |                    | mg/Nm <sup>3</sup> |
| SO <sub>x</sub> expressed as SO <sub>2</sub> | 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 <sup>(1)</sup>                                                                         | Applicability                         |
|--------------------------------------------------------------------------------------------------|---------------------------------------|
| Selection of raw materials for the batch formulation with a low content of chlorine and fluorine | The technique is generally applicable |

<sup>(1)</sup> 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 <sup>3</sup> |
| 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 <sup>(1)</sup>                                                              | Applicability                           |
|---------------------------------------------------------------------------------------|-----------------------------------------|
| (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                                                     |                                         |

<sup>(1)</sup> 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 <sup>(1)</sup> |
|--------------------------------------------------------------------------------------|------------------------|
|                                                                                      | mg/Nm <sup>3</sup>     |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 1                    |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 5                    |

<sup>(1)</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                          | Applicability                                                                                                                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| (i) Combustion control, including monitoring the associated emissions of CO.<br><br>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                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                |
| (iii) Wet scrubbers                                                                                                                                                                                                                                                                                                                                                                                                                               | The economic viability may limit the applicability of these techniques because of low waste gas volumes and VOC concentrations |

<sup>(1)</sup> 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 <sup>3</sup> |
| 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 <sup>(1)</sup>                                    | Applicability                         |
|-------------------------------------------------------------|---------------------------------------|
| Filtration system: electrostatic precipitator or bag filter | The technique is generally applicable |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Dust      | < 10 – 20          | < 0,05 – 0,15                        |

<sup>(1)</sup> The conversion factors of  $5 \times 10^{-3}$  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<sub>x</sub>) from melting furnaces

72. BAT is to reduce NO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                                                                                                                                                                                  | Applicability                                                                                                                                                                                               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Minimising the use of nitrates in the batch formulation<br>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<br>The technique consists of preventing the ingress of air into the furnace by sealing the burner blocks, the batch material feeder and any other opening of the melting furnace | The technique is generally applicable                                                                                                                                                                       |
| (iii) Combustion modifications                                                                                                                                                                                                            |                                                                                                                                                                                                             |
| (a) Reduction of air/fuel ratio                                                                                                                                                                                                           | Applicable to air/fuel conventional furnaces.<br>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:<br>— Air staging<br>— Fuel staging                                                                                                                                                                                 | Fuel staging is applicable to most conventional air/fuel furnaces.<br>Air staging has very limited applicability due to its technical complexity                                                            |

| Technique <sup>(1)</sup>        | Applicability                                                                                                                                                               |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (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 <sub>x</sub> burners | The technique is generally applicable.<br>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                                                                  |

<sup>(1)</sup> A description of the technique is given in Section 1.10.2.

Table 62

#### BAT-AELs for NO<sub>x</sub> emissions from the melting furnace in the frits glass sector

| Parameter                                    | BAT                | Operating conditions                                                | BAT-AEL <sup>(1)</sup> |                                      |
|----------------------------------------------|--------------------|---------------------------------------------------------------------|------------------------|--------------------------------------|
|                                              |                    |                                                                     | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| NO <sub>x</sub> expressed as NO <sub>2</sub> | Primary techniques | Oxy-fuel firing, without nitrates <sup>(3)</sup>                    | Not applicable         | < 2,5 – 5                            |
|                                              |                    | 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                                 |

<sup>(1)</sup> 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.

<sup>(2)</sup> The conversion factors of  $5 \times 10^{-3}$  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).

<sup>(3)</sup> The achievable levels depend on the quality of the natural gas and oxygen available (nitrogen content).

#### 1.9.3. Sulphur oxides (SO<sub>x</sub>) from melting furnaces

73. BAT is to control SO<sub>x</sub> emissions from the melting furnace by using one or a combination of the following techniques:

| Technique <sup>(1)</sup>                                                               | 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 |

<sup>(1)</sup> A description of the techniques is given in Section 1.10.3.

Table 63

**BAT-AELs for SO<sub>x</sub> emissions from the melting furnace in the frits sector**

| Parameter                                      | BAT-AEL            |                                      |
|------------------------------------------------|--------------------|--------------------------------------|
|                                                | mg/Nm <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| SO <sub>x</sub> , expressed as SO <sub>2</sub> | < 50 – 200         | < 0,25 – 1,5                         |

<sup>(1)</sup> The conversion factors of  $5 \times 10^{-3}$  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 <sup>(1)</sup>                                                                                                                                                                                                                              | 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<br><br>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                                                                                               |

<sup>(1)</sup> 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 <sup>3</sup> | kg/tonne melted glass <sup>(1)</sup> |
| Hydrogen chloride, expressed as HCl | < 10               | < 0,05                               |
| Hydrogen fluoride, expressed as HF  | < 5                | < 0,03                               |

<sup>(1)</sup> The conversion factor of  $5 \times 10^{-3}$  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 <sup>(1)</sup>                                                              | 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 |

| Technique <sup>(1)</sup>                                                                                                                                        | Applicability                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| (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                                                                                        |                                         |

(<sup>1</sup>) 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 <sup>(1)</sup> |                                      |
|--------------------------------------------------------------------------------------|------------------------|--------------------------------------|
|                                                                                      | mg/Nm <sup>3</sup>     | kg/tonne melted glass <sup>(2)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 1                    | < 7,5 × 10 <sup>-3</sup>             |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 5                    | < 37 × 10 <sup>-3</sup>              |

<sup>(1)</sup> The levels refer to the sum of metals present in the flue-gases in both solid and gaseous phases.

<sup>(2)</sup> The conversion factor of 7,5 × 10<sup>-3</sup> 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 <sup>(1)</sup>                                                                                                                                                                                                                                                                            | Applicability                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|
| (i) Applying wet milling techniques<br>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<br>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 |                                         |
| (iii) Applying a filtration system                                                                                                                                                                                                                                                                  |                                         |

<sup>(1)</sup> 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 <sup>3</sup> |
| Dust                                                                                 | 5 – 10             |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> )                                            | < 1 <sup>(1)</sup> |
| Σ (As, Co, Ni, Cd, Se, Cr <sub>VI</sub> , Sb, Pb, Cr <sub>III</sub> , Cu, Mn, V, Sn) | < 5 <sup>(1)</sup> |

<sup>(1)</sup> 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                                                         | <p>Bag filters are constructed from porous woven or felted fabric through which gases are flowed to remove particles.</p> <p>The use of a bag filter requires a fabric material selection adequate to the characteristics of the waste gases and the maximum operating temperature</p>                                                                                     |
| 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                                                   | <p>The technique consists of a melting furnace where the energy is provided by resistive heating.</p> <p>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 consequent, significant reduction of the volatilisation of batch components (i.e. lead compounds)</p> |

1.10.2. *NO<sub>x</sub> emissions*

| Technique                               | Description                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Combustion modifications</b>         |                                                                                                                                                                                                                                                                                                                                                                                               |
| (i) Reduction of air/fuel ratio         | <p>The technique is mainly based on the following features:</p> <ul style="list-style-type: none"> <li>— minimisation of air leakages into the furnace</li> <li>— careful control of air used for combustion</li> <li>— modified design of the furnace combustion chamber</li> </ul>                                                                                                          |
| (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                 | <ul style="list-style-type: none"> <li>— Air staging – involves substoichiometric firing and the addition of the remaining air or oxygen into the furnace to complete combustion.</li> <li>— 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</li> </ul> |
| (iv) Flue-gas recirculation             | <p>Implies the reinjection of waste gas from the furnace into the flame to reduce the oxygen content and therefore the temperature of the flame.</p> <p>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</p>                                               |
| (v) Low-NO <sub>x</sub> 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                                                                                                                      |

| Technique                                               | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (vi) Fuel choice                                        | In general, oil-fired furnaces show lower NO <sub>x</sub> emissions than gas-fired furnaces due to better thermal emissivity and lower flame temperatures                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Special furnace design                                  | <p>Recuperative type furnace that integrates various features, allowing for lower flame temperatures. The main features are:</p> <ul style="list-style-type: none"> <li>— specific type of burners (number and positioning)</li> <li>— modified geometry of the furnace (height and size)</li> <li>— 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</li> </ul>                                                                                                                                                                                                                                           |
| Electric melting                                        | <p>The technique consists of a melting furnace where the energy is provided by resistive heating. The main features are:</p> <ul style="list-style-type: none"> <li>— electrodes are generally inserted at the bottom of the furnace (cold-top)</li> <li>— 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</li> </ul>                                                                                                                                                                                                                                                                                                          |
| Oxy-fuel melting                                        | The technique involves the replacement of the combustion air with oxygen (> 90 % purity), with consequent elimination/reduction of thermal NO <sub>x</sub> 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 <sub>2</sub> 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 <sub>x</sub> to N <sub>2</sub> 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)                     | <p>The technique is based on the reduction of NO<sub>x</sub> to nitrogen in a catalytic bed by reaction with ammonia (in general aqueous solution) at an optimum operating temperature of around 300 – 450 °C.</p> <p>One or two layers of catalyst may be applied. A higher NO<sub>x</sub> reduction is achieved with the use of higher amounts of catalyst (two layers)</p>                                                                                                                                                                                                                                                                                                                                                                                          |
| Selective non-catalytic reduction (SNCR)                | <p>The technique is based on the reduction of NO<sub>x</sub> to nitrogen by reaction with ammonia or urea at a high temperature.</p> <p>The operating temperature window must be maintained between 900 and 1 050 °C</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Minimising the use of nitrates in the batch formulation | <p>The minimisation of nitrates is used to reduce NO<sub>x</sub> 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:</p> <ul style="list-style-type: none"> <li>— Reduce the presence of nitrates in the batch formulation to the minimum commensurate with the product and melting requirements.</li> <li>— Substitute nitrates with alternative materials. Effective alternatives are sulphates, arsenic oxides, cerium oxide.</li> <li>— Apply process modifications (e.g. special oxidising combustion conditions)</li> </ul> |

1.10.3. SO<sub>x</sub> 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 <sub>x</sub> emissions deriving from the decomposition of sulphur-containing raw materials (in general, sulphates) used as fining agents.<br><br>The effective reduction of SO <sub>x</sub> 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 <sub>x</sub> emissions deriving from the oxidation of sulphur contained in the fuel during combustion                                                                                                                                                                                                                                                                      |

## 1.10.4. HCl, HF emissions

| Technique                                                                                                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| 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                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| 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: <ul style="list-style-type: none"> <li>— minimising the quantity of metal compounds in the batch formulation (e.g. iron, chromium, cobalt, copper, manganese compounds) in the production of coloured glasses</li> <li>— minimising the quantity of selenium compounds and cerium oxide used as decolourising agents for the production of clear glass</li> </ul> |

| Technique                                                                                                            | Description                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| Minimising the use of selenium compounds in the batch formulation, through a suitable selection of the raw materials | <p>The minimisation of selenium emissions from the melting process may be achieved by:</p> <ul style="list-style-type: none"> <li>— minimising/reducing the quantity of selenium in the batch formulation to the minimum commensurate with the product requirements</li> <li>— selecting selenium raw materials with a lower volatility, in order to reduce the volatilisation phenomena during the melting process</li> </ul> |
| 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<sub>x</sub>, 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| Wet scrubbing                  | <p>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.</p> <p>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.</p> <p>In the mineral wool and continuous filament glass fibre sector, the most common systems applied are:</p> <ul style="list-style-type: none"> <li>— packed bed scrubbers with impact jets upstream</li> <li>— venturi scrubbers</li> </ul> |
| 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 |

| Technique                                                                                       | Description                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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<sub>2</sub>S, VOC emissions

|                        |                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Waste gas incineration | <p>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.</p> <p>Volatile organic compounds are thermally incinerated with consequent oxidation to carbon dioxide, water and other combustion products (e.g. NO<sub>x</sub>, SO<sub>x</sub>)</p> |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|