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Guidelines for Air Emission Regulation

Limitation of air pollution from installations

Miljøstyrelsen
Miljøministeriet

The Guidelines for Air Emission Regulation

Limitation of air pollution from installations

- These Guidelines include:
- The BAT principle
- Application of BAT
- Mass-flow limits
- Emission limit values
- Calculation of outlet height using the OML model
- Drawing up terms and inspection rules
- Methods of sampling and analysis
- Emission limit values for energy plants
- Requirements for the design of tanks and silos
- Recommended emission limit values etc. for thermal and catalytic oxidation installations for the destruction of organic solvents

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Foreword

In 1990 the Danish Environmental Protection Agency issued Guidelines No. 6/1990 on the limitation of air pollution from installations (published in English as Vejledning fra Miljøstyrelsen 9/1992: "Industrial Air Pollution Control Guidelines). The guidelines were based on observation of the various harmful effects of air pollution over many years as it became apparent that it was not sufficient simply to dilute substances harmful to the environment in the atmosphere.

The 1990 guidelines have subsequently been applied in the administration of the Environmental Protection Act through environment approvals and orders. The central terms are mass flow limits, emission limit values, and contribution values (C-values). Mass-flow values and emission limit values form the basis for determining whether it is necessary to clean the air emitted. Limit values for emissions stipulate maximum concentrations after purification or abatement. The C-value is a limit value for how much each installation may contribute to air pollution.

In view of the amendment to the approval scheme implementing Council Directive 96/61/EC on Integrated Pollution Prevention and Control (the IPPC Directive) into Danish legislation[1], the Danish EPA has found it appropriate to revise and clarify these guidelines.

The most important amendments are:

1. Limit values have been simplified so as to facilitate the processing of applications etc. For example, a number of emission limit values were listed as intervals in the previous guidelines. These intervals have now been changed to single values.
2. The definition of thinner mixes in the old guidelines led to slow processing of applications, and therefore the definition has been improved.
3. The terms in Chapter 3 (on recommended limit values) have been clarified, making the guidelines easier to use.
4. The 1990 guidelines contained an outlet-height calculation method which was applied to substances having the same effect. This method is correct when substances are emitted from the ***same outlet***, but it is unnecessarily restrictive when emissions are from ***several different outlets*** varying in height, or at some distance from each other. Chapter 4 therefore contains a new and improved method of calculation.
5. Chapter 5, which deals with terms in the approvals and check rules, has been made more accessible and thus easier to use. There are now check rules for when and how measurements should be made.
6. Chapter 5 on terms in the approvals and check rules has been supplemented by Chapter 8 on measuring emissions from air-polluting installations, including lists of methods describing methods for sampling and analysis.

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[1] See Act No. 369 of 2 June 1999, Amending the Environmental Protection Act and Statutory Order No. 646 of 29 June 2001 on approbation of Listed Activities.

7. In order to facilitate administration, the Danish EPA has prepared Chapter 6 on energy plants, stipulating guidelines for limit values for each type of energy plant. Today, for example, there are emission limit values of NO_x for almost all types of energy plants.
8. A new section on emissions from tanks and silos has been included in Chapter 7 and a section on thermal and catalytic oxidation installations has been included in Chapter 10.
9. The Danish EPA has stipulated new recommended emission limit values for PAH substances and lower emission values for dioxins and general dust, amongst other substances.
10. Examples of terms with emission limit values, outlet heights, and inspection requirements and rules have been included in the last part of Chapter 5. The objective of including these examples is to facilitate the processing of applications, etc.
11. Examples have been included to illustrate various problems with a view to facilitating the use of the guidelines.

Please note that these guidelines do not include many C-values, and that those included are only examples. In future, C-values will be published in a separate set of guidelines on C-values from the Danish EPA. The Danish EPA expects to revise these guidelines every two or three years.

The guidelines are not binding but are intended to offer advice to the authorities on how to process cases concerning the limitation of air pollution. The authorities should always base their actions on the guidelines when placing demands on emissions of substances from an installation.

In addition to these guidelines, the following guidelines also deal with air pollution (unfortunately they are not available in English):

- guidelines on limiting odour nuisance from installations[2],
- guidelines for the surface treatment of ships[3] ,
- guidelines for the seeds and fertilisers sector[4],
- guidelines for limiting pollution from combustion plants[5], and
- guidelines for limiting air pollution from installations emitting welding smoke[6].

All these guidelines still apply.

The odour guidelines regulate odour emissions from installations emitting mixtures of odorous substances where it is not possible to state the concentration in weight units of each substance.

The Danish EPA hopes that these guidelines will provide a clearer and more informative tool for preparing terms and reassessments of environmental approvals and for issuing orders.

These guidelines replace guidelines No. 6/1990 on limiting air pollution from installations.

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[2] The Danish EPA Guidelines No. 4/1985. Limiting odour nuisances from installations. A revision is planned for 2001-2002.
[3] The Danish EPA Guidelines No. 3/1991. Surface treatment of ships.
[4] The Danish EPA Guidelines No. 4/1991. Guidelines for the seeds and fertilisers sector.
[5] The Danish EPA Guidelines No. 2/1993. Limiting pollution from combustion plants.
[6] The Danish EPA Guidelines No. 13/1997. Limiting air pollution from installations that emit welding smoke.

1 The general principles of the Environmental Protection Act

1.1 Introduction to the BAT principle

The Environmental Protection Act[7] is based on the basic principle that the total pollution of the environment should be prevented or limited as far as possible. On the basis of this integrated idea, overall assessment of pollution from an installation is carried out, including air, wastewater and noise pollution. In addition, assessments should take account of the waste created by the installation, and the need to reduce consumption of natural resources and energy. The idea is that environmental problems should not be solved by transferring pollution from the air to water or soil, or vice-versa.

On the basis of this principle, the Environmental Protection Act requires the individual installation to apply the best available techniques (BAT) so that its total pollution becomes as little as possible.

Assessment of the best available techniques should primarily emphasise preventing pollution through the use of cleaner technology. In addition to this, unavoidable pollution should be limited as far as possible through pollution-reducing measures, including the best possible abatement technique.

These principles appear in Part 1 of the Environmental Protection Act and they provide the basis for decisions by the authorities under the Act.

1.2 What are the Best Available Techniques (BAT)?

The expression ”best available techniques” means the most advanced activities, processes, and operating methods, and the methods most effective in preventing or limiting pollution from a given sector at the time of assessment.

When installations and authorities decide what the best available techniques are for a specific sector, they do not just think of “technology” in the narrow sense of the word, but also

- how the installation is constructed, maintained, operated, and eventually shut down,
- up-to-date methods of production,
- possibilities for substituting dangerous substances with less dangerous substances,
- technologies that create the least possible waste,
- recycling and recovery,
- exploitation of raw materials, and
- energy efficiency.

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[7] See Section 3 (1) of the Environmental Protection Act.

The technique should have been tested – in Denmark or abroad – at a level appropriate for the relevant sector. Furthermore, there is a requirement that the technique should be technically and financially feasible for the relevant sector.

1.3 Where can you find information on BAT?

The best available techniques are under constant development. This is the whole philosophy behind the concept. When investigating the possibilities for using BAT, considerations should be based on material published by the Danish Environmental Protection Agency.

This may be
- sector-specific statutory orders
- sector guidelines
- sector-specific information documents.

The Danish Environmental Protection Agency has prepared sector-information documents (in Danish) for a number of sectors[8], which take as their point of departure the pollution problems of specific sectors, as well as the opportunities for using cleaner technology at installations and for authorities in processing applications under Part 5 of the Environmental Protection Act. The Danish EPA in association with the sector has determined the form and content of the individual sector-specific information documents.

A sector information document will typically contain a general description of the sector and its pollution situation, as well as a review of the technology and methods available to reduce pollution. In some cases the sector information document will contain actual recommendations according to agreements with the sector.

For some sectors, final sector guidelines[9] (in Danish) have been prepared. These are systematic reviews of the entire sector stating limit values, etc. which should form the basis for how the authorities process specific installations within the sector.

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[8] Orientering fra Miljøstyrelsen nr. 3/1993. Brancheorientering for varmforzinkningsindustrien (hot-galvanizing sector).
Orientering fra Miljøstyrelsen nr. 5/1993. Brancheorientering for autoophugningsbranchen (car breakers).
Orientering fra Miljøstyrelsen nr. 6/1993. Brancheorientering for galvanoindustrien (galvano sector).
Orientering fra Miljøstyrelsen nr. 4/1995. Brancheorientering for asfaltindustrien (asphalt sector).
Orientering fra Miljøstyrelsen nr. 6/1995. Brancheorientering for jern- og metalgenvindings virksomheder (iron and metal recovery sector).
Orientering fra Miljøstyrelsen nr. 5/1996. Brancheorientering for lak- og farve industrien (enamel and paint sector).
Orientering fra Miljøstyrelsen nr. 13/2000. Brancheorientering for autoværksteder (vehicle repair shops).

[9] Vejledning fra Miljøstyrelsen nr. 3/1991. Overfladebehandling af skibe (surface treatment of ships).
Vejledning fra Miljøstyrelsen nr. 4/1991. Retningslinjer for grovvarebranchen (seeds and fertilsers sector).
Vejledning fra Miljøstyrelsen nr. 2/1993 om begrænsning af forurening fra forbrændingsanlæg (limiting pollution from incineration plants).
Vejledning fra Miljøstyrelsen nr. 1/1995 om skydebaner (shooting ranges).

The Danish EPA has also issued a reference list[10] (in Danish) which includes information about reports on cleaner technology that can supplement the material mentioned above.

The European Commission regularly issues ”BAT reference documents” for installations marked with an (i)[11] in the list of installations requiring an approval to operate. These documents are referred to as “BREFs” below and contain

- general information about the sector,
- general information about the industrial processes in the relevant sector,
- data and information about current emission and consumption levels for the relevant sector, obtained from existing installations,
- the most obvious measures to limit emissions, including the consumption and emission levels which can be obtained through applying these measures,
- the costs of these measures,
- cross-media considerations,
- assessment of the applicability of the measures to new and old, as well as large and small installations,
- an assessment of the techniques and consumption and emission levels (BAT emission levels) which can generally be considered as BAT so as to provide a reference level to help determine BAT at the individual installation.

It is important to emphasise that the BREFs do not contain emission limit values, but only emission levels. The Danish EPA will issue information on a regular basis about the application of BREFs by the approving authorities. This information should be the basis for approving and supervisory authorities when laying down requirements for reductions on air pollution from installations marked with an (i). The sections in these Guidelines for Air Emission Regulation on outlet heights, terms for self-inspection, etc. would, however, always apply, even for this type of installation.

Full versions of the BREFs are published on the European IPPC Bureau website at

http://eippcb.jrc.es/

A short extract (executive summary) is published by the European Commission on its website section regarding the IPPC Directive.

http://europa.eu.int/comm/environment/ippc/index.htm

A total of 32 BREFs are planned up to 2003. At the end of 2000, the following eight BREFs were available:

- Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries,

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[10] Orientering fra Miljøstyrelsen nr. 8/2000. Referencer til renere teknologivurderinger ved miljøgodkendelser (References to cleaner technology assessments for environmental approvals).

[11] I.e. installations covered by the IPPC Directive and therefore marked with an (i) on the list in Annex 1 of Statutory Order No. 646/2001. In addition, items J 1, K 1d and K 2e, which are not covered by the IPPC Directive have been marked for this procedure.

- Reference Document on Best Available Techniques on the Production of Iron and Steel,
- Reference Document on Best Available Techniques in the Non Ferrous Metals Industries,
- Reference Document on Best Available Techniques in the Pulp and Paper Industry,
- Reference Document on Best Available Techniques in the Glass Manufacturing Industry,
- Reference Document on Best Available Techniques in the Ferrous Metals Processing Industry,
- Reference Document on Best Available Techniques in the Chloro-Alkali Manufacturing Industries,
- Reference Document on Best Available Techniques to Industrial Cooling Systems.

1.4 How to apply the BAT principle when processing a case

The BAT principle should form the basis for all cases under the Environmental Protection Act, i.e. both for issuing approvals and reassessing Listed Installations, and for assessing non-Listed Installations.

When requirements are set for an installation, a specific assessment must be carried out on the basis of the current information on the best available techniques for the relevant sector, taking into account the vulnerability of the surroundings.

As mentioned above, emphasis should primarily be on preventing pollution by using ***cleaner technology***, i.e. first assessments should be of whether:

- the opportunities for efficient use of energy and raw materials have been fully exploited,
- the opportunities for substituting harmful or suspect substances with less harmful or suspect substances have been fully exploited[12],
- the opportunities for optimising production processes have been fully exploited, e.g. by using closed processes or similar[13],
- generation of waste can be avoided or, where this is not possible, whether opportunities for recycling or recirculation have been fully exploited.

After this, the extent of necessary ***purification or abatement measures*** that should be applied may be assessed, such as

- filters,
- scrubbers,
- waste-water treatment,
- thermic combustion,
- precipitation equipment.

Finally, the extent ***other measures*** can contribute to limiting pollution may be assessed, such as

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[12] Examples of substitution: 1.Use of vegetable oils instead of organic solvents to clean printing rollers. 2. Use of water-based ink in mould cores instead of isopropyl-based ink. 3. Use of UV colourings instead of organic solvent colourings at print shops has reduced consumption of organic solvents by approx. 80%.

[13] Example of reorganising operations

An enamel and paint factory reorganised production. Manufacture of paints and enamels is now in a closed system where vapours from organic solvents are returned to the mixing vats. Emissions of organic solvents to the outside air have thus been reduced significantly.

- process monitoring,
- operation journals,
- layout of tank sites,
- requirements for collecting spillage,
- dilution, e.g. stacks or other air outlets, and marine outfalls,
- sound-absorbing barriers.

Requirements put on installations by the environmental authorities for pollution limits on the basis of the BAT principle should not normally be set as requirements to use a specific technology, but rather as requirements corresponding to a pollution level which can be achieved only by applying the best available techniques. In principle the installation can decide how requirements are to be met. However, this does not exclude the possibility of setting up very specific requirements for layout and operation when the goal cannot be expressed by limit values.

1.4.1 Approvals for new Listed Installations

When the authority issues an approval to a new installation, the authority should ensure that the installation is laid out and operated in accordance with what is considered best available techniques for the relevant type of installation. This means that, as a principle, new installations cannot use the excuse that the required technology is too expensive for the individual installation. The issue of cost has already been taken into account by deciding what the best available techniques are for the entire sector.

Furthermore, an independent assessment should be carried out of whether the establishment of an installation at a specific site is consistent with the vulnerability of the surroundings. The approving authority can therefore impose particularly stringent requirements when necessary to comply with any environmental quality norms[14] for the area. If it is not possible to comply with these requirements, the application will not be granted.

1.4.2 Reassessment of environmental approvals for existing Listed Installations

Reassessment[15] of existing Listed Installations should aim at the long-term operation of the installation based on what is considered BAT for the relevant type of installation. Realisable and realistic time limits should be given to the installation to carry out new investment and operational changes in order to bring the installation up to modern standards. It may also be relevant to impose new requirements on the installation, if these are necessary to comply with any environmental quality norms.

If there is both a cleaner-technology solution and end-of-line purification technology, both of which lead to the same environmental result, all else being equal, the cleaner technology solution should be selected. If the time horizons are not the same, for example in cases where end-of-line technology is immediately accessible while cleaner technology will take time to implement,

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[14] Examples of environmental quality norms: Statutory Order No. 119 of 12 March 1987 on limit values for the atmospheric content of nitrogen and Statutory Order No. 836 of 10 December 1986 on limit values for the atmospheric content of sulphur dioxide and suspended particulates. See also Statutory Order No. 921 of 8 October 1996 on quality requirements for aquatic areas and requirements on discharges of certain substances into water courses, lakes or the sea.

[15] See section 2.2.3.2.

the type and scope of the pollution may be decisive for whether to wait for the cleaner-technology solution.

1.4.3 Regulation of non-Listed Installations

Non-Listed Installations should also be laid out and operated on the basis of best available techniques. When the authority is to assess pollution from a non-Listed Installation, see Section 42 of the Environmental Protection Act, the point of departure should be the same principles as mentioned above in sections 1.4.1 and 1.4.2.

2 Contents and application of the guidelines

2.1 The contents of the guidelines

The Guidelines for Air Emission Regulation contain a complete description of how air pollution from installations should be regulated.

Central to these regulations is the use of mass flow limits, emission limit values, and contribution values (C-values). The mass flow limit determines whether it is necessary to clean the air emitted from an outlet, and the emission limit values determine the maximum concentration allowed after purification or abatement. These limits are described in ***Chapter 3*** in these Guidelines.

The Danish EPA regularly sets up new contribution values for substances. The most recent information on C-values can be found in Sector Information Document (***Orientering***) No. 15/1996 published by the Danish EPA (in Danish). These C-values are based on the knowledge the Danish EPA possessed about the substances in question at the time of publication.

The Danish EPA will publish a new set of guidelines on C-values in August-September 2001. The Guidelines for Air Emission Regulation only include examples of C-values, and as these can be amended, the Danish EPA's Information Document and new set of guidelines on C-values should always form the basis for using the values.

Chapter 4 includes calculation methods for outlet heights in order to comply with C-values. A computer-based model, the OML model, is used for these calculations.

When requirements for air pollution from an installation have been determined on the basis of Chapters 3 and 4, terms should be stipulated. ***Chapter 5*** deals with designing terms, which type of terms can be applied and how to check compliance with these terms.

With regard to energy plants, the Danish EPA has chosen to prepare a separate chapter, ***Chapter 6***, which includes a more detailed description of requirements for the different types of energy plant.

Furthermore, a special chapter, ***Chapter 7***, has been prepared on requirements for the design and operation of tanks and silos.

Chapter 8 deals with measuring emissions from air-polluting installations. This chapter also establishes methods for sampling and analysis.

Chapter 9 includes conversion tables for surplus air and moisture content.

Chapter 10 on recommended emission limit values and inspection rules includes emission limit values, etc., for thermal and catalytic oxidation installations for the destruction of gaseous organic solvents.

2.2 How to apply the guidelines

The Guidelines for Air Emission Regulation basically apply to all installations emitting substances to the air.

However, if emission limit values for a certain type of plant, installation or sector have been determined in a Statutory Order, the limit values stipulated in this Order should be complied with, regardless of whether the Guidelines for Air Emission Regulation contain stricter or more lenient emission limit values of the substance in question. This is because, when it was issued, the Statutory Order took into account the technical and financial possibilities of lowering emissions of the relevant substances for the sector in question.

If sector guidelines have been prepared, they must form the basis of the requirements for the installation in connection with issuing an approval for the installation.

With regard to installations marked with an (i) and included in a BREF[16], the Danish EPA will provide information on which requirements should be imposed on the installations described in the BREF.

Please note that the sections on outlet height, self-inspection, terms, etc., in the Guidelines for Air Emission Regulation are general and apply to all types of installations.

The Guidelines include minimum limits for emissions that require purification or abatement measures in order not to spend resources on limiting, monitoring, and controlling pollution of little significance to the environment.

A few small air outlets which cannot be integrated naturally into the overall discharge from an installation may be exempt from purification or abatement requirements, provided each outlet comprises less than 10 per cent of the mass flow limit for the substance(s) in question.

Diffused emissions, for example emissions from stock kept outdoors are not regulated by the guidelines. Instead, these emissions should be regulated through requirements for the operation and design of the installation.

These Guidelines do not regulate diffused pollution from installations affecting the indoor climate in adjacent residential housing in the same building.

The method of applying these guidelines when handling specific cases in pursuance of the Environmental Protection Act is explained in the following.

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[16] See footnote 11 in section 1.3.

2.2.1 Application for approvals for new Listed Installations

As mentioned in Chapter 1, the approving authority must ensure that the establishment and operation of the installation in question is based on the BAT principle.

This means that the approving authority must first assess the possibility of limiting pollution by using cleaner technology.

Based on the information included in the application on the nature of substances emitted and the volume of these emissions, the approving authority will then assess whether purification or abatement measures should be implemented.

Purification or abatement measures are required if the mass flow limit is exceeded and if the current emission limit values cannot be complied with. In such instances the approval should contain terms including emission limit values and the maximum volume of air.

Mass-flow limits and emission limit values can be found in Chapter 3 of these Guidelines.

Required outlet heights are calculated on the basis of C-values for the substances in question. The calculation method is described in more detail in Chapter 4. C-values should always be complied with under normal operating conditions. Moreover, the approving authority should set up instructions for operation in extraordinary situations, including starting up, closing down, by-pass, etc.

2.2.2 Application for expansion or changes to Listed Installations

If a Listed Installation intends to expand or change its operations in a way that entails increased pollution, the expansion or changes must be approved in advance[17]. The terms of the expansion or change as regards air pollution must be determined in accordance with the same principles as described in the above for approvals for new installations.

In practice, determining the terms of an expansion or change that entails increased air pollution often causes difficulties. In particular, there has been some uncertainty as to whether requirements can only be made for the expansion or changes, or whether air pollution conditions for the entire installation should be included, when stipulating requirements.

Requirements for purification or abatement and outlet heights in connection with typical extensions and changes will be explained in the following. See also the definitions in Chapter 3.1. It is a requirement that all possibilities for introducing cleaner technology have been assessed prior to the extension or change, including whether

- opportunities for efficient use of energy and raw materials have been fully exploited,
- opportunities for substituting harmful or suspect substances with less harmful or suspect substances have been fully exploited,
- opportunities for optimising production processes have been fully exploited, e.g. by using closed processes or similar,

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[17] See Section 33 of the Environmental Protection Act.

- production of waste can be avoided or, where this is not possible, whether opportunities for recycling or recirculation have been fully exploited.

Example 1. A Listed Installation holding an approval wants to change the operation of an existing plant

1. Changes entail increased emission of same substance

- First, determine the mass flow for the substance for the entire installation.
- If the mass flow limit has been exceeded, and if the current emission limit values cannot be complied with, purification or abatement must be rebuilt to include purification or abatement facilities must be implemented so that all outlets can comply with the emission limit values.
- Next, a maximum volume of air for each outlet should be determined.
- Finally, the necessary height of all outlets from the installation is calculated, based on the C-value for the substance[18].

2. Changes entail emissions of a new substance

- First, determine the mass flow for the new substance.
- If the mass flow limit has been exceeded, and if the current emission limit values cannot be complied with, the outlets from the installation not complying with the current emission limit values without purification or abatement must be rebuilt to include purification or abatement facilities.
- Next, a maximum volume of air for each outlet should be determined.
- So as to assess whether the outlet height should be raised, outlet heights should be calculated based on the C-value for the substance.

Note that in some cases where an installation emits a new substance, it may be required that other substances from the same substance group are included in calculation of mass flow and emission concentration

Example 2. A Listed Installation holding an approval wants to expand by adding a new plant with new outlets.

1. Expansion entails increased emissions of the same substance

- First, determine the mass flow of the substance for the entire installation.
- If the mass flow limit has been exceeded, and if the current emission limit values cannot be complied with, the outlets from the installation not complying with the current emission limit values without purification or abatement must be rebuilt to include purification or abatement facilities, and a time limit should be set for this work.
- Next, a maximum volume of air for the new outlet should be determined.
- Finally, the outlet height is calculated for all outlets from the installation based on the C-value of the substance, the emission limit values, and the maximum volume of air.

2. Expansion entails emissions of a new substance

- First, determine mass flow of the new substance.
- If the mass flow limit has been exceeded, and if the current emission limit values for the new substance cannot be complied with, the new outlets not complying with the current emission limit values without purification or abatement, must be rebuilt to include purification or abatement facilities.
- Next, a maximum volume of air for each of the new outlets should be determined.
- Finally, the outlet height is calculated for new outlets from the new plant at the installation based on the new substance's C-value, emission limit values of the new outlet and the corresponding maximum volumes of air.

Note that in some cases where an installation emits a new substance, it is may be required that other substances from the same substance group are included in calculation of mass flow and emission concentration.

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[18] It is not necessary to lay down conditions for compliance with contribution values as outlet calculations ensure compliance with the contribution value when there is compliance with emission limit values.

2.2.3 Regulation of existing Listed Installations

Application of the Guidelines to existing Listed Installations is explained in the following.

2.2.3.1 Listed Installations without an approval

Processing applications for approvals from existing Listed Installations is based on the same principles as processing applications from new installations. Depending on the scope and nature of pollution, a reasonable time limit for the implementation of any requirements for measures limiting pollution should be determined. In some cases a gradual reduction of pollution may be appropriate.

2.2.3.2 Reassessment of Listed Installations with an approval

2.2.3.2.1 Before expiry of the legal protection period

Within the first eight years[19] of issuing an approval, new requirements may only be made to the installations, if[20]

- new information has emerged about the harmful effects of pollution,
- pollution is harmful to the environment in a manner that could not be anticipated at the time of issuing the approval,
- pollution is greater than reported at the time of issuing the approval,
- significant changes to BAT enable considerable reduction of emissions without disproportionately raising costs,
- operation safety in connection with the process or activity requires that other techniques are applied, or
- new information on safety at risk installations[21] has emerged.

The result is that, under certain circumstances, the authorities can serve orders to installations within the first eight years following the issue of an approval.

However, the publication of new guidelines, information on BREFs and sector-specific information documents, as well as stricter C-values do not in themselves give authorities the right to make new requirements within the legal protection period. This also applies to limit values, which have been tightened in these Guidelines compared to previous guidelines.

Please note also that terms for self-inspection in current guidelines can be reassessed at any time with a view to improving self-inspection at the installation, even though the legal protection period[22] has not yet expired.

2.2.3.2.2 After expiry of the legal protection period

Regular reassessment of Listed Installations marked with an (i)

The supervising authority should reassess the entire installation on a regular basis and at least once every ten years. The terms of the approval should be changed as necessary to ensure that the operation of the installation remains based on the BAT principle[23]. The first reassessment should take place when

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[19] For some types of installation, this period has been reduced to 4 years.

[20] See Section 41a (2) of the Environmental Protection Act.

[21] See Statutory Order No. 106 of 1 February, 2000 on monitoring of risks for more serious accidents with dangerous substances.

[22] See Section 72 (2) of the Environmental Protection Act.

[23] See Section 41b of the Environmental Protection Act and Section 17 of the Statutory Order No. 807 of 25 October, 1999 on approvals for listed activities and installations.

the legal protection period for the installation's first approval expires. Note that installations must continue to limit pollution on the basis of developments in technology.

Reassessment of all other Listed Installations that are not marked with an (i)
Even though the Environmental Protection Act does not include an obligation to reassess approvals for Listed Installations not marked with an (i), there is clear authorisation to do so[24] and existing approvals should be reassessed on a regular basis. These installations should also live up to the BAT principle.

2.2.4 Regulation of non-Listed Installations

If an installation not requiring an approval causes significant pollution, the authorities can order it to implement measures to relieve the pollution[25].

The supervising authority should provide evidence that an installation is the cause of such high levels of pollution that measures to relieve pollution must be implemented. Such pollution levels may be:

- if mass flow limits and emission limit values have been exceeded simultaneously, or
- if the C-value has been exceeded considerably, or
- if limitation of emissions for Group 1 substances has not been implemented as stated in Chapter 3.

The supervising authority should collect information from the installation itself regarding

- which substances are emitted from the installation,
- the size of mass flow for each substance/substance group,
- concentration of each relevant substance, and
- whether the installation can comply with the current C-values.

If the mass flow limit is exceeded and if the current emission limit value is not complied with, there should be a requirement that emissions are reduced so as to ensure compliance with the current emission limit value.

If the C-values have been exceeded considerably, there should be requirements that they be complied with before a set date.

If limitation of emissions has not been implemented for Group 1 substances as stated in Chapter 3, requirements should be made for this.

Reasonable and realistic time limits should be set for implementation of possible purification or abatement measures.

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[24] See Section 41b of the Environmental Protection Act.
[25] See Section 42 of the Environmental Protection Act.

3 Recommended mass flow limits, emission limit values, and C-values

3.1 Terms, definitions, and explanations

The following is a description of the various types of limit values used in these Guidelines.

1. **The mass flow limit** is a limit used to determine when an emission must be limited. The mass flow is the measure of air pollution from installations prior to purification or abatement. Where the mass flow is greater than the mass flow limit and where the emission concentration is greater than the emission limit value, purification or abatement should be carried out, or production adjusted to comply with the emission limit value. Note that the mass flow limit is used as a criterion for when it may be relevant to limit emissions from installations. It does not in itself constitute a limit value that must be complied with.
2. **The emission limit value** is a limit value for the concentration of a given substance in the air emitted by installations through an outlet. Measurement is carried out for a period of time for control purposes, and only when the installation is in operation.
3. **The AMS inspection limit** is a limit for when an Automatic Measuring System must be installed, or when random testing must be carried out, as specified in chapter 5.
4. **The C-value**[26] is the total maximum permissible contribution from a single installation of one pollutant to the surrounding air, i.e. the ground-level concentration. The C-value must always be complied with when calculating according to the rules in these Guidelines.

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[26] See the forthcoming guidelines on contribution values (The C-value Guidelines). In Danish, C-values are referred to as “B-værdier” (for “bidragsværdier”)

Detailed explanation

Where the mass flow (prior to purification or abatement) is greater than the recommended mass flow limit, but the emission concentration is smaller than the recommended emission limit value, emissions need not be limited under these Guidelines.

Where the mass flow is less than the recommended mass flow limit, but the emission concentration is greater than the recommended emission limit value, emissions need not be limited under these Guidelines.

Where, for some or all outlets, the emission concentration is greater than the recommended emission limit value, and the mass flow is greater than the recommended mass flow limit, emissions must be limited for those outlets where the emission exceeds the recommended emission limit value.

The AMS inspection limit is a limit that determines when an Automatic Measuring System must be installed. Where automatic monitoring is not feasible, random testing should be carried out.

The AMS inspection limit is specified in Chapter 5.

3.1.1 Mass flow

The mass flow is the substance amount per time unit that would constitute the total emission of a given substance or substance class from an installation if no limitation of emissions were carried out. This means that the mass flow must be determined before the actual purification or abatement plant, but after the processing plant. The mass flow is measured as a mean value on the basis of a single working shift (7 hours).

If a mass flow limit is exceeded and if the emission concentration is greater than the emission limit value, emissions should be limited so that the specified emission limit value is complied with from each outlet.

No requirements regarding limitation of emissions should be made for installations that are only operated for relatively few hours per year, even if such installations exceed the mass flow limit and emission limit value.

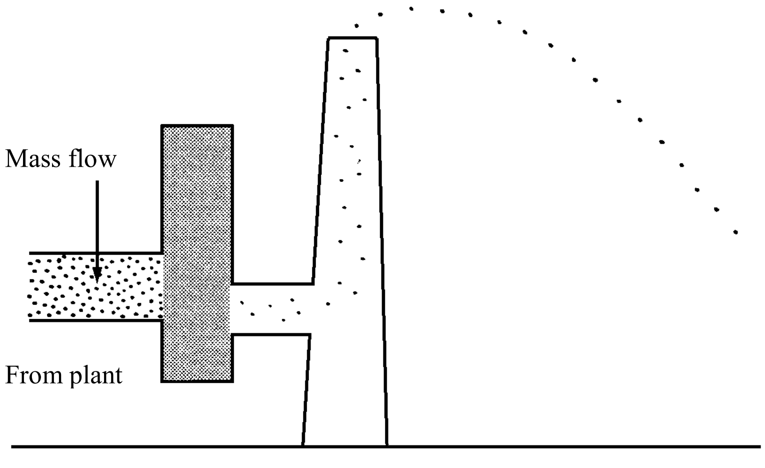

Figure 1 shows how mass flow is determined.

Example of calculation of mass flow

An installation is operated for seven hours per day. The installation emits acetone, which is an organic class III substance.

The operation of the installation varies. During the first two hours, the mass flow is 4 kg/hr, during the next three hours it is 10 kg/hr, and during the final two hours it is 0 kg/hr.

During a period of 7 hours, the mass flow is:

2 hours at 4 kg each = 8 kg
3 hours at 10 kg each = 30 kg
2 hours at 0 kg each = 0 kg
Total mass flow during the 7 hours = 38 kg

This is to say that the average mass flow during a period of 7 hours is 38 kg / 7 hr = 5.4 kg/hr.

3.1.2 Emission and reference condition

Emission means the emission into the atmosphere of polluting substances in solid, fluid, or gaseous form. The limit values also apply to aerosols, which are classified as dust within this context.

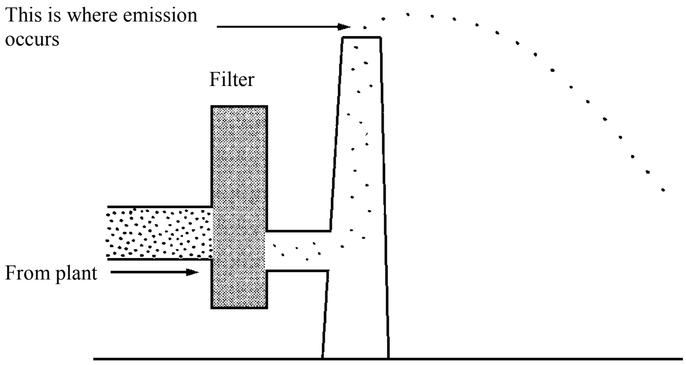

Figure 2 shows where emission to the atmosphere occurs from a single plant with a single outlet. See, however, figure 3.

Examples of other reference conditions

1. The reference condition for brick yards should be the relevant O_2 content at the reference condition (0°C, 101.3 kPa, dry flue gas), up to a maximum O_2 content of 18 per cent.
2. The reference condition for plants incinerating gaseous, organic substances should be the relevant O_2 content at the reference condition (0°C, 101.3 kPa, dry flue gas).
3. The reference condition for asphalt works should be the relevant O_2 content at the reference condition (0°C, 101.3 kPa, dry flue gas), up to a maximum O_2 content of 17 per cent.
4. The reference condition for installations manufacturing expanding clay aggregate, as well as for moler works, should be the relevant O_2 content for the installation in question at the reference condition (0°C, 101.3 kPa, dry flue gas), up to a maximum O_2 content of 16 per cent.
5. The Guidelines for crematoria[27] do not specify whether dry or wet flue gas should be used as a reference condition. As is the case with other combustion processes, dry flue gas should be used for reference purposes.

The reference condition should always be stated in the approval in connection with the emission requirements.

Usually, the polluted air is led from the plant to the stack through a flue duct as shown in Figure 3. The emission limit values apply to the polluted air in the flue duct.

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[27] Danish EPA Guidelines No. 2/1993: Begrænsning af forurening fra forbrændingsanlæg, Part 3, Krav i forbindelse med fastsættelse af vilkår for godkendelse af krematorieanlæg efter miljøbeskyttelsesloven *['Limitation of pollution from combustion plants, Part 3, requirements relating to the setting of conditions for approval of crematoria under the Environmental Protection Act"]*

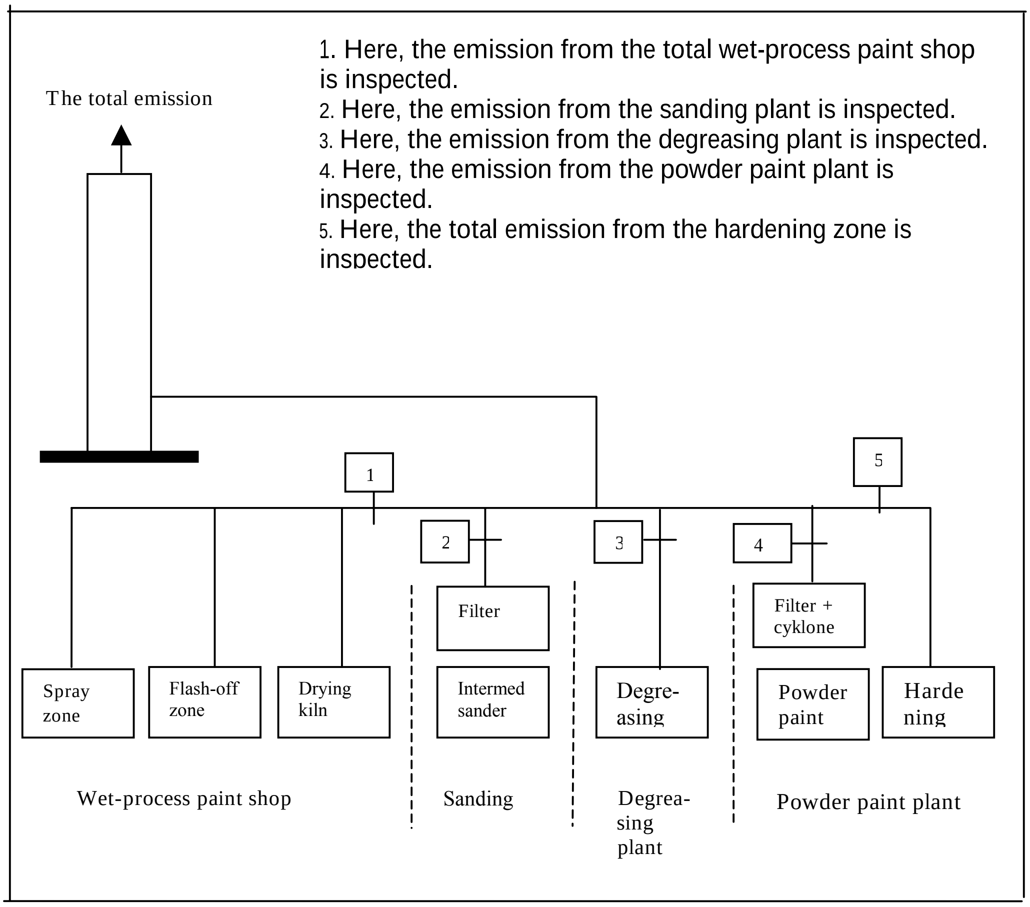

Figure 3 Example of an installation with emissions from different plants, showing where emission inspection is carried out.

Individual installations should not be allowed to comply with the emission limit values by means of ”dilution”, i.e. by using inordinately large quantities or air, e.g. through dilutions using indoor air or outlet air from other processes within the installation.

3.1.3 Ground-level concentration

This means the presence in outdoor air of solid, liquid, or gaseous pollutants – usually at a height of approximately 1.5 m above ground level. Where people live or stay in taller buildings (multi-storey homes, office buildings, factory premises, etc.), the ground-level concentration should be calculated at a height relevant to the building in question.

3.1.4 The C-value

The total maximum approved contribution from an installation to the concentration of a pollutant in the air at ground level is the ”C-value”. The C-value must be complied with everywhere outside the boundaries of the installation, regardless of the quantities emitted and the location of the installation.

The C-value must be compared to the results of an OML-model calculation. Such a calculation should be conducted for any outlet emitting pollutants into the air. The C-value must be complied with when taking the total emission from the installation into account, cf. chapter 4.

In these OML calculations, hourly average concentrations are computed. They may not exceed the C-value for more than 1 per cent of the time, ie. for more than 7 hours during a single month.

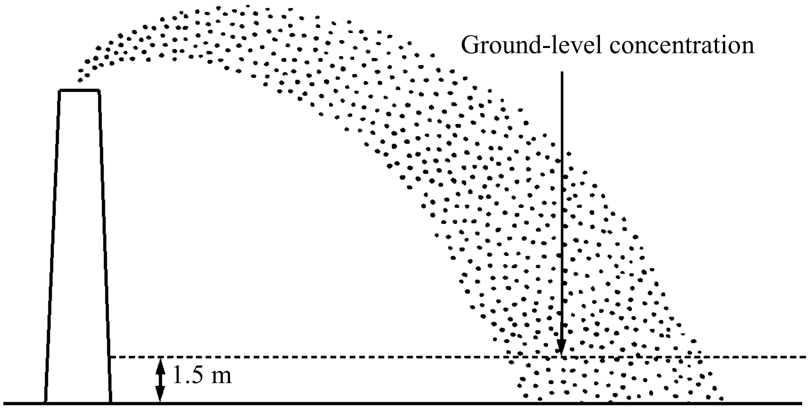

Figure 4 Drawing illustrating a ground-level concentration contribution

The size of the C-value, measured as mg/m^3 air for each substance is determined by the Danish EPA in accordance with procedures and principles for determining limit values for chemical substances.

The C-values apply regardless of the background concentration.

The C-value must not be confused with air quality requirements as specified in section 14 of the Danish Environmental Protection Act or in the method to measure such values. Air quality requirements are currently specified in:

- Statutory Order No. 836 of 10 December 1986 on limit values for the atmospheric content of sulphur dioxide and suspended particulates.
- Statutory Order No. 119 0f 12 March 1987 on limit values for the atmospheric content of nitrogen dioxides.

Also of note in this connection are Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, and European Parliament and Council Directive 2000/69/EC of 16 November 2000 relating to limit values for benzene and carbon monoxide in ambient air. These directives must be implemented in Denmark no later than 19 July 2001 and 13 December 2002, respectively.

The Danish EPA will assist the authorities by determining C-values for substances where no C-value has previously been set. For more information, please contact the Danish EPA.

The C-values stipulated are based upon the Danish EPA’s knowledge of the relevant substances at the time of publication.

The C-values for dust apply only to particles with a diameter of less than 10 µm.
For wood dust, however, the C-value applies to all particle sizes.

3.1.5 Relationship between mass flow limits, emission limit values, and C-values

3.1.5.1 Mass flow limits

The mass flow is a measure of the potential pollution of an installation.

3.1.5.1.1 Mass flow is smaller than the mass flow limit

If the mass flow for the relevant substance is smaller than the mass flow limit, no purification or abatement or adjustments to production in order to reduce emissions must be carried out. The emission should be determined by means of calculations, measurement, or similar. Outlets should be of such a height that the C-value can be complied with.

A dispersion calculation for the outlet, using the OML model[28] is then prepared to determine whether the C-value is complied with. This calculation is carried out with an emission corresponding to the emission limit value at the maximum flow rate. Where no emission limit value has been specified, the maximum hourly emission and the maximum flow rate are used instead. See also section 4.3.

Example where mass flow is smaller than the mass flow limit

An installation emits acetone. Mass flow is set at 5,400 g per hour. Acetone is a Group 2, organic substance, class III substance with a C-value of 0.4 mg/m^3. The emission limit value is 300 mg/normal m^3.

The mass flow limit for installations emitting organic substances belonging to class III is 6,250 g/hr.

As the mass flow is smaller than the mass flow limit, there is no need to carry out any limitation in emissions. No emission limit value is to be set. However, a requirement regarding a maximum emission per hour should be stipulated. The maximum hourly emission must be applied when calculating the dispersion coefficient[29].

The maximum hourly emission is set at 10,000 g/hr, corresponding to 2,778 mg/sec. This means that the dispersion coefficient is 2,778/0.4 = 6,944 m^3/sec.

As the dispersion coefficient is greater than 250 m^3/sec., it is necessary to determine the outlet height by means of a dispersion calculation using the OML model.

3.1.5.1.2 Small emissions

For small emissions where the dispersion coefficient – i.e. the ratio between the emission measured in mg/sec. and the C-value in mg/m^3 – is smaller than 250 m^3/sec., there is no need to carry out a dispersion calculation. In this case, the outlet should be at least 1 m above roof level[30] and the air stream directed upwards in order to ensure compliance with the C-value, see chapter 4 on the calculation of outlet heights.

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[28] See chapter 4.

[29] See Chapter 4, Section 4.3.2

[30] "Above roof level" normally refers to the roof on which the outlet is situated. In special cases, however, account must be taken of tall adjacent buildings, etc., in order to ensure free dilution.

3.1.5.1.3 Mass flow is greater than the mass flow limit

If the mass flow is greater than the mass flow limit for a given substance, the emission limit value must be complied with. This means that where the emission concentration is greater than the emission limit value, purification or abatement should be carried out, or production at the installation should be adjusted to achieve compliance with the emission limit value. The outlet must be established in such a manner and with sufficient height to ensure that the C-value is complied with.

In order to determine whether the C-value is complied with, a dispersion calculation using the OML model must be carried out for the outlet. The emission limit value and maximum flow rate must be used in this calculation.

Example where the mass flow is greater than the mass flow limit

An installation emits acetone. The mass flow is set at 8,200 g/hr. Acetone is a Group 2, organic substance, class III substance with a C-value of 0.4 mg/m^3. The emission limit value is 300 mg/normal m^3, see table 7.

The mass flow limit for installations emitting organic substances belonging to class III is 6,250 g/hr. This means that the mass flow is greater than the mass flow limit. Consequently, steps should be taken to ensure that the 300 mg/normal m^3 emission limit value is complied with.

The maximum emission of acetone measured over an hour is set at 9.0 kg/hr without any emission reduction. The air quantity from the outlet is 9,000 normal m^3/hr. This corresponds to a maximum hourly emission of 9,000,000/9,000 = 1,000 mg/normal m^3. This means that the emission of acetone must be reduced to 300 mg/normal m^3 or less.

The installation chooses to install a condensing plant, where a large proportion of the acetone condenses upon cooling, thus facilitating reuse. The condensing plant is equipped with an active carbon filter, which makes it possible to keep emissions below 300 mg/normal m^3.

On the basis of this information, the environmental authorities set an emission limit value of 300 mg acetone/normal m^3. As the dispersion coefficient, calculated in the same manner as in the previous example, is greater than 250 m^3/sec., the outlet height must be determined on the basis of this emission limit value by means of a dispersion calculation using the OML model. The emission value of 300 mg acetone/normal m^3 forms the basis for these calculations.

An example where mass flow is greater than the AMS limit can be found in chapter 5.

3.1.6 Classification of types of substance

For the purpose of these Guidelines, the pollutants are divided into two groups. These groups are in turn divided into substance groups and classes.

For more detailed information on groups, substance groups, and classes, please see the C-value Guidelines.

Chart illustrating this classification

Group	Substance group	Class
1. Particularly dangerous	(One group only)	I and II
2. Dangerous	1. Dangerous types of inorganic dust	I, II and II
	2. NO_x	
	3. SO_2	
	4. Other vaporous or gaseous inorganic substances	I, II, III, and IV
	5. Organic substances	I, II, and III
	6. Other dust	

3.1.7 Simultaneous emission of several substances. Average value C_r[31]

Where an installation emits several substances at the same time, it is very difficult to assess the total health impact associated with exposure to the substances in question. In principle, a combination of substances in a mixture may affect each other's mode of operation and effects in the following three ways:

1. the effects and mode of operation are independent of each other,
2. the substances mutually affect each other's effects, either reinforcing or weakening each other,
3. the substances have identical effects and mode of operation.

Re. 1.
Where the substances act independently of each other, the C-values for each substance must be complied with separately. The outlet height must be determined on the basis of the substance with the greatest dispersion coefficient.

Re. 2.
If the substances affect each other's effects and mode of operation, there is a risk that in certain mixtures, such substances may augment each other's effects. However, animal tests indicate that such effects do not manifest themselves unless each substance is present in a concentration which would in itself entail effects, i.e. when a substance is present in a concentrations greater than its zero-effect concentration.

In this connection, a C-value for an individual substance will typically be determined on the basis of data concerning the zero-effect concentration (animal or human test). The C-value will be set at a level equal to or lower than this zero-effect level, so that no effects are anticipated at the C-value. Compliance with the individual C-values of such substances is thus assumed to ensure that there will be no interaction between the substances, including reinforcing effects. Accordingly, the outlet height must be determined on the basis of the substance with the largest dispersion coefficient.

Re. 3.
Where the substances have identical effects and mode of operation, this constitutes a valid reason to total the exposure contributions for the relevant substances.

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[31] In the Danish version of this guideline, the symbol B_r is used for C_r.

In practice, C-values for substances with identical effects should be added up when:

- such substances are homologous (i.e. substances from the same chemical substance group, e.g. alcohols, ketones, ethers, etc.), ***and***
- such substances belong to the same substance group within these Guidelines (Section 3.1.6), ***and***
- such substances have health-related C-values (i.e. they are not marked L).

If all three of the above points are complied with, the outlet calculation should be made on the basis of the total substance emission. This may be done by determining the resulting C_r value (Equation 1). This C_r value represents a total C-value for the mixture, calculated on the basis of the source strength and C-values of the individual substances.

The procedure involving the use of a C_r value is correct when the substances are emitted from the same outlet, but it is excessively conservative if emissions come from several different outlets placed at some distance from each other, or of different heights. In such cases, an alternative method may be applied, as described in Section 4.4.2.2.

C_r is determined by means of Equation 1:

Equation 1

$$B_r = \frac{G}{\frac{G_1}{C_1} + \frac{G_2}{C_2} + \text{---} + \frac{G_n}{C_n}}$$

where
C_r is the resulting C-value in mg/m^3 ,
G is the sum of G_1, G_2...$G_{n,}$
G_1 is the source strength for substance 1 in mg/sec.,
C_1 is the C-value set for substance 1.

Please note that a C-value related to noxiousness, and therefore bearing an L label, cannot be converted into a health-related C-value.

3.1.8 C-value by intermittent[32] operation

The C-value may be made less rigid for installations emitting ***Group 1 substances and sawdust or α quartz from Group 2*** if the emissions from such installations are intermittent. If the intermittent operation is spread evenly throughout day and night and the annual cycle, a C-value for the intermittent operation, designated as C_i, may be used. This value is determined by means of Equation 2:

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[32] Periodic operation, i.e. an installation that is operated on/off within reasonable periods of time – e.g. a degreasing plant.

Equation 2

$$C_i = \frac{C \times 8760}{T_i}$$

where C is the C-value, and T_i is the total time of intermittent operation per year, measured in hours.

If the operation is not evenly distributed, Equation 3 is used instead:

Equation 3

$$C_{ic} = \frac{C \times 8760}{T_i \times 2}$$

where C_{ic} is the intermittent corrected value, adjusted by dividing by 2.

If the C-value is relaxed in accordance with these regulations, the installation's approved operation time must be specified in the requirements applying to the installation.

3.2 Mass flow limits and emission limit values

3.2.1 Introduction

Pollutants are divided into two groups (see section 3.1.6 on classification of substances).

Examples of Group 1 substances are listed in table 2 and table 2a.

Group 2 is divided into several substance groups. Some substance groups are divided into classes.

A recommended mass flow limit and a recommended emission limit value are indicated for each substance or substance class.

3.2.2 Group 1 substances

Group 1 includes chemical substances currently known to be especially harmful to health or the environment.

Various dangerous chemical substances are assigned to Group 1 on the basis of one of the following: their toxicity, their long-term impact on human health, and/or their unacceptable impact on nature.

The substances within Group 1 are divided into 2 classes (I and II) on the basis of the C-value.

Chart illustrating the division into classes

Group 1 C-value mg/m^3	Class
$\leq$ 0.001	I
> 0.001	II

Table 2 features examples of particularly dangerous substances used in large quantities in Denmark (i.e. more than 1 tonne a year).

Table 2a features examples of particularly dangerous substances used in quantities smaller than 1 tonne per year in Denmark. C-values have been determined for these substances, depending on the risk class in which a given substance is included according to the provisions on labelling.

Basically, very potent biologically active substances are regarded as Group 1 substances. The final classification of these substances, and their C-values is carried out by the Danish EPA on the basis of a specific assessment of the toxicological and eco-toxicological documentation available.

3.2.3 Limiting emissions, Group 1 substances

3.2.3.1 Emissions of dust, Group 1 substances

For emissions of dust, pre-purification or abatement should normally be carried out, using filtering processes with a relatively low filter surface load. Subsequently, the filtered air should be purified in an absolute filter with a retention degree of at least 99.97 per cent for particles of 0.3 µm.

This purification or abatement technique means that emissions can be reduced to concentrations well below 0.01 mg/normal m^3.

Please see chapter 5 regarding the inspection of filters.

3.2.3.2 Emissions of flammable substances, Group 1 substances

For emissions of flammable substances, purification or abatement should normally be carried out by means of thermal combustion or other, equally effective methods. Where necessary, this may be combined with absorption or adsorption methods.

By these means, such emissions can normally be brought to concentrations less than 0.1 mg/normal m^3.

The installation is responsible for deciding which method to use to limit emissions.

The installation should be able to choose freely among other purification or abatement methods, as long as such methods are of a quality corresponding to that of the methods specified in these Guidelines.

The effectiveness of the purification or abatement methods chosen should be checked using appropriate means. See also chapter 5.

3.2.3.3 If neither absolute filtering nor combustion can be used

If neither absolute filtering nor combustion can be used, the mass flow limits and emission limit values specified in table 1 should be used instead.

Table 1
Mass flow limits and emission limit values for Group 1 substances when emission limitation by means of absolute filtering or combustion is impossible.

Group 1 C-value mg/m^3	Class	Mass-flow limit g/hr.	Emission limit value mg/normal m^3
$\leq$ 0.001	I	0.5	0.25
> 0.001	II	25	2.5

Some substances are, however, so unsafe that particularly low emission limit values should be used.
These substances are specified in sections 3.2.3.4 – 3.2.3.8 below.

3.2.3.4 PCB

PCB is subject to an emission limit value[33] of 0.0001 mg/normal m^3.

3.2.3.5 Dioxins

Emissions of dioxins (polychlorinated dibenzodioxins and polychlorinated dibenzofuranes) should be limited as much as possible.

3.2.3.5.1 The CEN method

Emission limit values of dioxins should apply to measurements carried out using the CEN measurement method and the international toxicity factors that have now been implemented in Denmark. The CEN method is the measurement method given in the EU Waste Incineration Directive. Please refer to CEN standards EN 1948-1, EN 1948-2, and EN 1948-3.

3.2.3.5.2 Incineration of non-hazardous waste

Experience from waste-incineration plants shows that it is technically and financially feasible to limit emissions of dioxins to less than 0.1 ng I-TEQ/normal m^3 air (11 per cent O_2)[34]. This limit value is included in the protocol on limitation of persistent, organic compounds under the UN convention on Long-Range Transboundary Air Pollution, as well as in the new EU directive relating to waste incineration.

3.2.3.5.3 Incineration of dangerous waste

The Statutory Order on incineration of hazardous waste[35] sets an emission limit value for dioxins of 0.1 ng I-TEQ/normal m^3(11% O_2). The new EU directive on waste incineration also extends in scope to incineration of dangerous waste.

3.2.3.5.4 Industrial installations

Steps should be taken to limit dioxin emissions from industrial installations if the <u>annual mass flow</u> of dioxins is greater than 0.01 g I-TEQ.

The emission limit value should be set at 0.1 ng I-TEQ/normal m^3. In some cases, technical and financial considerations may render it necessary to accept

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[33] Methods of analysis and sampling for PCB will be published later.

[34] I-TEQ as defined in the Danish EPA Statutory Order No. 660 of 11 August 1997 on authorisation of plants incinerating hazardous waste. Appendix, item 9.

[35] Statutory Order No. 660 of 11 August 1997 (under revision).

an emission limit value of 0.2 ng I-TEQ/normal m^3 for certain installation types.

3.2.3.6 Asbestos

Statutory Order No. 792 of 15 December 1988 on limitations of emissions of asbestos to air from industrial plants applies to emissions of asbestos[36].

3.2.3.7 Formaldehyde

An emission limit value of 5 mg/normal m^3 at a mass flow greater than 25 g/hr applies to emissions of formaldehyde.

An emission limit value of 20 mg/normal m^3 at a mass flow greater than 100 g/hr applies to rockwool and glasswool factories, and wood/furniture factories.

3.2.3.8 Polyaromatic hydrocarbons, PAH

A mass flow limit at 25 mg benzo[a]pyrene equivalents/hr applies to emissions of PAHs. The emission limit value for PAH substances is 0.005 mg benzo[a]pyrene equivalents/normal m^3.

The list below of PAH substances specifies the PAH substances included in this requirement and how each PAH compound is weighted when calculating benzo[***a***]pyrene equivalents.

Definition

Benzo[***a***]pyrene equivalent = the sum of [conc_{PAH} x equivalence $\text{coefficient}_{\text{PAH}}$] for each PAH compound

Overview of equivalence coefficients for PAH

PAH compound	Equivalence coefficient
Acenaphthene	0.001
Acenapthylene	0.001
Anthracene	0.0005
Benzo[*a*]anthracene	0.005
Benzo[*b*]fluoranthene	0.1
Benzo[*k*]fluoranthene	0.05
Benzo[*ghi*]perylene	0.01
Benzo[*a*]pyrene	1
Chrysene	0.03
Dibenz[*a,h*]anthracene	1.1
Fluoranthene	0.05
Fluorene	0.0005
Indeno[1,2,3-*cd*]pyrene	0.1
Phenanthrene	0.0005
Pyrene	0.001

The C-value for PAH compounds is set at 2.5 ng benzo[***a***]pyrene equivalents/ m^3, by adding up all the contributions from the substances listed, measured as benzo[***a***]pyrene equivalents. The basis for this is that all of these substances are considered carcinogenic or are deemed to promote the carcinogenic process.

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[36] Asbestos: Chrysotile, Crocidotile, Amosite, Anthophyllite, Actionolite, and Tremolite.

The PAH substances listed here were originally selected by the US EPA and are now widely used internationally in connection with characterisation and assessment of PAH mixtures.

The Danish Veterinary and Food Administration, Institute for Food Safety and Toxicology has prepared the equivalence coefficients in connection with efforts to update the existing equivalence systems developed for PAH substances.

For further information on the setting of emission limit values of PAH to air, please see the background document (June 2000) at the homepage of the Danish EPA reference laboratory.

http://www.dk-teknik.dk/ref-lab/Rapporter/tekniske-undersogelser.asp.

3.2.4 Examples of Group 1 substances

Table 2
Examples of chemical substances assigned to Group 1 that are used in significant quantities (greater than 1 tonne) in Denmark, and the C-value of such substances. See also the current Guidelines on C-values.

Substance	CAS No.	Empirical formula	C-value mg/ m^3
Acetaldehyde	75-07-0	C_2H_4O	0.02
Arsenic compounds (measured as As)			0.00001
Benzene	71-43-2	C_6H_6	0.005
Chromates (measured as Cr^{VI})			0.0001
Nickel (measured as Ni)	7440-02-0		0.0001

Table 2a
Examples of chemical substances belonging to Group 1 that are used in less significant quantities in Denmark, with C-value for these substances. See also the current Guidelines on C-values.

Substance	CAS No.	Empirical formula	C-value mg/ m^3
Aziridine	151-56-4	C_2H_5N	0.0001
Benzyl violet 4B	1694-09-3	$C_{39}H_{41}N_3O_6S_2Na$	0.001
Bis(2-chlorethyl)ether	111-44-4	$C_4H_8Cl_2O$	0.0001
1,3-Bis(2,3-epoxypropoxy)benzene	101-90-6	$Cl_2H_{14}O_4$	0.001
1,1-Dichloroethylene	75-35-4	$C_2H_4Cl_2$	0.01

Example of approval for an installation producing proteolytic enzymes

Terms for air pollution
1. The installation must filter all air loaded with enzymes in an absolute filter with a retention degree of at least 99.97 per cent for particles with a size of 0.3 µm. The air must be pre-cleaned in a front filter prior to final purification or abatement in the absolute filter.
2. Inspection must be carried out as specified in Chapter 5.4.5.
3. All cleaned air must be emitted through stack A, which has a height of 30 m, to comply with the C-value.

3.2.5 Group 2

Group 2 encompasses substances that are harmful to human health or the environment other than those included in Group 1. Group 2 substances are divided into 6 substance groups, and some substance groups are sub-divided into classes.

1. Dangerous types of inorganic dust (Classes I, II, and III)
2. NO_X
3. SO_2
4. Vaporous or gaseous inorganic substances (Classes I, II, III, and IV) (except NO_x and SO_2)
5. Organic substances (Classes I, II, and III)
6. Other dust

The division into classes is based partly on knowledge of the health risk/harmful impact on the environment associated with a given substance, and partly on the technical and financial feasibility of emission limitation.

The following tables specify examples of mass flow limits, emission limit values, and C-values.

3.2.5.1 Dangerous types of inorganic dust

Table 3 includes examples of emission limit values, mass flow limits, and C-values for dangerous types of inorganic dust.

If a given outlet emits several substances within this substance group, and these substances belong to the same class, the emission limit value of this class applies to the sum of the concentrations of the substances emitted.

If a given outlet emits several substances that belong to several different classes, the emission limit value for each individual class should be complied with, and the total emission concentrations should not exceed 5 mg/normal m^3.

Table 3
Examples of mass flow limits, emission limit values, and C-values for dangerous types of inorganic dust. The C-values apply to dust with a diameter of less than 10 μm. See also the current Guidelines on C-values.

Substance	Class	Mass-flow limit g/hr	Emission limit mg/normal m^3	C-value mg/m^3
Beryllium compounds measured as Be	I	1	0.1	0.00001
Mercury compounds measured as Hg*)	I	1	0.1	0.0001
Lead compounds measured as Pb*)	II	5	1	0.0004
Cobalt compounds measured as Co		5	1	0.0005
Antimony compounds measured as Sb	III	25	5	0.001
Chromium compounds other than Cr^{VI} measured as Cr		25	5	0.001
α quartz, respirable		25	5	0.005
Cyanides measured as CN		25	5	0.06
Copper compounds measured as Cu		25	5	0.01
Sodium hydroxide		25	5	0.005

*) Small amounts of the emission of Hg, Pb, etc., may occur in gas phase, but are included as dust.

3.2.5.2 NO_x

NO_x is a designation for the total sum of the following nitrogen oxides: nitrogen oxide, NO, and nitrogen dioxide, NO_2.

Table 4
Mass-flow limit, limit value for emission, and C-value for installations emitting NO_X[37]

Mass-flow limit g/hr calculated as NO_2	Emission limit value mg/normal m^3 calculated as NO_2	C-value mg/m^3 for the proportion occurring as NO_2
5,000	400	0.125

The mass flow limit and the emission limit value apply to the emitted quantities of NO_X, calculated as NO_2.

The C-value applies to the part of the amount of NO_X that is emitted as NO_2.

The outlet height is calculated by counting all NO_X as NO_2 if no information on the distribution of the NO_x contents is available.

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[37] The mass flow limit and the emission limit value do not apply to energy plants. See Chapter 6.

If less than half of a given amount of NO_x is NO_2, calculations should always be made on the assumption that at least half of the NO_x emitted is NO_2.

Example of conversion of NO_X to NO_2

A chemical installation emits NO_X, consisting of 20 per cent by weight NO and 80 per cent by weight NO_2. The installation emits 1,000 g NO_X/hr.

The conversion to NO_2 is carried out as follows:
20 per cent by weight of the quantity emitted consists of NO, i.e. 20 per cent of 1,000 g NO_X/hr = 200 g/hr.

NO is converted into NO_2 for calculation purposes by multiplying the relevant figure by 1.53 (1.53 is the relationship between the molecular weights of NO_2 and NO).
When converted to NO_2, the emitted quantity of NO corresponds to 200g/hr x 1.53 ....306 g/hr
80 per cent by weight of the quantity emitted is NO_2, corresponding to ....800 g/hr
The total emission of NO_X converted into NO_2 is.. 1,106 g/hr

The emission limit value for NO_x does not apply to cement kilns, rockwool and glasswool factories, moler works, leca works, tile works, or lime works. Emission limit values for NO_x for such installations are set on the basis of BAT notes. Generally speaking, however, an emission limit value of 500 mg/normal m^3 measured as NO_2 should be aimed for.

3.2.5.3 SO_2

Table 5
Mass-flow limit, emission limit value and C-value for installations emitting SO_2[38]

Mass-flow limit g/hr	Emission limit value mg/normal m^3	C-value mg/m^3
5,000	400	0.25

The emission limit value for SO_2 must not, however, be used for installations with process plants using fuels and where there is direct contact between the flue gas and the product being manufactured ***if*** the relevant emission of SO_2 does not exceed the emission from any fuel used legally, irrespective of whether this leads to emission concentrations greater than what corresponds to 400 mg/normal m^3 at 10 per cent O_2.

See also Statutory Order No. 901 of 31 October 1994 on the limitation of sulphur content in fuels for heating and transport, and Statutory Order No. 532 of 25 May 2001 on the limitation of sulphur content in certain liquid and solid fuels.

Special conditions apply to lime works, moler works, leca works, rockwool plants, and tile works, as the SO_2 emitted comes largely from the raw materials used. In these cases, a specific assessment must be carried out to determine the emission limit.

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[38] The mass flow limit and the emission limit value do not apply to energy plants. See Chapter 6.

3.2.5.4 Other vaporous or gaseous inorganic substances

Table 6 presents examples of emission limit values, mass flow limits, and C-values for installations that emit vaporous or gaseous inorganic substances other than NO_x and SO_2.

Table 6
Examples of mass flow limits, emission limit values, and C-values for installations that emit vaporous or gaseous inorganic substances, except for NO_x and SO_2. See also the current guidelines on C-values for other substances.

Substance	Class	Mass-flow limit g/hr	Emission limit value mg/normal m^3	C-value mg/m^3
Phosgene	I	10	1.0	0.001
Chlorine	II	50	5	0.01
Hydrogen cyanide	II	50	5	0.06
Hydrogen fluoride	II	50	5	0.002
Hydrogen sulphide	II	50	5	0.001
Hydrogen chloride	III	500	100	0.05
Sulphur trioxide	III	500	100	0.01
Ammonia	IV	5,000	500	0.3

3.2.5.5 Organic substances

Organic substances are divided into three classes, usually in accordance with the criteria outlined below:

Outline of the classification of organic substances

Class	C-value mg/m^3
I	$\leq$ 0.01
II	> 0.01 $\leq$ 0.2
III	> 0.2

Mass-flow limits and emission limit values for organic substances can be found in table 7.

Table 8 features examples of C-values and classifications for organic substances.

If an installation emits substances that belong to several classes, and if the mass flow for all substances is > 6,250 g/hr, the emission limit value for each class should be complied with, and the sum of the emission concentrations should not exceed 300 mg/normal m^3.

Table 7
Mass-flow limits and emission limit values for installations that emit organic substances

Class	Mass-flow limit g/hr	Emission limit value mg/normal m^3
I	100	5
II	2,000	100
III	6,250	300

3.2.5.5.1 Thinner mixes

The definition of thinner mixes has been changed as a consequence of a review of the use and composition of thinner mixes.

A new C-value of 0.15 mg/m^3 has been set for thinner mixes. Thinner mixes are still classified as belonging to Group 2, organic substances, class III.

Hereafter, "thinner mixes" include organic solvents in paint products used in paint shops (iron, metal, plastic), at car paint shops, in furniture manufacture, etc.

Thinner mixes are defined as a mixture of at least three organic solvents – or at least two organic solvents for water-based paints – of which the relative proportion of a single organic solvent does not exceed 80 per cent by weight.

If the mix contains three or more organic solvents, three of these organic solvents must each account for more than 2 per cent by weight[39]. None of the organic solvents included in the mix may be substances belonging to Group 1 or Group 2, class I.

The C-value of 0.15 mg/m^3 has been set on the basis of odour thresholds set for a representative selection of the thinner mixes currently available. For emissions of thinner mixes, requirements on outlet heights are based exclusively on the C-value. This means that there is no need to supplement this by requirements based on the concentration of substance odorants (LE/m^3) in the surroundings of outlets emitting thinner mixes.

The C-value of 0.15 mg/m^3 applies to new installations. This includes the establishment of new paint shops at existing installations that have not previously included a paint shop. As a general rule, the 0.15 mg/m^3 C-value should also be complied with in connection with extensions to existing paint shops.

For existing paint shops where the outlets have been dimensioned on the basis of a C-value of 0.3 mg/m^3, orders to increase outlet heights, etc., with a view to ensuring compliance with a 0.15 mg/m^3 C-value should only be given if there are significant odour problems.

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[39] These figures apply in relation to the total organic solvent contents, which means that dry matter is not included in calculations. If the conditions are not met, the product at hand is not a ”thinner mix”.

Detailed explanation

An installation wishes to know whether the organic solvents contained in the paint products it uses can be regarded as thinner mixes in accordance with the new definition specified above.

The installation uses several different types of paint. These paints include a two-component paint where the hardening agent contains 0.5 per cent hexamethylene-1,6 diisocyanate. According to the C-value list (***Orientering*** No. 15/1996), hexamethylene-1,6 diisocyanate is a Group 2, class I substance.

According to the definition of thinner mixes, ”None of the organic solvents included in the mix may be Group 1 or Group 2, class I substances”.

The installation asks the following questions:
1. Is hexamethylene-1,6 diisocyanate an organic solvent?
2. When the paint used is a mixture of base, hardening agent, and possibly a thinner, should the organic solvents in each of these elements comply with the definition of a “thinner mix”, or is it the organic solvent composition in the finished, ready-to-use mixture that must comply with this definition?

The answers to these questions in relation to the definition of thinner mixes are as follows:

Question 1
Hexamethylene-1,6 diisocyanate is not regarded as an organic solvent in this connection.

Question 2
The organic solvent composition in the finished, ready-to-use mixture is the one that must comply with the definition of thinner mixes.

3.2.5.6 The VOC Statutory Order

On 11 March 1999, the European Council adopted Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations – (The VOC Directive). In Denmark, the VOC Directive will be implemented by means of a Statutory Order on limitations of emissions of volatile organic compounds from the use of organic solvents in certain installations and activities (the VOC Statutory Order). This Statutory Order applies to installations where one or more of the industrial processes and activities specified in appendix 1 are carried out ***and*** where the threshold values for use of organic solvents specified in appendix 2 A are exceeded.

As a point of departure, the VOC Statutory Order is exhaustively regulates emissions of volatile organic compounds from installations. It should, however, be observed whether an installation emits Group 1 substances which do not fall within the scope of the special provisions laid down in the VOC Statutory Order on substitution and limitation of emissions of certain substances that are particularly harmful to health, i.e. substances with the R phrases R45, R46, R49, R60 and R61. It should also be observed whether any emissions of organic substances that belong to Group 2, organic substances, class I, and which have a health-related C-value, are emitted from the installation. In these cases, the recommendations in these Guidelines should be followed. Such situations are expected to be rare, as installations often use thinner mixes.

3.2.5.6.1 Phenol

Phenol is a class I substance with an emission limit value of 5 mg/normal m^3.

For rockwool and glasswool factories, special technical production conditions may mean that a higher emission limit value must be accepted, e.g. up to 20 mg/normal m^3.

Table 8
Examples of classes and C-values for organic substances that belong to Group 2. The C-values are stated in mg/m^3.
Substances marked "L" have an odour-related C-value (for such substances, the C-value is lower (by a factor of 10 or more) than the value that would be set if the assessment was purely health-related). See also the current guidelines on C-values for other substances.

Substance	CAS No.	Empirical formula	Class	C-value
Acetone	67-64-1	C_3H_6O	III	0.4
Acrylic acid	79-10-7	$C_3H_4O_2$	II	0.02 L
Styrene	100-42-5	C_8H_8	II	0.2
Toluene	108-88-3	C_7H_8	III	0.4
1,1,1-Trichloroethane	71-55-6	$C_2H_3Cl_3$	III	0.5
Wood dust			I	0.025

3.2.5.7 Other dusts

General

The mass flow limits, emission limit values, and C-values specified in tables 9 and 9a apply to installations emitting types of dust that do not belong under any of the other sections in these Guidelines. Emission limit values for agricultural companies appear in the Danish EPA Guidelines No. 4/1991, ***Retningslinier for grovvarebranchen*** ("***Guidelines for produce and foodstuffs companies***").

3.2.5.7.1 Dry dusts

Table 9
Mass-flow limits, emission limits, and C-values for other dust
The C-value applies to dust with a diameter < 10 µm.

MASS FLOW kg total dust/hr	EMISSION LIMIT mg total dust/normal m^3		C-value for the proportion of dust with a diameter smaller than 10 µm mg/m^3
	New installations	Existing installations	
≤ 0.5	300	300	0.08
> 0.5 and ≤ 5	50	75	
> 5	10 This figure is 25 where only electro filters are used for production reasons	20-40 This figure is 50 where only electro filters are used for production reasons	

3.2.5.7.2 Wet dust

For a number of processes involving wet dust, reducing the relevant emission to a level below the specified emission limit values can be very problematic, either because the technology necessary to do so simply does not exist, or it is financially unfeasible for the relevant type of installation. For installations with mass flows greater than 0.5 kg/hr, a higher emission limit value for total dust emissions may be set within the framework specified below.

Table 9a
Emission limits for other dust, wet dust

Process	Emission limit measured as dry matter mg total dust/normal m^3
Grain dryers and dry feed presses	40
Alfalfa flour plants using cyclophanes, venticlones, or similar.	40
Dust in a drying process with a dew point down to 60-65°C, and moisteners.	100
Lime slakers.	100

The emission limit values specified in table 9a must apply where there is a valid reason for emissions not being brought below the normal emission limit.

The C-value for particles with a diameter of less than 10 µm is 0.08 mg/m^3.

4 Calculation of outlet heights

4.1 Introduction

This chapter contains instructions on how to calculate stack or outlet heights in order to ensure adequate dilution of emissions into the atmosphere to comply with C-values.

In general, these calculations must be based on the OML model. This model and its use is described in more detail in section 4.2. Section 4.3 explains the concepts “source strength G” and “dispersion coefficient D” used in OML calculations. Section 4.4 provides instructions regarding calculations. Section 4.5 describes the use of the model in connection with odour emissions, and section 4.6 specifies some of the limitations applying to this model.

Calculations using the OML model may be carried out by the applicant installations themselves, or by consultants. The approving authority assesses whether such calculations are adequate.

4.1.1 Information about the OML model

For information on the OML model, refer to the National Environmental Research Institute[40] manuals and supporting materials regarding this particular model. The National Environmental Research Institute also maintains a website that features information of interest to OML model users[41]. Here, anyone interested can find information on current versions of the model and any problems reported, and they can download tips and help files.

A PC version of OML-Point (the guidelines model) is available from the Danish Ministry for Environment and Energy Shop, Miljøbutikken[42]. All other software is available from the National Environmental Research Institute.

Inquiries regarding the normal application of these models should be made to the Danish EPA. Other, more technical questions on the application and function of models should be directed to the National Environmental Research Institute[43].

The previous version of these Guidelines included a description of a method for calculating outlet heights without using a PC, the so-called nomogram method. Due to subsequent developments in general PC usage, this method is not included here.

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[40] National Environmental Research Institute of Denmark

[41] http://www.oml.dmu.dk

[42] Miljøbutikken, Læderstræde 1-3, DK-1201 Copenhagen K, Tel. (+45) 33 95 40 00

[43] The National Environmental Research Institute of Denmark, Department of Atmospheric Environment, Frederiksborgvej 399, PO Box 358, DK-4000 Roskilde. Tel. (+45) 46 30 12 00

4.2 The OML model

OML is an acronym for the Danish “**O**perationel **M**eteorologisk **L**uftkvalitetsmodel” (Operational Meteorological Air Quality Model), and is used to calculate required outlet heights by means of a computer software package. This package is available in two versions: OML-Point and OML-Multi.

OML-Point is used to carry out calculations for point sources that are assumed to be at one single geographical point, whereas OML-Multi can take into account the relative positions of many outlets. This means that OML-Multi is used in cases involving several outlets with some distance between the individual outlets. Both versions are based on a Gaussian plume model. They include a division by a factor of 1 million in the sense that if emissions are submitted in g/sec, the resulting ground level concentration will be indicated $\mu g/m^3$.

4.2.1 Results from the model compared with C-values

The user must supply various information, such as a tentative outlet height. On this basis, the model calculates average concentrations for every hour of a reference year at a number of user-defined points – the so-called receptor points. As a measure for the concentrations, 99-percent fractiles are tabulated at all receptor points for each month of the reference year.

These calculated concentrations are compared to the C-values laid down in the C-value Guidelines, and repeated calculations using various outlet heights make it possible to determine an outlet height on the basis of the criterion that the 99-percent fractiles calculated must be less than or equal to the relevant C-values.

The C-values must be complied with for each month, and calculations must always be carried out for all 12 months of the year, even if emissions occur only for part of the year. C-values must be complied with everywhere outside of installation boundaries.

4.2.2 Data basis for OML calculations

Calculations using the OML model require information on source strength, volume flow, flue-gas temperature, inner and outer diameter of stacks, outlet height, topography, buildings in the immediate vicinity of the source, as well as time series meteorological data. Meteorological data for a reference year (Copenhagen Airport 1976) are supplied with the model. Section 4.3 features a more detailed description of the concepts of “source strength” and “dispersion coefficient”, which can be used for preliminary estimates.

4.3 Source strength and dispersion coefficient

4.3.1 Source strength “G”

Basically, the source strength G is the maximum permissible emission of a given substance during one hour of operation, measured as mg/sec. G should be determined by means of one of the following approaches:

1. G may be determined on the basis of the limit value for emissions laid down in the terms of the relevant approval for the outlet in question, and on the basis of the maximum hourly flow rate during operation. G is calculated by multiplying the limit value for emissions, mg/normal m^3, set in the approval with the maximum flow rate in the outlet measured in normal m^3/sec.

2. In cases where no limit value for emissions has been set, the maximum hourly emission during normal operation is used instead. In several cases, for example, G may be determined on the basis of the amount of paint used at a surface-treatment plant, where all organic solvents are normally emitted into the atmosphere. The maximum hourly consumption will then form the basis for calculations of source strength.

Where devices intended to reduce pollution have been installed, and these devices mean that emissions from the installation in question are significantly lower than the limit values for emissions laid down in these Guidelines, the actual emissions may be used when calculating outlet heights, if a maximum hourly emission can be determined on the basis of the figures available on actual emissions. The approving authority and the relevant installation should consider whether the emission limits should be reduced instead.

4.3.2 Dispersion coefficient “D”

The ***dispersion coefficient D*** is a concept that may be useful in connection with preliminary estimates**.**

The dispersion coefficient is defined as the source strength, G, measured as mg/sec of the relevant substance, divided by the C-value in mg/m^3 for the same substance.

Equation 4

$$D\ [\mathrm{m^3/sec}] = \frac{G\ [\mathrm{mg/sec}]}{C\text{-value}\ [\mathrm{mg/m^3}]}$$

D is measured in m^3/sec and expresses the quantity of air that the discharged substance must be evenly mixed with every second in order to comply with the C-value.

If the dispersion coefficient is less than 250 m^3/sec, the only requirement to the outlet is that it should be at least 1 m above roof level and directed upwards to ensure free dilution[44].

This rule may only be applied to a limited number of outlets within a single installation; the exact number depends on the size of the relevant installation.

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[44] “Above roof level" usually refers to the roof on which the outlet is situated, but in special cases, account should be taken of tall adjacent buildings, etc., in order to ensure free dilution.

Example:

The point of departure is the example in section 3.1.5 with a maximum hourly emission of acetone of 10 kg/hr, corresponding to 2,778 mg/sec.

$$D\ [\text{m}^3/\text{sec}] = \frac{G\ [\text{mg/sec}]}{\text{C-value}\ [\text{mg/m}^3]} = \frac{2{,}778}{0.4} = 6{,}945\ \text{m}^3/\text{sec}$$

As the dispersion coefficient D = 6,945 m^3/sec > 250 m^3/sec in the example above, an OML calculation must be carried out in order to determine the height of the outlet above ground level. The taller the outlet, the greater the dilution.

4.4 Calculation using OML

4.4.1 One or more outlets and one or more substances

Table 10
Which method should be used?

	Single substance	Several substances
Single outlet:	Carry out calculations using OML-Point or OML-Multi until a suitable outlet height – one where the contribution complies with the relevant C-value – can be determined. OML-Multi will provide the same results as OML-Point.	Determine the dispersion coefficient for each substance. Use the C-value applying to the substance that gives the greatest dispersion coefficient. Carry out calculations using OML-Point or OML-Multi until a suitable outlet height – one where the contribution complies with the relevant C-value – can be determined. OML calculations may also be carried out for all substances involved. OML-Multi may be used, but will provide the same results as OML-Point.
Several outlets:	Carry out calculations using OML-Point or OML-Multi, until a satisfactory set of outlet heights is determined. The total contribution from outlets must comply with the relevant C-value. OML-Point will provide conservative results.	Carry out calculations for all substances using OML-Point or OML-Multi, until a satisfactory set of outlet heights is determined for the relevant substances. The total contribution from outlets must comply with the relevant C-value for each substance. OML-Point will provide conservative results.

Note the following regarding this model:

The OML model calculates concentrations in the surroundings – not outlet heights. When OML calculations are carried out, these calculations must be repeated using a different outlet height each time until a height (or set of outlet heights) in compliance with the C-value has been successfully determined.

OML-Point is best suited for simple outlet conditions with only one point source. OML-Point may be used in situations involving several outlets, but it will provide results that err on the conservative side, whereas OML-Multi will give more realistic results. This is because OML-Point treats outlets as though they were situated at one single geographical location, whereas OML-Multi is capable of superimposing concentrations from different sources. As a rule of thumb, use of OML-Multi should be considered in situations where two separate outlets are located at a distance of more than two outlet heights from each other.

In cases involving outlets from comfort ventilation with concentrations less than the recommended limit values for indoor climate issued by the Working Environment Authority, and with dispersion coefficients (as defined in section 4.3) less than 250 m^3/sec, the only requirement to the outlet is that

it should be at least 1 m above roof level[45] and directed upwards or designed in some other environmentally friendly manner, so that the air emitted from the outlet can disperse freely.
In those special cases where an installation emits substances with identical toxicological properties, these substances must be considered one single substance in these calculations. Section 4.4.2 specifies how calculations are carried out in such cases.

The supporting material accompanying the OML model may provide helpful information and guidance when specifying input data for model simulations. This material is also available on the Internet[46].

These Guidelines do not include detailed instructions on how to calculate environmental contributions from sources other than point sources. It should, however, be noted that OML-Multi includes methods to perform calculations for the so-called area sources, i.e. sources where emissions may be assumed to be evenly distributed within a rectangular area.

4.4.2 Substances with identical effects

In special cases, where an installation emits different substances within the same substance group with identical toxicological effects and health-related C-values (see section 3.1.7), outlet calculations must be carried out on the basis of the total substance emission involved.

When substances have different C-values you may choose ***either*** an approach (‘the C_r method”) where the corresponding C-value is calculated as a weighted average value, C_r, ***or*** a more technical method (“the C_1 method”), where ***source strengths*** are normalised in a manner which makes it possible to apply a C-value of 1 mg/m^3.

4.4.2.1 The C_r method

The C_r method is exact when substances are emitted from ***one single outlet***, but it is unnecessarily conservative in scenarios where emissions occur from ***several different outlets*** situated at some distance from each other or of varying heights. The C_r method is also exact in cases where substances have identical C-values.

The C_r method with a weighted average value requires the calculation of a C_r value in accordance with the definition in section 3.1.7. This is followed by an OML calculation. In this OML calculation, emissions of all the substances with identical toxicological properties are included as if only one substance were involved.

4.4.2.2 The C_1 method

The C_1 method will always be exact, but the ground level concentration concentrations calculated will be fictitious and must be compared with a C-value of 1 mg/m^3.

According to the C_1 method, the source strength of each substance must be normalised according to its relevant C-value prior to the outlet calculation. This is done as follows:

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[45] ”Above roof level" usually refers to the roof on which the relevant outlet is situated, but in special cases account should be taken of tall adjacent buildings, etc., in order to ensure free dilution.

[46] http://www.dmu.dk/AtmosphericEnvironment/oml_info.htm

Equation 5

$$G_{n,i} = \frac{G_i}{|C_i|}$$

where $G_{n,i}$ is the normalised source strength for substance *i*, G_i is the source strength for substance *i*, and $|C_i|$ is the numerical value of the C-value, in mg/m^3, for substance *i*.

The OML calculation using OML-Multi is carried out taking into account all outlets and all substances with identical toxicological effects. If more than one substance is emitted from a single outlet, a total normalised source strength must be calculated for this outlet, as specified below in Equation 6. The result of the entire OML calculation must be compared to a C-value of 1 mg/m^3.

Equation 6

$$G_{n,\,outlet} = \sum_i \frac{G_i}{|C_i|}$$

The normalised source strength for the outlet is computed by adding contributions from all the substances with identical effects.

Example of application of the C_1 method for two substances with identical effects, A and B

From a given outlet, an installation emits substance A with a C-value of 1 mg/m^3, while also emitting, from a different outlet, substance B with a C-value of 0.1 mg/m^3. The source strength for substance A is 1 g/sec and for substance B 1 g/sec. Substances A and B have identical effects.

The normalised[47] source strength to be used in connection with the B_1 method is:
For substance A:

$$G_{nA} = \frac{1\ \text{g/sec}}{1} = 1\ \text{g/sec}$$

and for substance B

$$G_{nB} = \frac{1\ \text{g/sec}}{0.1} = 10\ \text{g/sec}$$

This means that OML-Multi must be used to carry out an OML calculation, in which the two outlets have source strengths of 1 g/sec and 10 g/sec, respectively, as calculated above. The resulting concentration must be compared to the C-value 1 mg/m^3.

4.5 Application of the OML model for odour emissions

The OML model can also be used to calculate outlet heights in connection with odour emissions. The source strength is the product of the odour-

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[47] No change in unit is made to the source strength, as normalisation is carried out using the numerical value of the contribution value.

emission concentration[48] stated as odour units/normal m^3 and the maximum permissible air quantity (normal m^3/sec). This concentration must be determined in accordance with current methods applying to odour-emission measurement. In order to take into account the fact that assessments of odour ground level concentrations are normally based on an averaging period of 1 minute rather than the 1 hour used in the OML model, the source strength must be corrected using a factor of 7.8. In practice, this means that the emission must be multiplied by a factor of 7.8 and divided by a factor of 1,000,000 in the model. The result is the odour ground level concentration stated directly in odour units/m^3.

4.6 Exceptions

4.6.1 Heavy gases

Note that the OML model cannot be applied to gases that are significantly heavier than the surrounding air. In calculations of plume rise, the relevant parameter is the bulk density of the gas mixture, not the molecular weight of individual pollution components. Consequently, the model should not be used in cases involving flue gas at low temperatures (in practice, the limit may be set at -5°C).

4.6.2 Wet flue gases

The OML model cannot be expected to produce reliable results when applied to flue gases with excessively high moisture contents (e.g. in connection with forage drying plants or certain types of flue gas scrubbers***).*** There may be an absence of lift in the plume, and the plume may also shed drops.

It is difficult to quantify problems involving wet smoke plumes, and such problems are not addressed in the OML model. The National Environmental Research Institute is currently establishing a knowledge bank for methods to counteract problems with very wet flue gases. Further information is available from the National Environmental Research Institute and on the Internet[49].

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[48] See the definition in the Odour Guidelines.

[49] http://www.dmu.dk/AtmosphericEnvironment/vaadroeg.htm

5 Terms and inspection rules

5.1 Introduction

In this chapter, section 5.2 describes the various types of terms and how they should be set up. The terms addressed are operating terms, emission terms, and inspection terms.

Three different types of terms require inspection of emissions:

- Emission terms, where inspection is carried out as performance inspection.
- Emission terms, where inspection is carried out by means of an Automatic Measurement System (AMS).
- Emission terms, where inspection is carried out as random testing.

For the purposes of these Guidelines, “performance inspection” means emission measurement carried out at intervals, e.g. once a year, where 3 samples are taken, each with a duration of one hour (or a different period of time, depending on the measurements or operating circumstances).

“AMS inspection” means continual emission measurement carried out over a relatively long period of time, typically throughout the plant’s life cycle.

“Random tests” means emission measurement carried out at intervals, such as 6 times a year.

Section 5.3 addresses inspection rules for inspection of operation and emissions. Section 5.3.3 describes the scope of emission inspection, both in the main text and in a diagram.

Section 5.4 describes when the emission limit values are complied with.

Section 5.5 shows examples of formulated terms.

This chapter may be used when deciding on terms and when setting inspection rules in an environmental approval or order. It may also be useful with regard to plans to change the terms or inspection provisions laid down in an environmental approval or order.

5.1.1 Definition of self-inspection

Self-inspection is defined as inspection paid for by the installation and either carried out by external laboratories or by in-house staff. This provides installations with the opportunity to take faster action to remedy excessive emissions. Such inspection may be combined successfully with an environmental management system. Measurements carried out by external laboratories should be carried out as accredited measurements. It is recommended that major installations which carry out self-inspection themselves on a regular basis consider applying for accreditation to carry out emission measurement whenever legislation allows for such accreditation.

The Danish EPA advocates inspection of air pollution from installations to be carried out via self-inspection.

5.2 Terms

5.2.1 General issues

Terms in approvals and orders should be clear and unambiguous, and it should be possible to carry out inspections to determine compliance with such terms without expending unreasonable resources.

Terms should be followed up by inspection in order to confirm compliance. The scope of such inspection should be adjusted to reflect the potential environmental impact.

5.2.2 Types of terms

The objective of terms for air pollution is to ensure that such pollution is kept below a specific limit.

These terms may be presented in various ways:

Operating terms
Operating terms are requirements that affect the design and operation of installations and have an impact on air pollution from such installations. Such requirements might involve the maximum capacity of the power plant or the use of specific raw materials.

Emission terms
Emission terms are requirements for air quantities and the concentration of substances emitted by installations, or requirements regarding maximum hourly emissions.

Terms for outlet heights
The objective of terms specifying outlet heights is to ensure compliance with the C-values.

The final part of this chapter features draft terms.

5.2.3 Operating terms

The objective of operating terms is to limit emissions of pollutants, e.g. by ensuring that purification or abatement equipment at installations is always working optimally.

As regards purification or abatement equipment, these terms might entail regular inspection and the setting of acceptable limits for e.g.:

- Visual inspection of bag filters.
- Measuring flow and pH at scrubbers and wet filters.
- Operating temperatures in connection with thermal or catalytic combustion.
- Deposits in cyclones.
- Leaks and corrosion.

Such inspection should be followed up, so that all faults are corrected and repaired as soon as the acceptable limits are exceeded.

Naturally, such monitoring requires instruments, indicators, inspection hatches, sampling ports, etc., necessary for inspection. If necessary, the approval must stipulate appropriate terms to ensure that such equipment is available and that all indicators and instrument displays are easily accessible and easy to read. These terms may stipulate that such displays must be situated in a control room or at the operating staff's usual place of work.

As a rule, purification or abatement plants should not be bypassed[50]. In some situations, however, purification or abatement plants may be bypassed for technical reasons.

For example,
- bypassing bag filters may be necessary when the flue gas temperature is too low during start-up (below the dew point), or
- in connection with accidents involving thermal or catalytic combustion plant.

The bypass period should be as short as possible and must not lead to unacceptable environmental impacts. The terms should state the acceptable extent of such bypass periods and how they should be registered.

Operating terms may be requirements regarding the preparation of an operating log, detailing e.g. the raw materials used, operating temperatures, operating failures and breakdowns, etc. There should also be terms demanding that logs are kept of faults, errors, or accidents on the installation itself (both process and purification or abatement equipment) or during operation.

The operating log and any operation instructions must be available to the supervising authorities upon request. The operating log must be stored at the installation for a specific period of time, for example three years.

5.2.4 Emission and inspection terms

The objective of emission terms is to establish limits for concentrations of the pollution and air quantity emitted. The emission limit value is set:
- as specified in chapter 3, and
- on the basis of an assessment of the potential performance of an effective and affordable purification or abatement installation of the relevant type.

Along with terms on maximum air quantities per time unit and outlet height, the emission terms will ensure that concentrations in the surroundings do not exceed the C-value.

As a minimum, emission terms should meet the following requirements:
- They should establish relevant limit values for pollutants.
- They should establish clear limits and inspection methods.
- It must be possible to check compliance with such terms without the need for using excessive resources.

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[50] "Bypass" means that the polluted air is led around the purification or abatement installation.

There are three different types of inspection procedures:

Performance inspection
Performance inspection is used at installations with significant pollution (i.e. where the mass flow limit has been exceeded, but where the AMS inspection limit has not).

AMS[51] inspection
AMS inspection is used at installations with very significant air pollution (i.e. where the AMS inspection limit has been exceeded), see section 5.3.3.3.

Random testing
Random testing is used at installations with very significant air pollution, where it is not technically or financially feasible to use AMS inspection.

The following issues should always be taken into consideration when setting up emission terms:

- the pollutant (see section 5.2.4.1),
- the emission limit value (see section 5.2.4.2),
- the inspection period (see section 5.2.4.3 and section 5.3),
- the measurement period (see section 5.2.4.4 and section 5.3),
- the number of individual measurements (see section 5.2.4.5),
- the operating circumstances during measurement (see section 5.2.4.6),
- the method of measurement (see section 5.2.4.7),
- the detection limit (see section 5.2.4.8).

For AMS inspections, steps should also be taken to ensure:

- that sufficient information on the quality of instruments is available (through tests on sensitivity, zero-point operation, measurement uncertainty, time constant), or that the instrument is approved by the supervisory authority before use,
- that instruments are installed correctly at the measuring point,
- that the instrument is serviced and maintained on a regular basis by qualified personnel in accordance with the manufacturer's recommendations,
- that the instrument is calibrated regularly, either by the installation itself or by an accredited laboratory, e.g. by means of parallel measurements once a year,
- that measurement data are stored on a suitable medium and processed for subsequent use by the supervisory authorities. All measurement data should be stored for at least three years,
- that measurement data are available, in a suitable form, to the operating personnel at their usual workplace via online systems.

5.2.4.1 The pollutant

The pollutant may be a chemical substance or a substance group, or pollution may be described in terms of a particular property (such as odour or biological activity).

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[51] The letters AMS form an acronym for Automatic Measuring System. An AMS system uses fixed measuring equipment to measure and record emissions. A CEN standard establishing performance requirements for AMS systems is currently being prepared. See also section 5.3.3.3.

The term used should state whether there are one or several states (e.g. both gas and particle phase), whether one or more elements are included in calculations for all compounds, etc., and whether the limit values apply, for example, to the sum of specific compounds.

5.2.4.2 The emission limit value

The emission limit value is a limit value for the maximum pollution. This pollution may be stated as mg pollutant/normal m^3 from a specific outlet measured at a maximum air flux. The emission limit value must be stated clearly and unambiguously and must include a specific measurement unit and reference condition. For more information on reference conditions, see section 3.1.2.

5.2.4.3 The inspection period

The inspection period is the period in which emissions are inspected. The length of these inspection periods is usually:

- three hours for performance inspections,
- one month for AMS inspections, and
- one year for random tests.

The inspection period should be sufficiently long to facilitate assessment of a representative part of the emission; i.e. long enough to ensure that random short-term high or low values do not influence the assessment significantly. At the same time, the inspection period should be short enough to make it possible to decide whether the term is complied with within a reasonable period of time.

5.2.4.4 Measurement period

The measurement period is the period used for each measurement. This applies to both manual and continual measurements. Terms should always include a specification of the measurement period.

Performance inspections normally have a measurement period of one hour or more, depending on what is being measured. If, for example, performance inspection is carried out by means of instruments that register data continuously, the measurement period is usually set at one hour. As a point of departure, performance inspection is carried out once a year, but the intervals between inspections may be longer or shorter, depending on specific assessment of the relevant situation.

For AMS inspections, the shortest theoretical measurement period will depend on the time constant of the instrument used. This time constant is usually less than one minute. In practice, the measurement period is set at one hour, which provides good time for a suitable statistical basis. AMS inspections are carried out on a continuous basis.

Random tests usually have a measurement period of one hour or more, depending on what is being measured. If, for example, random testing is carried out by means of instruments that register data continuously, the measurement period is usually set at one hour. Random tests are carried out regularly each year, but the number of samples taken varies, as specified in section 5.4.3.

It is recommended that the same one-hour measurement period is used for performance, AMS, and random tests alike. Any deviations from this measurement period should be based on special conditions in the process or in the method of measurement that favour a shorter or longer measurement period.

The measurement period may also be set at a period other than one hour if specified in international provisions, such as EU Directives.

5.2.4.5 *Number of individual measurements*

Inspection terms should state how many individual measurements should be taken. An individual measurement is a quantitative measurement to determine the emission over the measurement period.

Performance inspection is carried out by taking at least three individual measurements, each lasting one hour.

Automatic measuring and registering instruments are used for AMS inspections, and measurement is carried out all the time. If the measurement period is set at one hour, this means that 720 measurements will be carried out during a single month if the installation is operated around the clock. Otherwise the measurements are only carried out when the installation is operating and emissions occur.

Random tests are carried out on six randomly chosen days a year (the installation must be operating on these days). At least two individual measurements must be carried out each day.

Overview of inspection period, measurement period, and number of measurements

Inspection type	Inspection period	Measurement period	Number of individual measurements
Performance inspection	E.g. 3 hours	E.g. 1 hour	3 per inspection measurement
AMS inspection	1 month	1 hour	Continuous
Random testing	1 year	E.g. 1 hour	2 per sample

5.2.4.6 *Operating terms*

In connection with performance inspections, the term should clearly state at what type and level of production measurements should be carried out.

If emissions vary during operation, steps should be taken to ensure that measurements are carried out while emissions are at their maximum level. Emission terms apply to those periods where the installation is operating – i.e. when emissions occur. This means that non-active periods are not included. If the installation is operated for less than one hour at a time, the relevant operating period is used as the averaging time.

The operating circumstances influence the relevant emission limit value.

5.2.4.7 *Method of measurement*

The inspection terms should state the method of measurement to be used. Chapter 8 features methods of sampling and analysis which may be used when setting up these terms. If the measurements must be accredited, steps should be taken to ensure that accredited laboratories are, in fact, available for the method chosen. The inspection term should be phrased so that it is possible to use other measurement methods of a similar quality, if the installation can justify it.

5.2.4.8 Detection limit

The detection limit should normally be less than 10% of the emission limit value inspected. If the emission limit value applies to the sum of several substances, measurement results below the detection limit are not included in calculations.

5.2.5 Terms for outlet heights

The objective of the terms for outlet heights is to ensure compliance with the C-values. Outlet heights are calculated by means of the OML model.

At installations with few outlets, the terms will usually require specific outlet heights in order to ensure that the C-value is complied with when the emission limit value is met.

At installations with many outlets, it may be fair to impose terms regarding compliance with C-values as such a procedure will enable the installation to make its own decisions on distribution of outlet heights and purification or abatement, if applicable. Emission limit values must still be set in such cases.

5.3 Type and scope of inspection

Inspections of compliance with terms imposed on plants require inspection terms that specify when it can be said that a given term is complied with or exceeded.

Three different types of inspection are used:

- inspections of operation, see section 5.3.1,
- inspections of emissions, see sections 5.3.2 and 5.4,
- inspections of outlet heights, see section 5.4.4.

Inspections of operation are carried out by monitoring the relevant process or plant. Inspections of emissions are carried out by measuring or calculating the relevant emission.

5.3.1 Inspections of operation

The installation must carry out inspections of operation by monitoring the relevant processes and plants in accordance with the terms set. The operating terms are deemed to be complied with when the operating log has been correctly kept and the terms set up for the operation observed.

5.3.2 Inspection of emissions

Inspection of emissions may be carried out by measuring – if necessary by calculating – the relevant emission. All measurements must be carried out in accordance with the relevant emission terms.

Who carries out inspection of emissions?

- The installation may let an accredited laboratory carry out performance inspections or random tests.

- The installation may carry out performance inspections, AMS measurements or random tests itself.
- The emission may be calculated by means of mass balances, production data, or similar data.

Large-scale installations carrying out self-inspection on a regular basis should consider applying for accreditation to carry out emission measurements if current legislation allows for this. Measurements should be carried out as specified in chapter 8.

5.3.3 Type and scope of inspection of emissions

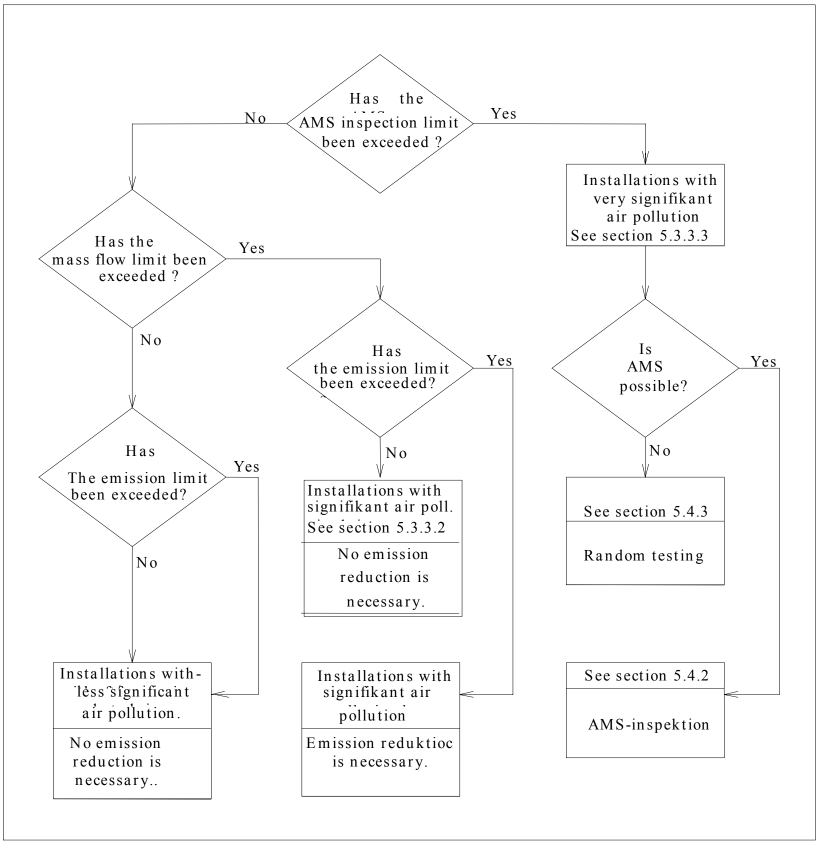

Figure 5 shows the scope of inspection of emissions.

The use of the various types of terms depends on the significance of the emissions. The installations are divided into the following categories:

5.3.3.1 Installations with less significant air pollution

Installations with less significant air pollution are installations where the mass flow (substance quantities prior to purification or abatement) is less than the mass flow limit. In such cases, emission measurements are usually not required, and inspection can be limited to an effective inspection of operation. However, emission measurements may also be required in order to document that the mass flow remains below the mass flow limit, as well as to determine the maximum hourly emission where this cannot be done by means of calculations.

5.3.3.2 Installations with significant air pollution

Installations with significant air pollution are installations where the mass flow (substance quantities prior to purification or abatement) exceeds the mass flow limit, but remains below the AMS inspection limit specified in section 5.3.3.3.

When issuing approvals to such installations, requirements should be made that inspections of compliance with the operating provisions that are significant to limiting air pollution should be carried out daily, or even more regularly. This must also apply to inspections to verify that all significant measures designed to limit pollution function correctly. There should also be requirements stipulating that emission measurements, usually in the form of performance inspection, must be carried out once a year if an emission limit has been specified. However, if the result of a performance inspection shows a value of less than 60 per cent of the emission limit value, such measurements need only be carried out every second year.

Performance inspection for dioxins and furans should be carried out for all outlets with a mass flow (substance quantity prior to purification or abatement) greater than 0.1 mg dioxins and furan/hr, measured as mg I-TEQ.

At normal operating circumstances, at least two (parallel or serial) individual samples must be taken for dioxin analysis twice a year for new installations and once a year hereafter, if the emission limit value is complied with. If the emission complies with the relevant requirements over a period of two years, measurements may be carried out at even greater intervals. The measurement period for individual samples must be 6-8 hours in order to ensure a sufficiently low detection limit.

5.3.3.3 Installations with very significant air pollution

Installations with very significant air pollution are defined as installations where the mass flow (substance quantities prior to purification or abatement) for each outlet exceeds the AMS inspection limits, as specified below. AMS for measurement of the relevant emissions should be mandatory for such installations.

5.3.3.3.1 AMS inspection limits for gaseous substances

Any outlet (individual outlet) with a mass flow (substance quantity prior to purification or abatement) greater than

- 200 kg/hr SO_2,
- 25 kg/hr organic substances, measured as TOC,
- 200 kg/hr NO_x, measured as NO_2,
- 2 kg/hr group 1 substance,

should be fitted with AMS for measurement of the relevant substances.

5.3.3.3.2 AMS inspection limits for particles, etc.

Any outlet (individual outlet) with a mass flow (substance quantity prior to purification or abatement) greater than 2 kg/hr of the substances specified below[52] should be fitted with AMS for measurement of the installation’s emissions of:

- group 1 substances,
- lead and lead compounds, measured as lead,

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[52] Both in particle form and gaseous form

- copper and copper compounds, measured as copper,
- mercury and mercury compounds, measured as mercury,
- tellurium and tellurium compounds, measured as tellurium,
- thallium and thallium compounds, measured as thallium,
- vanadium and vanadium compounds, measured as vanadium.

Any outlet (individual outlet) with a mass flow (substance quantity prior to purification or abatement) greater than 200 kg particles/hr (other than those specified above) should be fitted with AMS for measurement of the installation's particle emissions.

Random tests are used in situations where use of AMS is impossible.

5.4 When are the terms complied with?

What follows are descriptions of when terms are complied with. Such information should be included directly in terms in approvals and orders, as this will help avoid problems regarding the burden of proof in any subsequent legal action.

5.4.1 Performance inspection

The emission terms are complied with when the arithmetical average value of all individual measurements carried out during the performance inspection is less than or equal to the required value.

5.4.2 AMS inspection

The emission terms are complied with when the arithmetical average value of all individual measurements carried out during the inspection period (one calendar month) is less than or equal to the required value.

5.4.2.1 Inspection rules for individual measurements

If an individual measurement exceeds the emission limit value by a factor of three or more, the supervisory authority must be notified. At the same time, an account must be given of the reason behind this breach and of the measures taken, or about to be taken, in order to prevent future problems. In addition to this, intensified monitoring of the equipment designed to limit pollution must be carried out. This must be done in consultation with the supervising authority.

5.4.3 Random testing

In random testing, a number of samples are taken at intervals during the inspection period. In principle, these samples must be taken on six randomly selected operating days during a single year. A single sample comprises two individual measurements, each lasting one hour. The result of such a sample is the average value of these two measurements.

5.4.3.1 Inspection rule for random testing

The assessment of whether the required value is complied with is carried out in accordance with the following principles:

- K is the required value,
- M_1 is the inspection-limit value for the emission measured,
- M_2 is the inspection-limit value for the number of samples,

- M is the average value of all samples taken during the inspection period, and
- N is the number of samples taken.

On this basis, it is possible to establish the following two rules for whether the required value is complied with, and whether the number of samples taken is adequate:

5.4.3.2 The limit value rule

The limit value (K) is complied with if M (the measured value) is less than the inspection limit value for the emission measured. The inspection limit value (M_1) is calculated as follows:

Equation 7

$$M_1 = K \text{ x } 37$$

where q (the geometric dispersion) is calculated as follows:

$$q = \sqrt{\frac{SUM \log^2 M_i - \frac{1}{N}(SUM \log M_i)^2}{N(N-1)}}, \textit{ where}$$

M_i is the result of the individual samples.
log is the common logarithm.

5.4.3.3 The random sample rule

The number of samples taken is sufficiently large if M is less than the inspection limit value for the number of samples (M_2), which is calculated as follows:

Equation 8

$$\boxed{M_2 = 2 \text{ x } K \text{ x } 19^{-q}}$$

If this is not the case, the number of samples taken during the next inspection period must be increased by three.

The terms of both rules must be met in order to comply with the required value.

If the terms of the rule on limit values are not met, but the sample rule is complied with, the limit value is considered exceeded.

If neither the limit value rule nor the sample rule are met, the number of samples taken during the next inspection period should be increased, and measures should be taken to reduce emissions of the relevant parameter.

If the limit value rule is met, while the sample rule is not, this should lead to an increase in the number of samples taken during the next inspection period ***as well as*** increased inspection (inspection of operation) of the equipment designed to limit pollution.

If the results of at least two inspection periods show that the emissions measured amount to less than 50 per cent of the required values, the number of samples taken per inspection period may be reduced from six to four. If this pattern is repeated, the number of samples taken may be reduced further, from four to two, and finally to a single annual performance inspection. If the required value is exceeded, the number of samples to be taken each year will return to six.

5.4.3.4 Inspection rules for individual measurements

If an individual measurement exceeds the emission limit value by a factor of three or more, the supervisory authority must be notified. At the same time, an account must be given of the reason behind this breach and of the measures taken, or about to be taken, in order to prevent future problems. In addition to this, intensified monitoring of the equipment designed to limit pollution must be carried out. This must be done in consultation with the supervising authority.

Example of the application of this inspection rule

Terms:
The emission of cadmium from the installation outlet, measured as an annual mean value determined by means of random testing, must not exceed 100 µg/normal m³.

Data:

Sample No.	Emission m. (M_1)	log M_i	log² M_i
1	238	2.377	5.648
2	87	1.940	3.762
3	171	2.233	4.986
4	74	1.869	3.494
5	99	1.996	3.983
6	123	2.090	4.368
Sum	792 (A)	12.505 (B)	26.241 (C)

Exponent:

$$q = \sqrt{\frac{(C - B^2)/N}{N(N-1)}} = \sqrt{\frac{(26{,}241 - 12{,}502^2)/6}{6x5}}$$

q = 0.077

Inspection limits:
$M_1 = 100 \times 37^{0.077} = 132.1$ µg/normal m³

$M_2 = 2 \times 100 \times 190^{-0.077} = 159$ µg/normal m³

Mean value:
M = A/N = 792/6 = 132 µg/normal m³

Conclusion:
M less than M_1? Yes, 132 is less than 132.1: the emission is approved.
M less than M_2? Yes, 132 is less than 159.4: the number of samples taken is adequate.

5.4.4 Inspection of outlet height

The authority may request documentation for the height of the outlet.

5.4.5 Inspection of absolute filters

Absolute filters should always be checked for leaks after installation and repairs.

Absolute filters should not be inspected during normal operation. Inspections are carried out on demand, and must always be carried out when the filter has been removed, adjusted, or repaired. The filter must always, however, be inspected at least once a year.

The most widely used test method is a leak test (e.g. ASME N510 and DS/EN
1822/4 and 5). The leak should not exceed 0.03 per cent for particles with a size of 0.3 μm.

The separation efficiency of 99.97 per cent for 0.3 μm particles is tested by the manufacturer after production. For example, such a test may be carried out in accordance with DS/EN 1822/1-3.

5.5 Examples of terms

5.5.1 Example A. Installation with less significant air pollution

An installation uses paint that contains toluene. The surface treatment process used at this installation leads to the following emission of toluene: Toluene is emitted from outlet A, and the installation states that the mass flow of toluene over a single shift is approximately 2,000 g/hr. The air quantity in the outlet is estimated at approximately 4,000 normal m³/hr on the basis of information about the ventilation system. This means that the emission concentration, without purification or abatement, is approximately 500 mg/normal m³.

According to chapter 3, the mass flow limit for toluene is 6,250 g/hr.

As the mass flow is below the mass flow limit, the installation does not have to carry out any purification or abatement, and inspection can be carried out on the basis of operating terms.

The outlet height is determined on the basis of the maximum emission concentration of toluene over an hour. This value has been set at 1,000 mg/normal m³ on the basis of the consumption pattern for toluene during a single shift and the C-value for toluene, which is set at 0.4 mg/m³.

As the dispersion coefficient is 2,775 m³/s and this figure is greater than 250 m³/s, the installation has carried out an OML calculation to determine that the outlet must be at least 10 m above ground level.

Terms for air pollution from the installation and the inspection hereof are as follows:

Outlet height and operating terms

- The outlet must be at least 10 m above ground level.
- The installation must keep a log of day-to-day consumption of toluene. This may be done on the basis of the available information on paint consumption and paint content of toluene. On each day of operation, the following must be recorded as necessary: Date, toluene consumption, plant operating period, and signature of the person keeping the log.
- The supervising authority must have access to the log, which must be stored at the installation for at least three years.

5.5.2 Example B. Installation with significant air pollution

An iron foundry emits sand dust from two outlets due to sand mixing and knocking-out castings: outlet 1(sand mixing) emits an air quantity of 40,000 normal m^3/hr, and outlet 2 (knocking out) emits an air quantity of 17,000 normal m^3/hr.

The emission concentration of the air prior to purification or abatement in the two outlets is between 300 and 1,000 mg dust/normal m^3.

Calculations show that the total mass flow of the installation from the two outlets is approximately 50 kg/hr on average over 7 hours.

The dust in the outlets is considered to be total dust, i.e. dust that contains particles larger ***and*** smaller than 10 µm.

The dust belongs under table 9 of these Guidelines, “Other dust”, with a mass flow limit of 5 kg/hr and an emission limit value of 10 mg/normal m^3.

As the installation’s mass flow of sand is greater than the mass flow limit for other dust (5 kg/hr), and as the emission concentration in the two outlets for other dust is greater than the emission limit value for other dust, purification or abatement is necessary. This may be carried out by means of bag filters, etc.

The AMS inspection limit for dust is 200 kg/hr.

As the AMS inspection limit for dust has not been exceeded, there is no need to use AMS.

The terms for air pollution from the installation and inspection hereof are as follows:

Outlet No.	Pollutant	Air quantity normal m^3/hr	Emission limit value mg/normal m^3	Outlet height, calculated using OML-Point or OML-Multi. metres
No. 1	Sand dust	40,000	10	X
No. 2	Sand dust	17,000	10	Y

The emission limit values apply to both outlets (1 and 2).
Outlet No. 1 must be at least X m above ground level.
Outlet No. 2 must be at least Y m above ground level.

The sampling points in the outlets must be designed in accordance with guidelines in chapter 8 of the Danish EPA Guidelines for Air Emission Regulation. Documentation hereof must be submitted to the approving authority.

Inspection

Operating instructions for the filters must be available in the immediate vicinity of the filters. Operation and inspection of the bag filters must be carried out in accordance with the manufacturer’s operating instructions. A weekly log must be kept of the inspection of filters to check that the bag filters are not worn out. Any

operating disruptions, breakdowns, and other relevant information must be recorded in the log, stating the date, year, and possibly time.

The log must be available for inspection by the supervising authority and must be stored at the installation for at least three years.

Not later than three months after the receipt of this approval, the installation must carry out an accredited performance inspection of outlets 1 and 2 in order to document compliance with the emission limit value. Each performance measurement must include at least three individual measurements, each lasting approximately one hour. This measurement must include measurement of the relevant air quantity.

When this has been completed, performance measurements must be carried out at least once a year. However, if the result of a performance measurement is less than 60 per cent of the emission limit value, such measurements need only be carried out every second year.

The following method of measurement[53] must be used:

Substance	Method of measurement
Dust	VDI 2066/7

Deviations from this method of measurement must be duly justified and approved by the approving authority.

<u>Inspection rules for performance inspection</u>

The emission limit value is complied with when the arithmetic average of the three (or the relevant number) measurements carried out during the inspection period is less than or equal to the limit value. The inspection period is the total measurement period.

Operating terms must also be set.

5.5.3 Example C. Installation with very significant air pollution

An installation manufactures a number of organic coarse chemicals and organic intermediates for other chemical industries. These products are used as raw materials and intermediates by manufacturers in the pharmaceuticals sector.

Sulphur dioxide (SO_2) is emitted through the installation outlet P. The installation states that the mass flow of sulphur dioxide is approximately 300 kg/hr, and that the air quantity in the outlet is approximately 1,000 normal m^3 /hr. The concentration prior to purification or abatement is approximately 300 g/normal m^3.

According to chapter 3 of these Guidelines, the mass flow limit for SO_2 is 5,000 g/hr. The emission limit value for SO_2 is 400 mg/normal m^3.

According to section 5.3.3.3, the AMS inspection limit for SO_2 is 200 kg/hr.

As the installation's mass flow of SO_2 is greater than the mass flow limit for SO_2, and as the emission of SO_2 is greater than the emission limit value,

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[53] This method is recommended in the list of methods in chapter 8.

purification or abatement must be carried out in order to ensure compliance with the emission limit value for SO_2.

As the installation's mass flow of SO_2 is greater than the AMS inspection limit, the emissions must be inspected by means of AMS.

The outlet height has been determined by means of an OML calculation on the basis of the relevant limit value for emissions and the maximum air quantity, and has been set at Z m above ground level.

The terms for air pollution from the installation and the inspection hereof are as follows:
Emission limit value applying to outlet P:

Parameter	Emission limit value mg/normal m³	Outlet height, calculated using OML-Point or OML-Multi. metres
SO_2	400	Z

- ***The discharges from outlet P must be at least Z m above ground level.***
- ***The air quantity in outlet P must never exceed 1,200 normal m³/hr.***
- ***The purification or abatement plant must always be operating during production.***

Inspection

Instruments and software (methods of analysis) intended for use in AMS measurements for SO_2 must be approved by the supervisory authority before use. The instruments must be installed correctly at the point of measurement, and must be serviced and maintained regularly by qualified staff in accordance with the manufacturer's directions. The procedures for operation and maintenance of equipment must be available in a manual.

The air quantity must be checked when the plant is established.

The operating instructions must be available in the immediate vicinity of the equipment.

The measurement instruments must be calibrated in accordance with the manufacturer's directions. In addition to this, parallel measurements must be carried out in the form of performance inspection. The first of these measurements must be carried out no later than two months after the installation begins operation, and once every year after that. These inspections must be carried out by an accredited laboratory.

The following method of measurement must be used[54]:

Substance	Method of measurement for AMS
SO_2	DS/ISO 7935

Deviations from this method of measurement must be duly justified and approved by the approving authority.

The sampling points in the outlets must be designed in accordance with the guidelines featured in chapter 8.

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[54] See the list of methods in chapter 8.

All measurement data from the AMS measurements in outlet P must be continually displayed on-screen and recorded. It must also be possible to have hourly and daily values displayed on-screen. All measurement data must be stored for at least three years and must be presented to the supervising authority upon request.

Inspection rules for AMS measurements

The emission limit value is complied with when the arithmetic average of all one-hour measurements taken during the inspection period is less than or equal to the limit value. The inspection period is one calendar month. Periods without any emission of the relevant substance must not be included in the inspection period.

If a single one-hour measurement exceeds the emission limit value by a factor of 3 or more, the supervising authority must be notified. At the same time, an account must be given of the reason behind this breach and of the measures taken, or about to be taken, in order to prevent future problems. In addition to this, intensified monitoring of the equipment designed to limit pollution must be carried out. This must be done in consultation with the supervising authority.

Furthermore, operating terms must be set.

6 Energy plants

6.1 Introduction

The emission limit values featured in this section apply to all plants that produce power and heat. For example, a plant in which a substance is dried or concentrated by using flue gas as the source of energy, but where there is no contact between the gas and the substance/material being dried/concentrated, is considered an energy plant.

The main fuels used at energy plants in Denmark are natural gas, light fuel oil, coal, and heavy fuel oil. Renewable fuels such as biogas, straw, and wood are also used. Dust is emitted from these plants in the form of soot, oil coke, NO_x, etc., and polluting components arising from impurities in the fuel. Examples of such impurities are sulphur, chlorine, and fluorine, as well as ashes containing heavy metals such as nickel, vanadium, etc.

Rules regarding the maximum sulphur content of fuels have been stipulated in order to limit emissions of SO_2. These rules can be found in the Statutory Order on limitation of sulphur content in fuel for heating and transport[55] and the Statutory Order on limitation of sulphur content in certain liquid fuels[56].

Emissions of sulphur dioxide are normally proportional to the sulphur content of the relevant fuel. In such cases, 0.02 kg SO_2 is emitted per kilo fuel used per percentage point sulphur.

Except in cases where special plants have been established to clean flue gas, emissions correspond to the content of the relevant substances in the fuel concerned. Please note, however, that some of the substances emitted into the atmosphere are also bound in cinders and ashes to a lesser extent.

It is important that all energy plants are constructed, maintained and adjusted so that the inevitable pollution of the air is reduced to a minimum. The fact that there is some correlation between the concepts of minimum pollution and maximum energy efficiency provides a double incentive to reduce pollution from energy plants.

If a energy plant has equipment for flue-gas purification or abatement, such equipment should be sufficiently effective to ensure that terms regarding emission limit values included in an approval can be met throughout the energy plant's entire life cycle and under all normal operating conditions. This means that purification or abatement equipment at energy plants should be designed for emissions that are significantly lower than the limit values.

This section features special emission limit values from energy plants. The mass flow limits and emission limit values laid down in these Guidelines apply to all substances that are not expressly specified in connection with each item (energy plant). The C-values apply to all substances. Only in exceptional

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[55] Statutory Order No. 901 of 31 October 1994.
[56] Statutory Order No. 580 of 22 June 2000

cases will it be necessary to stipulate emission limit values other than those specified for each fuel type below.

The emission limit values for NO_x in this chapter apply to all NO_x converted into NO_2.

For combustion plants with two-channel burners and modulating burners, outlet heights are calculated at various loads. The load resulting in the highest outlet must be chosen.

Please note that the physical conditions mentioned below, e.g. calorific values, may change if the chemical composition of the fuel is changed.

6.2 Natural gas, LPG, and biogas

6.2.1 General information

Calorific value for natural gas:

Lower calorific value:	approximately 48.6 MJ/kg or approximately 39.3 MJ/normal m^3.
Upper calorific value:	approximately 56 MJ/kg.

When natural gas is burned, approximately 57 g CO_2/MJ is formed. When LPG is burned, approximately 65 g CO_2/MJ is formed.

When 1 kg natural gas[57] is burned, the following approximate quantity of flue gas is formed:

Equations 9 and 10

$$\frac{203}{21 - \%\, O_2} \quad \text{normal } m^3 \text{ dry flue gas}$$

or

$$2.57 + \frac{205}{21 - \%O_2} \quad \text{normal } m^3 \text{ wet flue gas}$$

where % O_2 denotes O_2 content in the flue gas, expressed as a percentage by volume.

6.2.2 Gas motors and gas turbines using natural gas

Emissions from such plants are regulated in accordance with Statutory Order No. 720 of 5 October 1998 on the limitation of emissions of nitrogen oxides, unburned carbon hydrides and carbon monoxide from gas motors and gas turbines.

From 1 July 2003, an emission limit for formaldehyde of 10 mg/normal m^3 at 5 % O_2 at an efficiency (in electricity production) of 30 per cent also applies to gas motors with a total input effect of 5 MW or more. This limit value is adjusted upwards or downwards in equal proportion to the electricity efficiency.

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[57] Natural gas has a bulk density of approximately 0.8 kg/normal m^3.

The emission of formaldehyde from gas turbines is significantly below this limit value, and so there is no need to set an emission limit value for gas turbines.

The outlet height is determined by means of an OML calculation.

6.2.3 Combustion plants with an input effect of less than 120 kW

An input effect of 120 kW corresponds to consumption of approximately 8.6 kg natural gas per hour.

The stack must be constructed in accordance with current regulations on gas and building construction.

6.2.4 Combustion plants with a total input effect of 120 kW or more, but less than 5 MW

Before purchasing new equipment, the installation should make sure that such equipment complies with the following emission limit values:

NO_X measured[58] as NO_2 = 65 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 75 mg/normal m^3 dry flue gas at 10 per cent O_2.

For existing plants, up to 125 mg NO_X/normal m^3 dry flue gas at 10 per cent O_2, measured as NO_2, is acceptable.

Outlet heights are determined in accordance with current regulations on gas and construction or by means of an OML calculation.

An input effect of 5 MW corresponds to the consumption of approximately 360 kg natural gas per hour.

6.2.5 Combustion plants with a total input effect of 5 MW or more, but less than 50 MW

These plants should comply with the following emission limit values:

NO_X measured as NO_2 = 65 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 75 mg/normal m^3 dry flue gas at 10 per cent O_2.

For existing plants, the environmental authorities may accept up to 125 mg NO_X/normal m^3 dry flue gas at 10 per cent O_2 measured as NO_2, if it turns out that the emission limit value must be relaxed.

The outlet height is determined by means of an OML calculation.

An input effect of 50 MW corresponds to the consumption of approximately 3.6 tonnes natural gas per hour.

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[58] See the example in section 3.2.5.2 on conversion of NO_X into NO_2

Example: Determining the emission limit value and outlet height for gas-fired plants with an input effect of 5 MW or more, but less than 50 MW

A plant states that the emission of NO_X from their boiler plant, which uses natural gas, will be less than 50 mg/normal m^3. It is stated that 90 per cent of the emitted quantity of NO_X is NO by weight. The rest is NO_2. The approving authority approves the plant and sets a emission limit value of 65 mg NO_X measured as NO_2 pr. normal m^3, which is the emission limit for NO_X. The outlet height is determined on the basis of the assumption that half of the 65 mg NO_X per normal m^3 consists of NO_2, see section 3.2.5.2.

6.2.6 Combustion plants with an input effect of 50 MW or more

More detailed provisions on plants with an input effect of 50 MW or more are given in Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., are set according to the BAT principle on the basis of a specific assessment, see chapter 1.

The outlet height is determined by means of an OML calculation.

6.2.7 Inspection

For gas-fired plants with an input effect of 5-30 MW, performance inspections should be used to verify compliance with the limit values for NO_X and CO.

Gas-fired plants with an input effect of more than 30 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the burning process. Such plants should also be fitted with AMS equipment for NO_X. In addition to this, performance inspections should be used to verify compliance with the limit value for CO.

If an emission limit value of formaldehyde is set, performance inspections should be used to verify compliance with this limit value.

For plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October
1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides, and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

6.3 Light fuel oil

6.3.1 General information

Calorific value:

Lower calorific value:	approximately 43 MJ/kg.
Upper calorific value:	approximately 45 MJ/kg.

When light fuel oil is burned, approximately 74 g CO_2/MJ is formed.

When 1 kg light fuel oil is burned, the following approximate quantity of flue gas is formed:

Equations 11 and 12

$$\frac{222}{21 - \%\ O_2} \quad \text{normal m}^3 \text{ dry flue gas}$$

or

$$1.41 + \frac{228}{21\text{-}\%O_2} \quad \text{normal m}^3 \text{ wet flue gas}$$

where % O_2 denotes the O_2 content in flue gas, expressed as a percentage by volume.

No emission limit values for sulphur dioxide have been given for plants that burn light fuel oil, as such emissions are proportional to the sulphur content in the oil used. A total of 0.02 kg SO_2 is emitted per kg oil used per percentage point sulphur.

Rapeseed oil that has been produced specifically for burning and which is of a quality corresponding to that of light fuel oil may be burned under the rules set up in this section.

Oil combustion plants that are mainly used for domestic heating fall within the scope of the Ministry of Environment and Energy Statutory Order No. 785 of 21 August 2000 on the inspection measurement, adjustment and purification or abatement of oil combustion plants.

6.3.2 Input effect less than 120 kW

No actual emission limit values have been set for these plants.

The stack must be constructed in accordance with current building regulations.

An input effect of 120 kW corresponds to consumption of approximately 10 kg light fuel oil per hour.

6.3.3 Total input effect of 120 kW or more, but less than 5 MW

Prior to purchasing new equipment, all installations should ensure that such equipment complies with the following emission limit values:

NO_X measured as NO_2 = 110 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.

For existing plants, the environmental authorities may accept up to 250 mg NO_X/normal m^3 dry flue gas at 10 per cent O_2 measured as NO_2 if it turns out that the emission limit value must be relaxed.

The outlet height is determined by means of an OML calculation.

An input effect of 5 MW corresponds to the consumption of approximately 440 kg light fuel oil per hour.

6.3.4 Total input effect of 5 MW or more, but less than 50 MW

These plants should comply with the following emission limit values:

Dust = 30 mg/normal m^3 dry flue gas at 10 per cent O_2.
NO_x measured as NO_2 = 110 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.

For existing plants, the environmental authorities may accept up to 250 mg NO_x/normal m^3 dry flue gas at 10 per cent O_2, measured as NO_2, if it turns out that it is necessary to relax the emission limit value.

The outlet height is determined by means of an OML calculation.

An input effect of 50 MW corresponds to the consumption of approximately 4.2 tonnes light fuel oil per hour.

6.3.5 Total input effect of 50 MW or more

More detailed provisions on light fuel oil fired plants with an input effect of 50 MW or more are given in Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., are set according to the BAT principle on the basis of a specific assessment, see chapter 1.

The outlet height is determined by means of an OML calculation.

6.3.6 Inspection

For light fuel oil fired plants with an input effect of 5-30 MW, compliance with the limit values for NO_x and CO should be checked by means of performance inspection.

Light fuel oil fired plants with an input effect of more than 30 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the combustion process, and with AMS equipment for NO_x. In addition to this, performance inspections should be used to verify compliance with the limit value for CO.

For plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

6.4 Heavy fuel oil

This section applies to plants that burn heavy fuel oil, orimulsion, and fuels of similar quality.

6.4.1 General information about heavy fuel oil

Calorific value:
Lower calorific value: approximately 41 MJ/kg.

Upper calorific value: approximately 43 MJ/kg.

When heavy fuel oil is burned, approximately 78 g CO_2/MJ is formed.

When 1 kg heavy fuel oil is burned, the following approximate quantity of flue gas is formed:

Equations 13 and 14

$$\frac{212}{21 - \% O_2} \text{ normal m}^3 \text{ dry flue gas}$$

or

$$1.29 + \frac{211}{21 - \% O_2} \text{ normal m}^3 \text{ wet flue gas}$$

where % O_2 denotes O_2 content in the flue gas, expressed as a percentage by volume.

6.4.2 Total input effect of 2 MW or more, but less than 50 MW

Heavy fuel oil, orimulsion, and other fuels of similar quality may not be used in burners with an input effect of less than 2 MW.

The following emission limit values apply to these plants:

Dust = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.
NO_x measured as NO_2 = 300 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.
Hg = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.
Cd = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.

The sum (Σ) of:
Ni
V
Cr
Cu
Pb = 5 mg/normal m^3 dry flue gas at 10 per cent O_2.

The SO_2 emission depends on the sulphur content of the relevant fuel. The maximum sulphur content in heavy fuel oil is regulated in the Statutory Order on the limitation of sulphur contents in fuel for heating and transport[59] and the Statutory Order on the limitation of the sulphur content in certain liquid fuels[60]. As a result, no emission limit value for SO_2 is given.

If a supplier of heavy fuel oil guarantees compliance with the above limit values for heavy metals (on the basis of the composition of the heavy fuel oil), there is no need to stipulate further requirements on such substances.

For existing plants, emission limit values are determined on the basis of emission measurements and an assessment of the possibilities for reducing emissions of NO_x.

Outlet heights are determined by means of OML calculations.

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[59] No. 901 of 31 October 1994.
[60] No. 580 of 22 June 2000.

6.4.3 Total input effect of 50 MW or more

An input effect of 50 MW corresponds to a consumption of 4.4 tonnes heavy fuel oil per hour.

For more detailed provisions on plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

In addition to these requirements, all plants should comply with the following emission limit values:

Hg = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.
Cd = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.

The sum (Σ) of:
Ni
V
Cr
Cu
Pb = 5 mg/normal m^3 dry flue gas at 10 per cent O_2.

If a supplier of heavy fuel oil guarantees compliance with the above limit values for heavy metals (on the basis of the composition of the heavy fuel oil), there is no need to stipulate further requirements on such substances.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., are set according to the BAT principle on the basis of a specific assessment, see chapter 1.

The outlet height is determined by means of an OML calculation.

6.4.4 Inspection

For heavy fuel oil fired plants with an input effect of 5-30 MW, compliance with the limit values for NO_x and CO should be checked by means of performance inspection.

Fuel-oil-fired plants with an input effect of more than 30 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the combustion process. Such plants should also be fitted with AMS equipment for NO_x. In addition to this, performance inspections should be used to verify compliance with the limit value for CO.

Heavy fuel oil fired plants with an input effect of over 50 MW should be fitted with AMS sampling apparatus for dust, SO_2, NO_x, and O_2. Compliance with the emission limit values for the heavy metals specified here should be checked by means of performance inspection at least twice a year.

For more detailed provisions on plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

Emissions of metals may often be calculated on the basis of the metal content in the relevant fuel. In many cases, such calculations are sufficiently accurate to replace emission measurement.

6.5 Waste oil

Waste oil or oil waste is hazardous waste, but falls outside the scope of the regulations on incineration of hazardous waste, as specified in the Ministry of Environment and Energy Statutory Order No. 660 on the approval, etc., of plants incinerating hazardous waste, see Section 1 (5), 1st clause of this Order. Incineration of oil waste falls within the scope of special provisions; see Section 57 and Appendix 11 of the Ministry of Environment and Energy Statutory Order No. 619 of 27 June 2000 on Waste (the Waste Order). Waste oil may only be incinerated at plants with a thermal output of more than 1 MW.

Outlet heights are determined by means of an OML calculation.

6.5.1 Inspection

Appendix 11 of the Statutory Order on Waste states that it should be possible to provide documentation of compliance with the emission limit values, either by means of calculations or emission measurements.

Measurements of emissions should be carried out by means of performance inspection.

Waste oil fired plants with an input effect of more than 5 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the incineration process. In addition to this, plants with an input effect of more than 30 MW should also be fitted with AMS equipment for NO_X.

Waste oil fired plants with an input effect of more than 50 MW should be fitted with AMS equipment for dust, SO_2, $NO_{X,}$ and O_2. As regards the substances specified in Appendix 11 of the Statutory Order on Waste, the emission limit values should be checked by means of performance inspection.

6.6 Coal

This section includes plants that burn coal, pet-coke, and lignite or other fuels of similar quality.

6.6.1 General information

Calorific value for coal:
Lower calorific value: approximately 25 MJ/kg.
Upper calorific value: approximately 26 MJ/kg.

When coal is burned, approximately 95 g CO_2/MJ is formed.

When 1 kg coal is burned, the following approximate quantity of flue gas is formed:

Equations 15 and 16

$$\frac{212}{21 - \%\, O_2} \quad \text{normal m}^3 \text{ dry flue gas}$$

or

$$1.29 + \frac{211}{21\text{-}\%O_2} \quad \text{normal m}^3 \text{ wet flue gas}$$

where % O_2 denotes O_2 content in the flue gas, expressed as a percentage by volume.

Coal, petcoke, and lignite should not be used in new plants with an input effect of less than 5 MW.

6.6.2 Total input effect of 5 MW or more, but less than 50 MW

An input effect of 5 MW corresponds to a consumption of approximately 720 kg of coal per hour.
An input effect of 50 MW corresponds to a consumption of approximately 7.2 tonnes of coal per hour.

The following emission limit values apply to these plants:

Dust = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.
NO_X measured as NO_2 = 200 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 100 mg/normal m^3 dry flue gas at 10 per cent O_2.
Hg = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.
Cd = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.
HCl = 10 mg/normal m^3 dry flue gas at 10 per cent O_2.

The sum (Σ) of:
Ni
V
Cr
Cu
Pb = 5 mg/normal m^3 dry flue gas at 10 per cent O_2.

If a supplier of coal guarantees compliance with the above limit values for heavy metals (on the basis of the composition of the coal in question), there is no need to stipulate further requirements in connection with such substances.

The SO_2 emission depends on the sulphur content of the relevant coals. The maximum sulphur content in coal and petcoke is regulated in the Statutory Order on the limitation of sulphur contents in fuel for heating and transport[61]. As a result, no emission limit value for SO_2 is given.

The emission limit value of NO_X for existing plants is determined on the basis of emission measurements and an assessment of the possibilities for reducing NO_X emissions. For existing plants that are also used for the removal of noxious substances, the limit for NO_X emissions should be determined on the basis of a specific assessment.

Outlet heights are determined by means of an OML calculation.

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[61] No. 901 of 31 October 1994.

6.6.3 Input effect of 50 MW or more

For more detailed provisions on plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

In addition to these requirements, all plants should comply with the following emission limit values:

HCl = 10 mg/normal m^3 dry flue gas at 10 per cent O_2.
HF = 1.0 mg/normal m^3 dry flue gas at 10 per cent O_2.
Hg = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.
Cd = 0.1 mg/normal m^3 dry flue gas at 10 per cent O_2.

The sum (Σ) of:
Ni
V
Cr
Cu
Pb = 5 mg/normal m^3 dry flue gas at 10 per cent O_2.

If a supplier of coal guarantees compliance with the above limit values for heavy metals (on the basis of the composition of the coal in question), there is no need to stipulate further requirements on such substances.

For older plants, which do not fall within the scope of the Statutory Order, emission limits, inspection, etc., is determined on the basis of specific assessment by means of the BAT principle. See chapter 1.

Outlet height is determined by means of an OML calculation.

6.6.4 Inspection

If limit values for heavy metals have been set for installations using coal-fired plants, performance inspections should be carried out to check compliance with the emission limit value for the heavy metals specified.

Coal-fired plants with an input effect of more than 5 MW should be fitted with automatic measuring equipment for measurement and registration of dust emissions in accordance with the principle of opacity or methods of similar quality. They should also be fitted with sampling apparatus and regulation equipment for O_2 in order to control the burning process.

Coal-fired plants with an input effect of 5-30 MW should be monitored by means of performance inspections in order to verify compliance with the limit value for NO_X. Plants with an input effect greater than 30 MW should also be fitted with AMS equipment for measurement of NO_X.

Coal-fired plants with an input effect of over 50 MW should be fitted with AMS equipment for dust, SO_2, NO_X, and O_2. The emission limit value for heavy metals specified should be monitored by means of performance inspection.

For plants with an input effect of 50 MW or more, please see Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

Emissions of metals may often be calculated on the basis of the metal content in the relevant fuel. In many cases, such calculations are sufficiently accurate to replace emission measurement.

6.7 Wood

This section addresses combustion plants using wood and waste wood complying with the purity requirements specified in the Statutory Order on biomass waste[62].

6.7.1 General information

The calorific value depends on the water content. The calorific value for wood containing 25 per cent water is approximately 13.7 MJ/kg.

When 1 kg wood is burned, the following approximate quantity of flue gas is formed:

Equations 17 and 18

$$\frac{72}{21 - \%\,O_2} \quad \text{normal m}^3 \text{ dry flue gas}$$

or

$$0.82 + \frac{73}{21 - \%O_2} \quad \text{normal m}^3 \text{ wet flue gas}$$

where % O_2 denotes O_2 content in the flue gas, expressed as a percentage by volume.

6.7.2 Wood-fired stoves

If a stove causes significant pollution or significant environmental nuisance, the local authorities may order the owner to reduce such pollution. This is laid down in Section 42 (1) of the Environmental Protection Act, and applies regardless of whether the stove in question is located within a residential area or an industrial area, and whether it belongs to a company or to a private individual.

Information on the use of stoves is available in the leaflet ***"Før du fyrer løs"*** ["Before you light up"] from the Danish EPA, and in the leaflet ***"Korrekt fyring. Sådan udnyttes brændslet bedre"*** ["How to make the most of your fuel"] from the Danish Ministry of Housing and Urban Affairs. Unfortunately, these leaflets are only available in Danish.

Please note that only unadulterated wood may be used in stoves. This means that stoves may not be used to burn waste such as painted wood, impregnated wood, chipboard, MDF boards, or other types of household waste. Newspapers may, however, be used to light fires.

Please note that orders issued pursuant to Section 42 of the Environmental Protection Act relating to fixed, non-commercial facilities cannot be appealed

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[62] Statutory Order No. 638 of 3 July 1997 on biomass waste.

to any other administrative authority. This is specified in Section 19 of Statutory Order No. 366 of 10 May 1992 on non-commercial animal husbandry, unhygienic conditions, etc.

6.7.3 Input effect of 120 kW or more, but less than 1 MW

Before purchasing new plants of this type, all installations should make sure that they comply with the following emission limit values:

Dust = 300 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 500 mg/normal m^3 dry flue gas at 10 per cent O_2.

Outlet heights are determined by means of an OML calculation.

6.7.4 Total input effect of 1 MW or more, but less than 50 MW

The following emission limit values apply to these plants:

Dust = 40 mg/normal m^3 dry flue gas at 10 per cent O_2.[63]
NO_X measured as NO_2 = 300 mg/normal m^3 dry flue gas at 10 per cent O_2[64].
CO = 625 mg/normal m^3 dry flue gas at 10 per cent O_2.

If, for example, condensing equipment is used, the emission limit value for dust may be relaxed to 100 mg/normal m^3 dry flue gas at 10 per cent O_2.

Outlet heights are determined by means of an OML calculation.

6.7.5 Input effect of 50 MW or more

Plants using wood and with an input effect of 50 MW or more fall within the scope of Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., must be set according to the BAT principle on the basis of a specific assessment, see chapter 1.

Outlet heights are determined by means of an OML calculation.

6.7.6 Inspection

For wood-fired plants with an input effect greater than 1 MW but less than 5 MW, performance inspection should be carried out to verify compliance with the emission limit values.

Wood-fired plants with an input effect of 5 MW or more should be fitted with automatic measuring equipment for measurement and registration of:

- Dust emissions in accordance with the principle of opacity or methods of a corresponding quality, and

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[63] As a point of departure, this also applies to condensing wood-fired plants and plants without dust filters.

[64] This only applies to plants with an input effect of 5 MW or more. When firing with wood chips with high bark content and a large proportion of needles, the emission limit value may be raised to 400 mg/normal m^3

- CO emissions.

For wood-fired plants with an input effect of 5-30 MW, compliance with the limit value for NO_x should be checked by means of performance inspection.

Wood-fired plants with an input effect of more than 1 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the burning process. In addition to this, plants with an input effect of more than 30 MW should also be fitted with AMS equipment for NO_x.

Wood-fired plants with an input effect of more than 50 MW should be fitted with measuring equipment for CO, dust, NO_X, and O_2.

For plants with an input effect of 50 MW or more, please see Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

6.8 Straw

6.8.1 General information

The Statutory Order on biomass[65] includes more detailed information on which types of straw may be used as a fuel.

Calorific value: 14.5 MJ/kg.

When 1 kg straw is burned, the following approximate quantity of flue gas is formed:

Equations 19 and 20

$$\frac{83}{21 - \%\ O_2} \quad \text{normal m}^3 \text{ dry flue gas}$$

or

$$0.72 + \frac{85}{21 - \%O_2} \quad \text{normal m}^3 \text{ wet flue gas}$$

where % O_2 denotes the O_2 content in the flue gas, expressed as a percentage by volume.

6.8.2 Total input effect of 1 MW or more, but less than 50 MW

The following emission limit values apply to these plants:

Dust = 40 mg/normal m^3 dry flue gas at 10 per cent O_2.
NO_X measured as NO_2 = 300 mg/normal m^3 dry flue gas at 10 per cent O_2[66].
CO = 625 mg/normal m^3 dry flue gas at 10 per cent O_2.

These figures are hourly mean values and must not be exceeded after ten minutes from firing.

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[65] Statutory Order No. 638 of 3 July 1997 on biomass waste.

[66] This only applies to plants with an input effect of 5 MW or more.

Due to the risk of nuisance caused by smoke, it is recommended that new plants should be 200 m or more from the nearest dwelling.

The outlet height is determined by means of an OML calculation.

6.8.3 Input effect of 50 MW or more

Straw-fired plants with an input effect of 50 MW or more fall within the scope of Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., are set according to the BAT principle on the basis of a specific assessment, see chapter 1.

The outlet height is determined by means of an OML calculation.

6.8.4 Inspection

For straw-fired plants with an input effect greater than 1 MW but less than 5 MW, performance inspection should be carried out to verify compliance with the emission limit values.

Straw-fired plants with an input effect of 5 MW or more should be fitted with automatic measuring equipment for measurement and registration of:

- Dust emissions in accordance with the principle of opacity or methods of a corresponding quality, and
- CO emissions.

For straw-fired plants with an input effect of 5-30 MW, compliance with the limit value for NO_x should be checked by means of performance inspection.

Straw-fired plants with an input effect of more than 1 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the combustion process. In addition to this, plants with an input effect of more than 30 MW should also be fitted with AMS equipment for NO_x.

Straw-fired plants with an input effect greater than 50 MW should be fitted with measuring equipment for CO, dust, NO_x, and O_2.

For plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

6.9 Biomass waste

6.9.1 General information

Statutory Order No. 638 of 3 July 1997 on biomass waste and its Annex provide more detail on the types of biomass waste accepted for use as fuel.

6.9.2 Input effect of 120 kW or more but less than 1 MW

Before purchasing new plants, all installations should make sure that such plants comply with the following emission limit values:

Dust = 300 mg/normal m^3 dry flue gas at 10 per cent O_2.
CO = 500 mg/normal m^3 dry flue gas at 10 per cent O_2.

The outlet height is determined by means of an OML calculation.

6.9.3 Total input effect of 1 MW or more, but less than 50 MW

The following emission limit values apply to these plants:

Dust = 40 mg/normal m^3 dry flue gas at 10 per cent O_2.
NO_X measured as NO_2 = 300 mg/normal m^3 dry flue gas at 10 per cent O_2[67].
CO = 625 mg/normal m^3 dry flue gas at 10 per cent O_2.

The outlet height is determined by means of an OML calculation.

6.9.4 Input effect of 50 MW or more

Plants with an input effect of 50 MW or more fall within the scope of Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

For older plants, which do not fall within the scope of this Statutory Order, the various emission limits, inspection measures, etc., must be set according to the BAT principle on the basis of a specific assessment, see chapter 1.

Outlet heights are determined by means of an OML calculation.

6.9.5 Inspection

For biomass-fired plants with an input effect greater than 1 MW, but less than 5 MW, performance inspection should be carried out to verify compliance with the emission limit values.

Biomass-fired plants with an input effect of 5 MW or more should be fitted with automatic measuring equipment for measurement and registration of:

- Dust emissions in accordance with the principle of opacity or methods of a corresponding quality, and
- CO emissions.

For biomass-fired plants with an input effect of 5-30 MW, compliance with the limit value for NO_X should be checked by means of performance inspection.

Biomass-fired plants with an input effect of more than 1 MW should be fitted with measurement and regulation equipment for oxygen (O_2) to control the

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[67] This only applies to plants with an input effect of 5 MW or more. When firing with wood chips with high bark content and a large proportion of needles, the emission limit value may be raised to 400 mg/normal m^3

combustion process. In addition to this, plants with an input effect of more than 30 MW should also be fitted with AMS equipment for NO_X.

Biomass-fired plants with an input effect greater than 50 MW should be fitted with measuring equipment for CO, dust, NO_X, and O_2.

For plants with an input effect of 50 MW or more, refer to Statutory Order No. 689 of 15 October 1990 on the limitation of emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, as amended by Statutory Order No. 518 of 20 June 1995.

6.10 Waste incineration plants

As regards waste incineration plants, a distinction is made between plants burning hazardous waste, and plants that burn household waste, commercial waste, etc.

Plants burning hazardous waste are regulated in Statutory Order No. 660 of 11 August 1997 on the approval, etc., of plants burning hazardous waste.

However, ***incineration of oil waste***, which is also a hazardous waste, does not fall within the scope of Statutory Order No. 660/1997. Instead, such incineration falls within the scope of special provisions, see Appendix 11 in Statutory Order No. 619 of 27 June 2000 on waste. Oil waste may only be incinerated at plants with a thermal output of more than 1 MW. See also section 6.5.

More detailed rules on plants incinerating ***non-hazardous waste*** are laid down in Statutory Order No. 41 of 14 January 1997 on waste incineration plants[68] and in the Danish EPA Guidelines No. 2/1993 on the limitation of pollution from incineration plants.

Outlet heights are determined by means of an OML calculation.

6.10.1 Inspection

The Statutory Orders specified above feature inspection regulations for the incineration of waste.

6.11 Calorific value, conversion factors, NO_X, methods of measurement, etc.

6.11.1 Calorific value

The calorific value is a measure for the amount of heat released upon combustion. A distinction is made between the concepts “lower” and “upper” calorific value. The lower (effective) calorific value describes the quantity of heat which is usually utilised by an energy plant. The upper (calorimetric) calorific value includes the heat that is released from condensation of flue-gas content of steam (water vapour).

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[68] See Directive 2000/76/EC on waste incineration. This Directive addresses both hazardous and non-hazardous waste. There will be consultation on a Statutory Order.

The calorific value for each type of fuel is specified under the heading "General information" in each section.

6.11.2 Conversion from ppm to mg/normal m^2

- 1 ppm SO_2 = 2.93 mg/normal m^3 SO_2 at 0°C and 101.3 kPa.
- 1 ppm NO = 1.34 mg/normal m^3 NO at 0°C and 101.3 kPa.
- 1 ppm NO_2 = 2.05 mg/normal m^3 NO_2 at 0°C and 101.3 kPa.
- 1 ppm CO = 1.25 mg/normal m^3 CO at 0°C and 101.3 kPa.
- 1 ppm CO_2 = 1.98 mg/normal m^3 CO_2 at 0°C and 101.3 kPa.

6.11.3 NO_X

NO_X is the name used for the sum of the following nitrogen oxides: nitrogen monoxide (NO) and nitrogen dioxide (NO_2).

When determining emissions of NO_X, all NO_X must be converted into NO_2. In practice, emissions of NO and NO_X are measured in ppm. The resultant values are totalled, and the sum is converted into mg/normal m^3 NO_2 by means of the conversion factor for NO_2.

See also the example of a conversion from NO_X to NO_2 in section 3.2.5.2.

When standard fuels are burned, the resultant NO_X comprises approximately 10 per cent NO_2 and 90 per cent NO.

This does not apply to gas motors[69], which generate significantly more NO_2.

6.11.4 Measurements and methods of measurement

Measurements should generally be carried out by installations or persons with the appropriate accreditation; see section 5.3.2 for more details. Chapter 8 describes methods of measurement and sample extraction.

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[69] For gas motors, please contact the Danish Gas Technology Centre (DGC), Dr. Neergaards Vej 5**A,** 2970 Hørsholm. Tel.: (+45) 45 76 60 44. www.dgc.dk.

7 Design and operation of tanks and silos

7.1 Introduction

Tanks are normally used to store liquid substances, whereas silos are used to store solid substances. For the purposes of these Guidelines, “Very noxious substances” means substances that are present in the gaseous phase in concentrations corresponding to more than 100,000 LE/m^3 at the storage temperature.

Tanks to be used for gaseous substances are not included.

There is no need to carry out OML calculations for tanks and silos.

7.2 Tanks

7.2.1 Storage tanks for principal group 1 substances and very noxious substances[70]

7.2.1.1 Design of tanks

The exterior walls and roofs of tanks situated above ground should be painted in a colour with a total reflection coefficient for radiant heat of at least 70 per cent. For existing tanks, this can be carried out as part of standard regular maintenance work. This requirement regarding paint does not, however, apply to tanks linked to a condensation plant or other air-cleaning plants.

7.2.1.2 Existing tanks with external floating roofs

Tanks with external floating roofs and intended for storage of principal group 1 substances and very noxious substances should be fitted with a primary seal, covering the ring-shaped gap between the tank walls and the outer circumference of the floating roof. They should also be fitted with a secondary seal above the primary seal. These seals should be designed so that at least 95 per cent of the vapours are retained when compared to corresponding tanks with fixed roofs which are not fitted with equipment designed to retain vapours (i.e. tanks with fixed roofs, fitted with a pressure/vacuum safety valve only).

7.2.1.3 New tanks

All new tanks should be constructed either as tanks with fixed roofs linked to a condensation plant (air-cleaning plant) or designed with an external or internal floating vapour barrier with a primary and secondary seal that meets the requirements stipulated in section 7.1.1.2.

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[70] Storage of petrol must be in accordance with Statutory Order from the Ministry of Energy and Environment No. 852 of 11 November 1995 on the limitation of emissions of vapours from storage and distribution of petrol. Appendix 2 of this Statutory Order includes a number of provisions on storage plants at terminals.

7.2.1.4 Existing tanks with fixed roofs

Existing tanks with fixed roofs should either be linked to a condensation plant in accordance with the provisions laid down in Appendix 3 of Statutory Order No. 852 of 11 November 1995, or be fitted with an internal floating vapour barrier with a primary seal, constructed in a way that a total of at least 90 per cent of the vapours are retained when compared with corresponding tanks with fixed roofs and not fitted with equipment designed to retain vapours.

7.2.1.5 Filling tanks

Tanks should be filled by injecting liquid below the surface level inside the tank.

Example of storage in a closed system

In 1998, a Danish refinery built a new three-cut splitter for distillation of benzene. The fractionation column distils 250 tonnes of benzene from petrol every 24 hours, thus ensuring that the Danish requirements for a maximum benzene content in petrol of 1 per cent are complied with. In this connection, the installation constructed a new closed system, encompassing the fractionating column, storage, and distribution of benzene.

7.2.2 Storage tanks for principal group 2 substances, including diesel oil and other substances not mentioned under 7.1.1

The guidelines specified below apply to tanks larger than 50 m^3.

7.2.2.1 Storage

Products with a vapour pressure greater than 1.3 kPa[71] should be stored in tanks with fixed roofs. These tanks should be linked to a condensation plant in accordance with the provisions laid down in Appendix 3 of the Statutory Order on the limitation of emissions of vapours from storage and distribution of petrol. They may also, however, be fitted with an internal float with a primary seal, which should be constructed in a way that a total of at least 90 per cent of the vapours are retained when compared to corresponding tanks with fixed roofs and not fitted with equipment designed to retain vapours.

Products with vapour pressures less than 1.3 kPa (diesel oil, heavy fuel oil, and other substances with similar vapour pressures) should be stored in tanks with fixed roofs and a pressure/vacuum valve. Pressure/vacuum valves may be omitted on existing tanks not constructed for varying pressures corresponding to the range of the pressure/vacuum valve.

7.2.2.2 Painting tanks

The exterior walls and roofs of tanks situated above ground level should be painted in a colour with a total reflection coefficient for radiant heat of at least 70 per cent. For existing tanks, this can be carried out as part of standard regular maintenance work.

7.2.2.3 Filling tanks

Tanks should be filled by injecting all liquids below the surface level within the tank.

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[71] In this context, “vapour pressure” means the vapour pressure of the substance within the tank at the relevant storage temperature.

7.3 Silos

Silos for storage of solid substances should be fitted with suitable filters (V-pocket filters or filter cartridges), so that the limit values for emissions set up in these Guidelines for Air Emission Regulation can be complied with in connection with filling the silo.

Example of air terms for a silo filter

> An installation using hydrated lime in its production stores the lime in a silo. This silo must be equipped with an effective silo filter capable of retaining emissions of hydrated lime during injection into the silo. This filter must be able to reduce emissions to less than 10 mg/normal m^3.

8 Measurement of emissions from installations causing air-polluting

8.1 Introduction

The objective of this chapter is to provide guidelines on how to carry out measurements of emissions into air. It will describe methods of sampling and analysis, and set up guidelines on the design of sample-extraction sites, and on the measurement report.

8.2 List of recommended methods from the Danish Environmental Protection Agency

The Danish EPA reference laboratory for measurement of emissions into air [hereafter referred to as "the reference laboratory"] has published (at the end of 2000) a list of recommended methods regarding performance monitoring, AMS, and random testing. The list also includes method sheets with standard operating procedures for a number of common emission parameters (substances), as well as a method sheet for planning and reporting emission measurements.

The list of recommended methods is available on the reference laboratory website[72], where the full text in the method sheets can be seen and downloaded.

8.2.1 List of recommended methods, performance monitoring, and random testing

The recommended methods are listed in table 11. It is recommended to use these methods for performance monitoring and random testing. In special cases, it may be appropriate to apply modifications to these methods, or to use other methods of measurement than those recommended. In such cases, the choice of method should be justifiable and approved by the supervisory authority before measurement is carried out. If in doubt, please contact the reference laboratory.

8.2.2 List of recommended methods from the Danish Environmental Protection Agency

8.2.2.1 Performance monitoring and random testing

Table 11 features a list of recommended methods for parameters[73], based on the national and international standards available.

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[72] http://www.dk-teknik.dk/ref-lab/ref-lab.asp Address: Gladsaxe Møllevej 15, DK-2860 Søborg. Tel. (+45) 39 55 59 99

Table 11. Recommended methods for measurement of air pollution from installations (emission): Methods for performance monitoring and random testing

Substance group	Parameter	Recommended method			
		Standard	Title	Measurement range	Note
Dust	Particles measured as total dust	VDI 2066, Sheet 2 (1993)	*Messen von Partikeln; Manuelle Staubmessung in strömenden Gasen; Gravimetrische Bestimmung der Staubbeladung; Filterkopfgeräte (4 m*^{3}*/h & 12m*^{3}*/h)*	1-1,000 mg/m^3	To be used for measurement of high concentrations (> 50 mg/m^3)
		PrEN 13284-1 (1999)	*Stationary source emissions. Determination of low range mass concentration of dust.*	0-50 mg/m^3	To be used for measurement at low concentrations (<50 mg/m^3)
	Particles <10mm	VDI 2066/Sheet 2. (1993)	*Messen von Partikeln; Manuelle Staubmessung in strömenden Gasen; Gravimetrische Bestimmung der Staubbeladung; Filterkopfgeräte (4 m*^{3}*/hr & 12m*^{3}*/hr)*	1-1,000 mg/m^3	To be used for measurement of particles <10 µm
Inorganic compounds	Carbon monoxide (CO)	US EPA Method 10 (1995)	*Determination of Carbon Monoxide Emissions From Stationary Sources. rev. 4.*	0-1,000 ppm (0-1,250 mg/m^3)	
	Nitrogen oxides (NO_x)	US E.P.A. Method 7E, rev. 1 (1985)	*Determination of nitrogen oxide emissions from stationary sources. Instrumental analyzer* procedure.	Not stated	

	Hydrogen chloride (HCl)	DS/EN 1911, parts 1-3 (1997)	*Luftundersøgelse. Emissioner fra stationære kilder. Manuel bestemmelse af HCl.*	1 – 5,000 mg/m^3	
	Hydrogen fluoride (HF)	VDI 2470, Sheet 1 (1975)	*Messung gasförmiger Emissionen.* *Messen gasförmiger Fluor-Verbindungen.* *Absorptions-Verfahren.*	0.05 – 200 mg F^-/m^3.	
	Sulphur dioxide (SO_2)	ISO 7934 (1989) and the appendix Amd. 1 (1998)	*Stationary source emission – Determination of the mass concentration of sulfur dioxide –hydrogen peroxide/ barium-perchlorate/* *Thorin method.*	30-2,000 mg/m^3	Inspectors may choose between the two methods used to determine SO_2 contents
		DS/ISO 11632 (1998)	*Emissioner fra stationære kilder – Bestemmelsen af massekoncentrationen af svovldioxid – Ionchromatografisk metode.*	6-333 mg/m^3	Inspectors may choose between the two methods used to determine SO_2 contents
	Hydrogen sulphide (H_2S)	US EPA Method 11 *(1978)*	*Determination of Hydrogen Sulfide Content of Fuel Gas Streams in Petroleum Refineries*	Not stated	
Metals	Mercury (Hg)	Final draft PrEN 13211 (2000)	*Air quality – Determination of the concentration of total mercury in stationary source emissions.*	0.001-0.5 mg/m^3	

Metals *(continued)*	Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Manganese (Mn), Nickel (Ni), Lead Pb), Antimony (Sb), Thallium (Tl), and Vanadium (V).	CEN/TC 264 N404 (WI 00264013) *(2000)*	*Determination of Total Emission of Specific Elements.*	No final range	Not yet adopted by the CEN, but sufficiently far advanced to be recommended as a method. Until this standard is formally adopted, US EPA Method 29, VDI 3868 Bl.1 and VDI 2268 may be used. Particles should be measured according to US EPA Method 29 (plan filter), Gaseous metals should be measured according to VDI 3868 Bl. 1, and digestion of filter and analyses should be carried out according to VDI 2268.
Volatile organic compounds (VOC)	Total organic carbon (TOC)	*EN 12619:1999*	*Stationary source emissions Determination of the mass concentration of total gaseous organic carbon at low concentrations in flue gasses – continuous flame ionisation detector method*	0-20mg C/m³(n)	Used for measurement of flue gases. The measurement range may be extended until a new standard becomes available for measurement of flue gases at high levels, (prEN 13526) is available.
		VDI 3481 sheet 3 *(1995)*	*Determination of volatile organic compounds, especially solvents – FID*	From 1-2 mg C/m³	Used for measurement in outlets without combustion.
Secondary parameters	Volume flow	ISO 10780 (1994)	*Stationary Source Emissions – Measurement of velocity and volume flow-rate of gas streams in ducts*	5- 50 m/s	
Secondary parameters *(continued)*	Carbon dioxide (CO_2) Oxygen (O_2)	US EPA Method 3A (1989)	*Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources*	Not stated	
	Water (H_2O)	US EPA Method 4 (1977) (Rev. 3, 5/94)	*Determination of Moisture Content in Stack Gases*	Not stated	
	Temperature	IEC Publication 584-2 (1989)	*Thermocouples*	Down to -40 °C, up to 1,600 °C *(depending on type) (tolerance class 2).*	

8.2.3 List of methods, AMS

Use of the methods of measurement listed in table 12 below is recommended in connection with AMS. In special cases, it may be appropriate to apply modifications to these methods, or to use other methods of measurement than those recommended here. In such cases, the choice of method should be well founded and approved by the supervisory authority before measurement is carried out.

8.2.3.1 Measurement of installation

Generally speaking, these standards do not include measurement ranges. Instead, the requirements are related to measurement ranges and/or concentrations measured.

Table 12. Recommended methods for measurement of air pollution from installations (emission): Methods for installation measurement using Automatic Measuring Systems (AMS)

Substance group	Parameter	Recommended method		
		Standard	Title	Note
Dust	Particles measured as total dust	DS/ISO 10155 *(1995)*	Emissioner fra stationære kilder. Automatisk overvågning af partikel-mængder. Præstationskrav, prøvningsmetoder og specifikationer.	(Translation) Emissions from stationary sources. Automated monitoring of particle quantity. Performance requirements, sampling methods and specifications.
Inorganic compounds	Carbon monoxide (CO) Carbon dioxide (CO_2) Oxygen (O_2)	ISO/CD 12039.2 *(1995)*	Stationary source emissions – Determination of the volumetric concentration of CO, CO_2 and oxygen. Performance characteristics and calibration of an automated measuring system	
	Nitrogen oxides (NO_X)	DS/ISO 10849 *(1996)*	Emissioner fra stationære kilder. Bestemmelse af nitrogenoxid-koncentrationen. Funktionsdata for automatisk måleudstyr.	(Translation) Emissions from stationary sources. Determination of concentration of nitrogen oxide. Performance characteristics and calibration of an automated measuring system
	Sulphur dioxide (SO_2)	DS/ISO 7935 *(1996)*	Emissioner fra stationære kilder – Bestemmelse af svovldioxin- koncentrationer – Præstationskrav for automatiske målemetoder.	(Translation) Emissions from stationary sources. Determination of sulphur dioxide concentrations. Performance requirements for automated measuring methods.

8.2.3.2 Design of sampling site

For the purposes of these Guidelines, ”sampling site” means the area of space required for a sampling location, i.e. the area where sampling equipment is placed, and from where sampling technicians are able to handle and operate such equipment.

Note that all access to sampling sites must be entirely safe and in accordance with current regulations issued by the Danish Working Environment Authority.

It is necessary to distinguish between designs of sampling sites at large-scale installations, where measurement is carried out regularly, and small installations, such as outlets, where only very few measurements may be called for. This makes it unfeasible to establish definite guidelines. The following, however, gives some recommendations which should be observed at large-scale installations where repeated measurements are called for, and where measurement is carried out at heights greater than 6 m above ground level:

Sampling sites should

- be 3-5 m² in size (the exact size of the sampling platform depends on the type of measuring equipment used),
- be able to support a point load of at least 400 kg,
- have handrails built with kickboard approximately 0.25 m in height and two rails at heights of approximately 0.5 m and 1.2 m,
- be situated in a manner ensuring that the railings do not obstruct access to sampling apparatus,
- include stairs or a fixed ladder leading to the sampling site. Where the stairs or ladder meet the sampling site, the railings must have gates that close automatically or a similar safety device,
- feature 230V electric connections,
- have a pulley or similar device to lift equipment,
- have good lighting and ventilation,
- include protection against severe weather,
- have a non-skid surface.

The conditions regarding safety at sampling sites are regulated by the Danish Working Environment Authority. This means that no terms should be included in environmental approvals for these facilities.

8.2.3.3 Design of sampling location

For the purposes of these Guidelines, “sampling location” means the point where emission measurement is carried out within a given duct. Sampling locations in stacks or ventilation ducts are typically made accessible by means of nozzles for securing exhaust probes

The location of such sampling locations and the number of sampling ports in a certain duct are very significant for the quality of the measurement results.

8.2.3.3.1 Particle measurements and volume-flow measurements

As gas velocities, particle concentrations, and distributions of particle sizes may vary within a given duct cross-section, sampling locations should be designed to facilitate extraction of representative samples in the gas flow. This is ensured by creating opportunities for traversing across the entire duct cross section, by inducing good gas mixture (i.e. avoiding layering), and by creating uniform flow conditions throughout the entire cross section.

8.2.3.4 Location of sampling location

- Cross sections for measurement should be placed at a right angle to the gas flow.
- Where possible, sampling locations should be located in vertical ducts.
- Horizontal ducts should be rectangular.
- There should be a straight section M_1 without obstacles before the sampling location. For circular ducts, the length of M_1 should be at least 5 x D, and for rectangular ducts, M_1 should be at least 2.5 x (H + W). At existing installations, a shorter straight section is acceptable if the number of sampling points is increased, see section 8.2.3.6.
  - D = inside diameter of a circular duct.
  - H = inside height of a rectangular duct.
  - W = inside width of a rectangular duct.
- There should be a straight section M_2 without obstacles after the sampling location. For circular ducts, the length of M_2 should be at least 1 x D, and for rectangular ducts, M_2 should be at least 0.5 x (H + W). (At existing installations, a shorter straight section is acceptable if the number of sampling points is increased, see section 8.2.3.6.
- There should be a straight section M_2 after the sampling location and before the opening of the outlet of at least 5 x D or 2.5 x (H + W) in length.
- If the gases in a duct rotate, a flow straightening device should be fitted before the entrance of the straight section of the duct.
- Sampling locations should be located in a manner ensuring that they do not interfere with AMS measurements or reference measurements.

If the measurement technician considers that a given sampling location has not been designed in accordance with current regulations, and that this fact entails greater uncertainty as to measurement results, the relevant installation and supervisory authorities should be notified before measurement commences.

8.2.3.5 Number and design of sampling ports

General instructions:

- The sockets used must be 4" BSP sockets with an internal thread. Deviations may be made from the 4" dimension, if duct dimensions or duct parameters so dictate. Such deviations should always be discussed with an accredited laboratory.
- Socket depth should be between 30 and 70 mm.
- There should be at least 1.5 m of open space in front of each sampling port to facilitate insertion and removal of sampling apparatus (probes, etc.) from the duct. If the diameter of a given duct (height/width) is greater than 1 metre, the area of free space in front of each sampling port should extend to a distance equal to the duct diameter + 0.5 metres outside each sampling port.
- Where measurement must be carried out for several parameters at the same time, extra sampling ports should be fitted, particularly if the parameters to be measured include particles or metals.
- All sampling ports are fitted with plugs. It must be possible to remove such plugs without difficulty.
- Ducts with thick walls (e.g. insulation) should be fitted with an opening to the outside of the duct itself (where the sampling ports are located). Such an opening should be rectangular, with inside

measurements of 100 x 500 mm, or should be dimensioned in consultation with an accredited laboratory.

Circular ducts:

- Two sampling ports should be placed 90° apart.
- Where D + P is greater than 3 m, a total of 4 sampling ports should be placed at relative angles of 90° to each other. D = internal diameter and P = port depth.

See also figure 7.

Rectangular ducts:

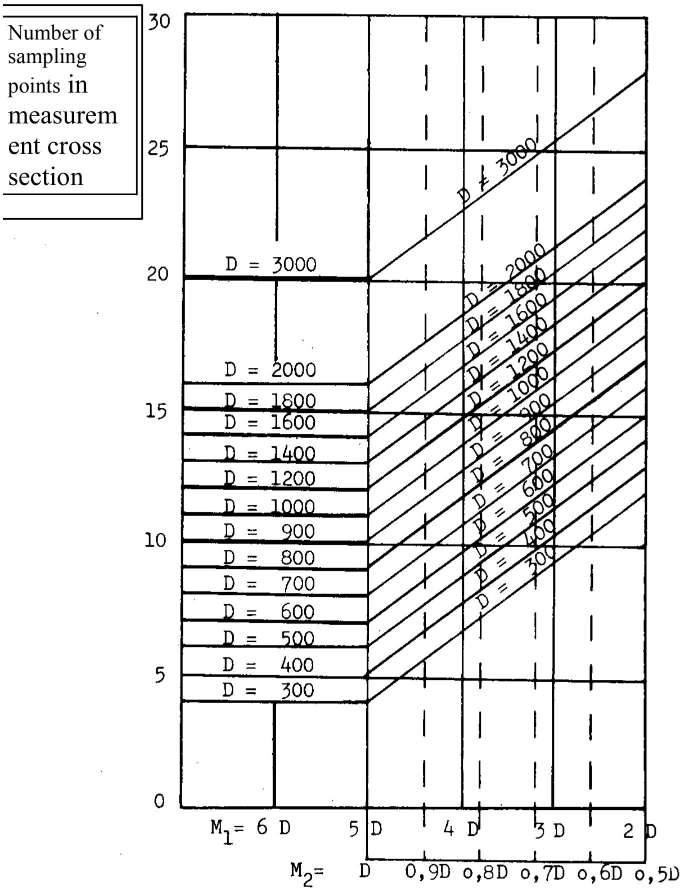
- The sampling ports should be fitted on one of the vertical sides of the duct, so that the required number of sampling points can be distributed evenly across the cross section.
- Thus the number of sampling ports depends on the number of sampling points and the dimensions of the duct. See section 8.2.3.6 for details concerning the number of sampling points.

See also figure 8.

8.2.3.6 Number of sampling points

The number of sampling points in a cross section is based on the area of the cross section, as well as on the length of the straight duct sections before and after sampling locations.

The required number of sampling points in both circular and rectangular cross sections must be calculated as illustrated in the following diagram:



D = internal diameter in mm for circular measurement cross sections

D = 0.5 (H+B) mm for rectangular measurement cross sections

H = internal height in mm

B = internal width in mm

M_1 = length of straight duct without interruptions before the measureme

M_2 = length of straight duct without interruptions after the measurement

Figure 6 Number of sampling points in cross sections

In circular cross sections, the number of sampling points should be divisible by four. The sampling points should be distributed symmetrically along two diameters placed at right angles to each other.
For short, straight duct sections, the number of sampling points should be registered for both M_1 and M_2. The highest number of sampling points should then be selected.

Example 1

A circular cross section has a D = 1,000 mm. M_1 is greater than or equals 5 x D and M_2 is greater than or equals 1 x D. According to the diagram, there should be 11 sampling points. The number of sampling points should, however, be divisible by four. This means that a total of 12 sampling points should be chosen instead.

Table 13. Location of sampling points in a circular cross section

Sampling point along cross section	Number of sample points in a circular cross section						
	2	4	6	8	10	12	14
1	85	93	96	97	97	98	98
2	15	75	85	90	92	93	94
3		25	70	81	85	88	90
4		7	30	68	77	82	85
5			15	32	66	75	80
6			4	19	34	64	73
7				10	23	36	63
8				3	15	25	37
9					8	18	27
10					3	12	20
11						7	15
12						2	10
13							6
14							2

This table illustrates the position of sampling points within a circular cross section. The table indicates the distances from the inside duct wall to the various sampling points. These distances are given as percentages of the duct diameter D.

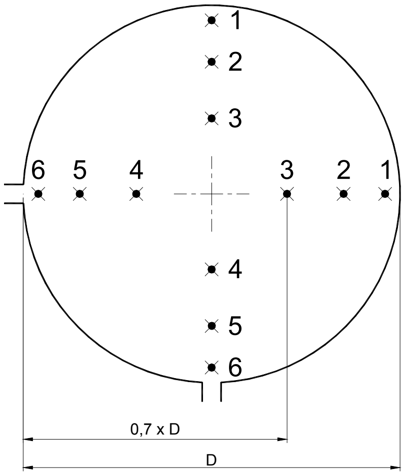


Figure 7 Example of sampling point location in a circular cross section

Example 2

In a rectangular cross section at an existing installation, H = 1,100 mm and W = 700 mm. The straight sections without any disruptions of flow are short, M_1 = 2.5 x D and M_2 = 0.6 x D. The theoretical diameter D = 0.5 x (1,100 + 700) = 900. According to the diagram, there should be 17 sampling points. A total of 3 x 6 = 18 sampling points should then be selected. The rule for circular ducts and rectangular ducts is that figures should then be rounded up.

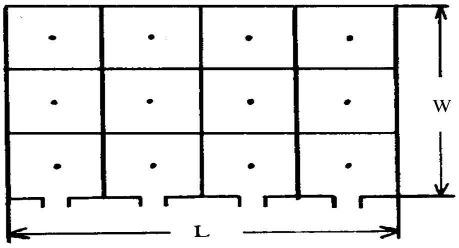


Figure 8 Example of the distribution of 12 sampling points in a rectangular cross section

8.2.3.7 Sampling gaseous air pollutants

When sampling gaseous air pollution, in principle the samples should be taken at a sufficient number of points within the cross section to arrive at a representative volume of the average concentration. Under good flow conditions, where it is estimated that concentrations are not layered in the cross section, sampling may be carried out from a single point.

In general, the requirements on measurement-position design outlined in section 8.2.3.5 also apply to measurements of gas. In certain situations, such as when measuring in circular ventilation ducts, it may be sufficient to have access to the duct via two 1” BSP sockets placed 90° apart. If an installation wishes to deviate from the requirements on the design of sampling locations, as specified in section 8.2.3.5, this should be approved by the supervisory authorities and an accredited laboratory.

8.2.3.8 Ducts less than 300 mm in diameter

Special rules on the measurement of particles and volume flow apply to circular ducts with a diameter of less than 300 mm (0.5 x (H + W) <300 mm for rectangular ducts). If the requirements concerning distance, as specified in section 8.2.3.6, are complied with, particle measurements may be carried out isokinectically at a single point in the middle of the duct. Measurements of volume flow are traversed as usual. However, no measurements should be carried out at points situated less than 30 mm from the duct walls.

It may be helpful to select smaller sockets for smaller ducts. If an installation wishes to deviate from the requirements on socket dimensions, etc., as specified in section 8.2.3.5, this should first be approved by the supervisory authorities and an accredited laboratory.

8.2.4 Performance monitoring and random testing

8.2.4.1 Measurement report

Performance monitoring or random testing should be reported in the form of an accredited measurement report. Such reports must, as a minimum, meet the requirements laid down in DS/EN 45 001 or EN/ISO 17025, as stipulated in each accreditation.

The following points should be included in a measurement report:

- the name and address of the test laboratory, the site tested, and the person or enterprise requesting the test,
- unambiguous identification of the report (e.g. through a serial number) and each page therein, and indication of the total number of pages,
- a description and identification of the test subject (outlet or stack),

- date and time of sampling,
- identification of test/sample specification (reference) or a description of the sample method or procedure used,
- a description of the sample-extraction procedures,
- any deviation from, addition to, or omissions regarding test specifications, as well as any other information of importance regarding a specific sample/test,
- identification of any non-standard test/sample method used, including deviations from recommended methods,
- measurements, surveys, and results, supported as necessary by tables, diagrams, drawings and photographs, and by records of all errors identified,
- a statement regarding measurement uncertainties,
- signature and job title or similar identification of the person(s) assuming technical responsibility for the test report, as well as the date of issue of the report,
- a statement that the sample results apply only to the sample subjects,
- a statement that the report may not be reproduced, except in its entirety, without written permission from the test laboratory.

All quantitative results must include statements regarding calculated or estimated uncertainty. This means that the total uncertainty for a given measurement must be calculated or estimated and included in the report. In addition to the uncertainty associated with the measurement method used, other factors include the design of sampling locations, the measurement process, and the composition of the gas may affect the total uncertainty involved.

A measurement report must include a description (sketch) of the design of the relevant sampling location, including information on duct dimensioning and orientation, the length of straight sections before and after the sampling location, and the number of sampling ports and their relative positions. All matters that influence measurement uncertainty must be described.

The measurement report must include a measure for the level and type of production during the control period. For example, this may concern “energy” and the type of coal involved, or the number of objects painted, their surface, and the type of coating used. For certain types of production plants, it may be sufficient to state whether production is rated as “normal” or “maximum”.

9 Conversions regarding surplus air and moisture content

In the following, all percentages are volume % dry gas.

9.1 Conversion to CO_2%

$$C_{ref.} = \frac{CO_2\%_{(ref.)}}{CO_2\%_{(measured)}} \cdot C_{measured}, \text{ where}$$

$C_{ref.}$ = concentration at reference $CO_2\%$ $\left[mg / normal\ m^3_{(ref.)}\right]$

$C_{measured}$ = measured concentration $\left[mg / normal\ m^3_{(measured)}\right]$

$CO_2\%_{(ref.)}$ = reference $CO_2\%\left[Vol\%\right]$

$CO_2\%_{(measured)}$ = measured $CO_2\%\left[Vol\%\right]$

If the substance is measured at a concentration of 150 mg/normal m^3 at 5% CO_2, at 10% CO_2 this will correspond to:

$$\frac{10\%}{5\%} \cdot 150\ mg / normal\ m^3 = 300\ mg / normal\ m^3_{(ref.)}$$

9.2 Conversion to reference O_2%

$$C_{ref.} = \frac{21 - O_2\%_{(ref.)}}{21 - O_2\%_{(measured)}} \cdot C_{measured}, \text{ where}$$

$C_{ref.}$ = concentration at reference $O_2\%$ $\left[mg/normal\ m^3_{(ref.)}\right]$

$C_{measured}$ = measured concentration $\left[mg/normal\ m^3_{(measured)}\right]$

$O_2\%_{(ref.)}$ = reference $O_2\%\left[Vol\%\right]$

$O_2\%_{(measured)}$ = measured $O_2\%\left[Vol\%\right]$

If the substance is measured at a concentration of 150 mg/normal m^3 at 15% O_2, at 10% O_2 this will correspond to:

$$\frac{21 - 10\%}{21 - 15\%} \cdot 150\ mg / normal\ m^3 = 275\ mg / normal\ m^3_{(ref.)}$$

9.3 Conversion between $CO_2\%$ and $O_2\%$

$$O_2\% = 21 - \frac{21 . CO_2\%_{(measured)}}{CO_2\%_{(max.)}}$$

9.4 Conversion between $O_2\%$ and $CO_2\%$

$$CO_2\% = \frac{(21 - O_2\%_{(measured)}) . CO_2\%_{(max)}}{21}$$

The following values for ***$CO_2\%_{(max)}$*** can be used (for rough calculations)

Wood and straw:	20%
Household waste:	19%
Coal:	19%
Heavy fuel oil:	16%
Light fuel oil:	15%
Natural gas:	12%

$CO_2\%_{(max)}$ gives $CO_2\%$, when combustion is without air surplus.

9.5 Conversion from dry to moist volume flow

The definition of moisture percent in the air as used in OML calculations expresses the proportion of water vapour in relation to the total volume (the volume H_2O / total volume of air (including water vapour))[74]. Conversion between the total volume and dry volume is according to the following equation:

$$Q_{moist} = Q_{dry} . \frac{100}{100 - H_2O\%}$$, where

Q_{moist} = the total amount of moist gas $\left[m^3, moist / h\right]$

Q_{dry} = amount of dry gas $\left[m^3, dry / h\right]$

$H_2O\%$ = volume percentage of water vapour in relation to the total amount of moist gas $\left[Vol\%\right]$

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[74] Moisture percentages should always be expressed as mentioned above. Certain methods of measurement (e.g. gravimetric determination of water content) allow the possibility of stating results as the amount of water vapour in relation to the dry volume of air. This result should always be converted to Vol% H_2O before correction.
Recalculation from ”dry” Vol% H_2O to Vol% H_2O:
Vol% H_2O = Vol% H_2O(dry) * 100 / (100 + Vol% H_2O(dry)).

9.6 Conversion from dry to moist concentration

$$C_{moist} = C_{dry} \cdot \frac{100 - H_2O\%}{100}$$, where

C_{moist} = concentration in moist gas $[mg / m^3, moist]$

C_{dry} = concentration in dry gas $[mg / m^3, dry]$

$H_2O\%$ = volume percentage of water vapour in relation to the total amount of moist gas $[Vol\%]$

9.7 Conversion from ppm to mg/normal m^3

- 1 ppm SO_2 = 2.93 mg/normal m^3 SO_2 at 0^oC and 101.3 kPa.
- 1 ppm NO = 1.34 mg/normal m^3 NO at 0^oC and 101.3 kPa.
- 1 ppm NO_2 = 2.05 mg/normal m^3 NO_2 at0^oC and 101.3 kPa.
- 1 ppm CO = 1.25 mg/normal m^3 CO at 0^oC and 101.3 kPa.
- 1 ppm CO_2 = 1.98 mg/normal m^3 CO_2 at 0^oC and 101.3 kPa.
- 1 ppm C = 1.87 mg/normal m^3 C at 0^oC and 101.3 kPa.
- 1 ppm HCl = 1.63 mg/normal m^3 HCl at 0^oC and 101.3 kPa.

9.8 Units of energy and output

1 J/s = 1 W
1 MJ/s = 0.8598 Gcal/h
1 kJ = 2,778 x 10^{-4} kWh
1 kWh = 3,600 kJ
1 kWh = 859.8 kcal
1 kcal = 1.163 x 10^{-3}kWh
1 kcal = 4.1868 kJ

9.9 Prefixes

peta	(P)	10^{15}
tera	(T)	10^{12}
giga	(G)	10^{9}
mega	(M)	10^{6}
kilo	(k)	10^{3}
milli	(m)	10^{-3}
micro	(µ)	10^{-6}
nano	(n)	10^{-9}
pico	(p)	10^{-12}
femto	(f)	10^{-15}
atto	(a)	10^{-18}

10 Recommended limit values for emissions and inspection rules for thermal and catalytic oxidation installations for the destruction of organic solvents

10.1 Introduction

This chapter deals with thermal and catalytic oxidation installations used for destruction of organic solvents containing carbon, oxygen and hydrogen. Where other elements such as halogens and nitrogen are involved, please refer to the rules in chapter 3.

10.2 Operating conditions

Destruction of organic compounds should not commence before the installation reaches its optimal operating conditions (e.g. temperatures at the set points).

10.3 Limit values for emissions

10.3.1 Limit value for emissions of TOC (Total Organic Carbon gases)

The limit value for emissions of TOC is set at 1 % by weight of the expected maximum concentration in g TOC/normal m^3 added to the installation (averaged over 1 hour), but normally up to a maximum of 100 mg TOC/normal m^3 and down to a minimum of 20 mg TOC/normal m^3. Reference condition is the actual concentration of oxygen.

10.3.2 Limit value for emissions of CO

100 mg/normal m^3 at actual concentration of oxygen.

10.3.3 Limit value for odours

At first, the limit value for emissions of odours can be set at 4,000 LE/normal m^3 at the actual concentration of oxygen. However, in some cases, for technical or financial reasons, it may be necessary to set a high limit value. (In such cases more than 95 % purification or abatement should be required.)

10.3.4 Limit value for emissions of NO_X

200 mg/normal m^3 calculated as NO_2 at actual concentration of oxygen.

10.4 Calculation of the height of outlets

The source strength which has the greatest dispersion coefficient found in sections 10.4.1 – 10.4.5, should be used to calculate the height of stacks and other outlets, see chapter 4.

10.4.1 Unburned specific organic compounds

Source strength is equal to the unburned part of the specific organic compounds measured or calculated after purification or abatement.

10.4.2 TOC (Total Organic Carbon gases)

As a basis, calculations of dispersion coefficients should use a C-value of 0.1 mg TOC/m^3. This C-value should take into account the fact that unknown, harmful substances such as aldehydes are formed during combustion. However, at effective combustion plants, most of the substances emitted will be light hydrocarbons such as methane, ethane, and propane. If it is possible to confirm that most of the TOCs emitted comprise these light hydrocarbons, the C-value can be increased to 1 mg/m^3

10.4.3 CO

The source strength for CO is calculated on the basis of the limit value for emissions of CO.

10.4.4 NO$_X$

The source strength for NO$_x$ is calculated on the basis of the limit value for emissions of NO$_X$.

10.4.5 Odours

The source strength for odours is calculated as described in section 4.5.

10.5 Monitoring

10.5.1 AMS

1. If the mass flow exceeds 25 kg TOC/hour, the installation should be equipped with automatic measuring and registration devices to monitor emissions of TOCs from the installation.

2. The installation should establish continuous monitoring and registration of temperature. The measuring point and set point for temperature measurements should be approved by the supervising authority. Normally, measurement of the highest temperature occurring at the installation will be relevant.

Refer also to section 5.2.4.

10.5.2 Performance measurements

Performance measurements for TOC should be carried out with a flame ionisation detector (FID).

11 Glossary

Random tests	Random tests are where emission measurement is carried out at intervals, such as 6 times a year. Random testing is used at installations with very significant air pollution, where it is not technically or financially feasible to use AMS inspection.
Recommended methods	At the end of 2000, the Danish Environmental Protection Agency reference laboratory for measurement of emissions into air has published a list of recommended methods for performance monitoring, AMS, and random testing. The list also includes method sheets with standard operating procedures for a number of common emission parameters (substances), as well as a method sheet for planning and reporting emission measurements. The list of recommended methods is available on the reference laboratory website http://www.dk-teknik.dk/ref-lab/ref-lab.asp, where the full text in the method sheets can be seen and downloaded.
Terms	The objective of terms for air pollution is to ensure that such pollution is kept below a specific limit. These terms may be presented in various ways: Operating terms Operating terms are requirements that affect the design and operation of installations and have an impact on air pollution from such installations. Such requirements might involve the maximum capacity of the power plant or the use of specific raw materials. Emission terms Emission terms are requirements for air quantities and the concentration of substances emitted by installations, or requirements regarding maximum hourly emissions. Terms for outlet heights The objective of terms specifying outlet heights is to ensure compliance with C-values.
Thinner mix	Thinner mixes are defined as a mixture of at least three organic solvents – or at least two organic solvents for water-based paints – of which the relative proportion of a single organic solvent does not exceed 80 per cent by weight. If the mix contains three or more organic solvents, three of these organic solvents must each account for more than 2 per cent by weight . None of the organic solvents included in the mix may be substances belonging to Group 1 or Group 2, class I. The definition of thinner mixes has been changed as a consequence of a review of the use and composition of thinner mixes. A new C-value of 0.15 mg/m^3 has been set for thinner mixes. Thinner mixes are still classified as belonging to Group 2, organic substances, class III. Thinner mixes include organic solvents in paint products used in paint shops (iron, metal, plastic), at car paint shops, in furniture manufacture, etc.