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Section 18

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18 SUMMARY OF ENVIRONMENTAL REGULATIONS18.1 Introduction

Many of the more highly industrialised countries have enacted legislation to restrict the emission to the atmosphere of certain classes of material present in the products of combustion of fossil fuels. The stack gases from fluidised combustor installations may contain compounds in the following categories:

- (a) nitrogen, oxygen and rare gases.
- (b) carbon dioxide and water vapour.
- (c) sulphur compounds, present principally as sulphur dioxide.
- (d) solid particles sufficiently small to be entrained by the gas stream.
- (e) oxides of nitrogen.
- (f) unburnt combustible gaseous compounds such as carbon monoxide and hydrocarbons.
- (g) hydrogen chloride together with varying amounts of other chlorides.
- (h) trace element materials such as alkali metal compounds and heavy metal compounds.

Currently the environmental regulations are concerned with emissions of compounds in categories (c), (d) and (e) above. Emissions of unburnt combustible gases are also controlled in a few countries. However only a negligible quantity of these last compounds is likely to be present in the stack gases from fluidised combustor installations operating at excess air levels recommended in this Manual. Entrained particulate material is usually present in fluidised combustor stack gases even when gas cleaning equipment is installed and there is no visible smoke. The compounds present in only trace quantities are found both in the entrained particulate material and in the gas stream itself. The concentrations of trace element compounds are normally well below any levels which might give rise to concern about the environment. However trace element emissions can be of importance through their influence on fluidised combustor design. See Sections 12.6, 14.2.3.3 and 14.2.4.

As a guide to acceptable emission levels the limits currently in force in a number of countries for sulphur dioxide, particulate material and nitrogen oxides emissions are summarised in table form in this Section. It must be emphasised that the values quoted are for guidance only. The subject of environmental regulations is very complicated. Both national and regional standards exist in most countries, the methods of expression vary widely between countries and the regulations are frequently altered and updated. For any particular application the emission limits will be determined by the current local regulations which should be consulted.

18.2 Factors Affecting Allowable Emission Limits

The aim of environmental legislation in all countries is to prevent further increases in the ambient concentrations of certain pollutants in the atmosphere and to obtain a progressive reduction in concentrations to more acceptable levels in some regions. The manner in which the legislation is framed to achieve this aim varies considerably from country to country according to the urgency of the situation and the technical considerations involved and also, in some countries, according to political considerations (18.1).

In most countries initial legislation has specified the maximum allowable sulphur contents of fuel oil grades as a means of controlling emissions of sulphur dioxide. The emission of "dark" or "black" smoke, as defined by various comparative visual scales, has also been controlled. More sophisticated control methods have subsequently been adopted by the more highly industrialised countries.

The approaches to pollution control that are currently adopted fall into three main groups

- (a) overall "blanket" control on the quantity of pollutant that may be emitted from a plant; e.g. US legislation.
- (b) control of quantity of pollutant emitted but with due regard to local conditions which may allow greater or less than standard quantities to be emitted whilst maintaining an acceptable ambient air quality; e.g. Japanese legislation.

- (c) control by dispersion of the pollutant in the upper atmosphere; e.g. UK legislation through stack height specification.

In some countries combinations of these approaches are found.

Besides these different approaches to pollution control the following factors may affect the maximum allowable emission levels of a particular pollutant in a given country.

1. Date of installation of equipment. Dispensations are generally made for older and existing equipment to give time for improvements or replacements to meet the more stringent limits applicable to new installations.
2. Location. In some countries individual state legislation may be stricter than the federal regulations. Additionally, most countries have designated certain regions as "special" where stricter regulations apply. Reasons for "special" regions include: high population density, high concentration of industrial installations, geographic and climatic peculiarities, national parks, recreational areas and wild life reservations, and the conservation of buildings of special interest.
3. Scale of operation. Emission limits are generally linked to the scale of operation of the installation and may become more restrictive the larger the scale.
4. Type of application. It is recognised that it is technically more difficult to restrict emissions from some applications than from others. Also, a given country may wish to encourage certain specific industries. All these considerations are reflected in the environmental legislation. Relaxations in emission limits are generally allowed for domestic applications.
5. Fuel type. As with the type of application, technical and economic factors connected with the use of different fuels are reflected in the emission legislation.
6. Period of operation. Dispensations on emission limits are usually allowed for start-up and cleaning of equipment during operation. Emission limits may also be exceeded for short periods and final values are calculated on an average or rolling average basis.
7. Stack height. Minimum stack heights are specified in various countries to ensure adequate dispersal and dilution of pollutants in the atmosphere so that given ground level concentrations are not exceeded.

18.3 Environmental Regulations

18.3.1 Notes to the tables

1. Entries have been compiled from data given in references (18.2), (18.3) and (18.4). Values of maximum sulphur content of fuel oils are quoted in % w/w. Emission limits for sulphur oxides, particulates and nitrogen oxides are quoted for the following conditions.

National standards

Yearly averages

Steady state, full load operation

New installations

Bulk steam and power generation applications. (Unless otherwise stated)

Relaxation of the limits quoted is allowed in many countries for existing installations, for domestic applications, for special uses and for temporary operating conditions. Limits may be more stringent in special regions of each country and examples are given.

2. The tabulated values are quoted for guidance only. Regulations are frequently updated.
3. The size of a unit is expressed in terms of the thermal input, Q , MW or the flue gas volume at NTP, V , m^3/h , or the fuel mass flow, M_x , kg/h.
4. The sulphur content of fuels is expressed as % w/w.
5. Smoke appearance is expressed as a number and a letter denoting the comparative scale used. R = Ringelmann, B = Bacharach
6. Sulphur emissions are expressed in terms of sulphur dioxide equivalent.
7. Nitrogen oxide emissions are expressed in terms of equivalent NO_2 as this is the most toxic oxide. The main component in the stack gases is NO , which is gradually oxidised to NO_2 in the atmosphere; see Section 12.2.2.
8. Conversion units. To avoid confusion the tabulated values are given in SI units only. The following conversion factors may be used.

Power

1 MW = 3.412×10^6 Btu/h
= 0.86×10^6 k cal/h
= 860 thermies/h (th/h)
100 MW = 360 GJ/h
1100 MW = 4 TJ/h

Concentration

1 mg/m³ = 1 mg per Normal m³
= 1000 µg/m³
= 0.35 ppm SO₂ v/v
= 0.49 ppm NO₂ v/v
100 ng/J = 0.233 lb/(10⁶ Btu)
= 418.5 mg/th
= 418.5 mg/(10³ k cal)

Note: These concentrations are based on heat input.

18.3.2 Tabulated data

Data is listed by country in the following order.

Australia
Austria
Belgium
Canada
Denmark
Finland
France
Greece
Holland
Italy
Japan
Norway
Singapore
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States of America
West Germany

AUSTRALIA

Maximum allowable fuel sulphur content % w/w

No National standards.
Each State has its own requirements which are being progressively adjusted towards the recommended National levels.

- e.g. New South Wales
 - generally
 - metropolitan areas (new plant)

Maximum allowable emissions

- Sulphur dioxide

National
State requirements are currently based on stack height as in UK.

100 mg/m³

- Particulate material

National

250 mg/m³

R ≤ 1

- Nitrogen oxides

National

500 mg/m³

as NO₂

Solid fuels

Liquid fuels

oils 2.5
" 1.0

<u>AUSTRIA</u>	Solid fuels	Liquid fuels
<p><u>Maximum allowable fuel sulphur content</u> % w/w</p>		<p>gas oil 0.3 light fuel oil 0.75 medium fuel oil 1.5 heavy fuel oil 2.0</p>
<p><u>Maximum allowable emissions</u></p> <p>- <u>Sulphur dioxide</u></p>		
<p>- <u>Particulate material</u></p>	<p>R ≤ 2</p>	<p>150 mg/m³</p>
<p>- <u>Nitrogen oxides</u></p>		

<u>BELGIUM</u>	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.3 light fuel oil 0.5 24 cSt fuel oil 1.9 85 cSt fuel oil 1.9 175 cSt fuel oil 2.2 370 cSt fuel oil 2.8
Special protection zones		all 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u> (at stoichiometric conditions)		
Q < 1.2 MW		850 mg/m ³
Q ≥ 1.2 MW		4700 mg/m ³
(depends on stack height)		
Power plant		5000 mg/m ³
- <u>Particulate material</u>		
Q > 2.4 MW		60 ng/J
Power plant	coal > 20% ash 500 mg/m ³ coal < " 350 "	B ≤ 4
Other applications		
- general) - special zones) solid fuels	300 mg/m ³ 150 ng/J	
Other applications (liquid fuels)		
Q < 0.2		B ≤ 3
0.2 < Q < 2.3 MW		B ≤ 4
Q > 2.3 MW		B ≤ 5
Domestic heating	143 ng/J	B ≤ 3
- <u>Nitrogen oxides</u>		

<u>CANADA</u>	Solid fuels	Liquid fuels																
<p><u>Maximum allowable fuel sulphur content</u> % w/w</p>																		
<p>Federal objectives plus Provincial and Municipal control e.g.</p>		<table border="0"> <tr> <td></td> <td>(a)</td> <td>(b)</td> <td>(c)</td> </tr> <tr> <td>light fuel oil</td> <td>0.5</td> <td></td> <td>0.4</td> </tr> <tr> <td>medium "</td> <td>1.5</td> <td></td> <td>1.0</td> </tr> <tr> <td>heavy "</td> <td>1.5</td> <td>2.5</td> <td>1.5</td> </tr> </table>		(a)	(b)	(c)	light fuel oil	0.5		0.4	medium "	1.5		1.0	heavy "	1.5	2.5	1.5
	(a)	(b)	(c)															
light fuel oil	0.5		0.4															
medium "	1.5		1.0															
heavy "	1.5	2.5	1.5															
<p>(a) Toronto, (b) Quebec, (c) Montreal</p>																		
<p><u>Maximum allowable emissions</u></p>																		
<p>- <u>Sulphur dioxide</u></p>																		
<p>- <u>Particulate material</u></p> <p>Quebec 3 < Q < 15 MW Q > 15 MW</p>		<p>60 ng/J 45 ng/J</p>																
<p>- <u>Nitrogen oxides</u></p>																		

<u>DENMARK</u>	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.5
		fuel oil 2.5
Copenhagen		fuel oils 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
- <u>Particulate material</u>		
Q < 30 MW		2.5 g/kg fuel
30 < Q < 300 MW		1.5 "
Q > 300 MW		1.0 "
- <u>Nitrogen oxides</u>		

<u>FINLAND</u>	Solid fuels	Liquid fuels
<p data-bbox="43 342 509 420"><u>Maximum allowable fuel sulphur content</u> % w/w</p> <p data-bbox="43 763 509 807"><u>Maximum allowable emissions</u></p> <ul data-bbox="43 818 509 1581" style="list-style-type: none"><li data-bbox="43 818 509 862">- <u>Sulphur dioxide</u> <li data-bbox="43 1183 509 1227">- <u>Particulate material</u> <li data-bbox="43 1537 509 1581">- <u>Nitrogen oxides</u>		<p data-bbox="1084 442 1383 486">gas oil 0.8</p>

FRANCE	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.3 fuel oil No. 1 2.0 fuel oil No. 2 4.0
Special protection zones category 1 e.g. central Paris category 2 e.g. suburban Paris		all 1.0 " 2.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
Heavy fuel oil allowable only for installations > 1.2 MW		
Category 2 zones " 1 "	956 ng/J 478 "	
- <u>Particulate material</u>		
General		
Q < 4 MW	240 ng/J	
4 < Q < 10 MW	48 "	all oils { 48 ng/J 48 " 36 "
Q > 10 MW	36 "	
all scales	B ≤ 6	
Special protection zones		
Q < 4 MW	140 - 240 ng/J	
4 < Q < 10 MW		48 ng/J
Q > 10 MW		36 ng/J
	(The above values may be increased several-fold for periods of 200 or 400 hours/year)	
	B ≤ 4	B ≤ 4
- <u>Nitrogen oxides</u>		

GREECE	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		Kerosine. 0.2 Gas oil 0.5 Light fuel oil 3.5 Heavy fuel oil 4.0
Athens (for the protection of historical buildings)		all fuel oil 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
- <u>Particulate material</u>		
- <u>Nitrogen oxides</u>		

<u>HOLLAND</u>	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.3 light fuel oil 0.5 heavy fuel oil 2.0
Special zones		all 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
For the whole country the SO ₂ emission is to be limited to 5×10^8 kg/year		
- <u>Particulate material</u>		
- <u>Nitrogen oxides</u>		

<u>JAPAN</u>	Solid fuels	Liquid fuels
<p><u>Maximum allowable fuel sulphur content</u> % w/w</p> <p>(Each grade is intended for a specific end use.)</p>		<p>Gas oil No. 1 1.2</p> <p>Gas oil No. 2 1.2</p> <p>Gas oil No. 3 1.1</p> <p>Gas oil No. 3 Sp. 1.0</p> <p>Fuel oil, Cl 1, No.1 0.5</p> <p>" " 1, No.2 2.0</p> <p>" " 2, 3.0</p> <p>" " 3, No.1 1.5</p> <p>" " 3, No.2 3.5</p> <p>" " 3, No.3 1.5</p>

Maximum allowable emissions

- Sulphur dioxide.

$$SO_2 = K \times 10^{-3} \times H_e^2$$

where SO_2 = sulphur dioxide emission, m^3/h at 0 °C and 1 atm

K = constant according to the geographical region,

1.17 < K < 2.34 for new plant in special zones.

3 < K < 17.5 for existing plant.

H_e = actual stack height + smoke ascent height, m

- Particulate material (mg/m^3).

		(a) (b)		(a) (b)
$V < 40\ 000\ m^3/h$ $40\ 000 < V < 200\ 000$ $V > 200\ 000$	}	coal, Cal. Val < 21 MJ/kg other coals	{	oil oil oil
		800 400		300 200 200 50 100 50

(a) General, (b) Special zones.

- Nitrogen oxides

	Solid fuels	Liquid fuels	Gaseous fuels
$V < 10\ 000\ m^3/h$	400 ppm (816)	180 ppm (367)	150 ppm (306)
$10\ 000 < V < 40\ 000$	" "	150 (306)	130 (265)
$40\ 000 < V < 500\ 000$	" "	150 (306)	100 (204)
$V > 500\ 000$	" "	130 (265)	60 (122)

Values given in brackets are in units of mg/m^3 .

<u>NORWAY</u>	<u>Solid fuels</u>	<u>Liquid fuels</u>
<u>Maximum allowable fuel sulphur content % w/w</u>		
General South Norway Oslo, Drammen		oil 2.5 " 1.0 " 0.3
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
- <u>Particulate material</u>		
- <u>Nitrogen oxides</u>		

SINGAPORE	Solid fuels	Liquid fuels
<p><u>Maximum allowable fuel sulphur content</u> % w/w</p> <p>Rate > 2300 kg/h of fuel</p>		<p>all 2.0 (In designated areas 1.0).</p>
<p><u>Maximum allowable emissions</u></p> <p>- <u>Sulphur dioxide</u></p>		
<p>- <u>Particulate material</u></p>	<p>R ≤ 2</p>	<p>all 400 mg/m³ R ≤ 2</p>
<p>- <u>Nitrogen oxides</u></p>		

SPAIN	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.5 fuel oil No. 1 2.7 fuel oil No. 2 3.6
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u> mg/m ³		
Power plant	coal) anthracite) 2400 lignite 9000	oil 3000
Other applications	coal) anthracite) 2400 lignite 6000	gas oil 850 fuel oil No. 1 1700 fuel oil No. 2 3400
Boilers, Q > 300 MW		oil 20 g/kg fuel
- <u>Particulate material</u> mg/m ³		
Power plant		
Q < 50 MW	coal 250	oil 175
50 < Q < 200 MW	150	150
Q > 200 MW	150	120
	R ≤ 1	R ≤ 1
- <u>Nitrogen oxides</u>		

SWEDEN

Maximum allowable fuel sulphur content % w/w
General

Maximum allowable emissions

- Sulphur dioxide

General
Protected areas

General Q > 300 MW

- Particulate material

50 < Q < 300 MW
Q > 300 MW
Smoke

- Nitrogen oxides

Solid fuels

Liquid fuels

gas oil 0.3
heavy fuel oil 1.0

oils 600 ng/J
" 240 "

oils 20 g/kg
(~ 450 ng/J)

1.5 g/kg
1.0 g/kg
B ≤ 3

<u>TURKEY</u>	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		domestic 2.5
Ankara		all 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
- <u>Particulate material</u>		
- <u>Nitrogen oxides</u>		

UNITED KINGDOM	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u> % w/w		
General		gas oil 0.5 light fuel oil 3.5 medium " " 4.0 heavy " " 4.5
City of London		all 1.0
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>	Stack height criteria to limit short term ground level SO ₂ concentration to $\leq 0.17 \text{ ppm SO}_2$ (500 $\mu\text{g}/\text{m}^3$)	
- <u>Particulate material</u>		
Q, MW	ng/J	ng/J
1	757	96
10	277	96
20	252	83
50	219	56
100	199	46
140	189	44
160	189	43
(> 160)	"Best Practicable Means" as determined by the Alkali inspector)	
	$R \leq 2$	$R \leq 2$
- <u>Nitrogen oxides</u>		

<u>UNITED STATES OF AMERICA</u>	Solid fuels	Liquid fuels
<u>Maximum allowable fuel sulphur content</u>		
<u>Maximum allowable emissions</u>		
- <u>Sulphur dioxide</u>		
General Q > 73 MW	520 ng/J 90% S reduction unless emission is 260 ng/J when 70% S reduction is allowable State and local	340 ng/J 90% S reduction unless emission is < 86 ng/J when no treatment needed. regulations
Special zones.		
- <u>Particulate material</u>		
General Power plant Steam generation	13 ng/J 43 ") 13 ng/J)
- <u>Nitrogen oxides</u> (as NO ₂)		
General, Q > 73 MW Power plant	{ sub-bituminous coal, shale oil, coal derived fuel other solids	} 210 ng/J 260 "
Steam generation	all types	300 " 130 ng/J
		<u>Gaseous fuels</u> 86 ng/J

W. GERMANY	Solid fuels	Liquid fuels																					
<p><u>Maximum allowable fuel sulphur content</u> % w/w</p>		<p>gas oil 0.3 heavy fuel oil 2.8</p>																					
<p><u>Maximum allowable emissions</u></p> <p>- <u>Sulphur dioxide</u></p> <p>Regulations linked with stack height, fuel sulphur and plant size.</p> <p>Stack height < 30 m 11 < Q < 1100 MW Q > 1100 MW</p>	<p>coal S < 1.0 desulphurisation by at least 80%</p>	<p>fuel S < 0.5 " < 1.0 desulphurisation by at least 80%</p>																					
	Gaseous fuels																						
	natural gas 50 mg/m ³	coke oven gas 100 mg/m ³																					
<p>- <u>Particulate material</u> mg/m³</p> <p>Linear interpolation should be used for intermediate flue gas volumes.</p> <p>V = 0 m³/h V = 70 000 m³/h V = 100 000 m³/h V > 100 000 m³/h Water tube boilers) (lignite V > 500 000 m³/h) (coal Fire tube boilers</p> <p>(a) total dust (b) particles < 10 µm</p>	<p style="text-align: center;"><u>Solid fuels</u></p> <table border="1"> <thead> <tr> <th>(a)</th> <th>(b)</th> </tr> </thead> <tbody> <tr><td>500</td><td>250</td></tr> <tr><td>150</td><td>100</td></tr> <tr><td>150</td><td></td></tr> <tr><td>150</td><td></td></tr> <tr><td>100</td><td></td></tr> <tr><td>150</td><td></td></tr> <tr><td>300</td><td></td></tr> </tbody> </table> <p style="text-align: center;">R ≤ 1</p>	(a)	(b)	500	250	150	100	150		150		100		150		300		<p style="text-align: center;"><u>Liquid fuels</u></p> <table border="1"> <thead> <tr> <th>(a)</th> </tr> </thead> <tbody> <tr><td>150</td></tr> <tr><td>50</td></tr> <tr><td>50</td></tr> <tr><td>50</td></tr> </tbody> </table> <p>(light R ≤ 2 (heavy R ≤ 3</p>	(a)	150	50	50	50
(a)	(b)																						
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<p>- <u>Nitrogen oxides</u></p>																							

18. References

- 18.1 Zabel, S.A. "Comparative controls for sulfur oxides in four countries".
Int. Symp. on Sulphur Emissions and the Environment, Soc. of Ch. Ind.
Water and Environment Group, London. p.314-324, (8-10 May, 1979).
- 18.2 Rubin, E.S. "Air pollution constraints on increased coal use by
industry". J. Air Pollution Control Association, 31 No. 4, 349-360,
(1981).
- 18.3 "Limitations des emissions de polluants et qualite de l'air",
vol 1 and 2; vol 2 "Normes pour rejets emissions". Institut Francais
de l'Energie, 3 Rue Henri Heine, Paris 75016, (1980).
- 18.4.. BP Report TS 53/80/U "Summary of worldwide legislation on emissions
from the combustion of petroleum fuels", Issue No. 2, (April 1980).