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A REVIEW OF GAS APPLIANCE CO EMISSIONS LEGISLATION

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Executive Summary

This report is part of a study to establish the feasibility of determining the need for servicing of gas appliances by measuring carbon monoxide (CO) in the flue gas. The report covers the current situation in the UK and presents a comparison with practices elsewhere. A variety of sources were used in obtaining data for this report, including existing in-house knowledge, archive material, historical records, industry contacts by telephone, e-mail and internet searches.

British Gas Services currently has a policy whereby the service engineer uses a portable analyser as a diagnostic aid, and the CO/CO_2 ratio of the combustion gases in the secondary flue are used as a measure of combustion efficiency. It was shown that CO/CO_2 in the flue is influenced by internal cleanliness, but is largely independent of the model of appliance. The practical conclusion was that an improvement in service could be achieved, with no reduction in safety, if unnecessary stripping and cleaning could be avoided.

From the information that has been obtained during the course of this part of the programme, it seems that the United Kingdom is the only country that uses flue gas CO/CO_2 ratio as a measure of gas appliance combustion performance in service. The system has now been in operation within the UK for many years, and experience has shown it to be remarkably robust. However, the current British Gas Services system was devised specifically for central heating boilers, and the validity is not so well proven when used on other appliances.

The information on emissions requirements for other countries indicates a picture that, at best, can be described as patchy. It is unfortunate that definitive details have not been forthcoming from some countries in the time available, but it is clear that much interest is being shown in many parts of the world. In a few cases this takes the form of open debate whilst, elsewhere, there seems to be a reticence to confront what may be considered a politically sensitive issue. The routine inspection of gas appliances and flues in service is certainly not considered to be a high priority at present by a significant proportion of respondents.

It is recommended that the use of flue gas CO/CO_2 ratio as a measure of in-service combustion performance for domestic gas appliances, other than central heating boilers, should be investigated in depth and compared with measurements of CO alone.

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1 INTRODUCTION

This report is part of a study to establish the feasibility of determining the need for servicing of gas appliances by measuring carbon monoxide (CO) in the flue gas. This can be compared directly to the method used currently in the UK by British Gas Services for central heating boilers. The report covers the current situation in the UK and presents a comparison with practices elsewhere.

2 SOURCES OF INFORMATION

A variety of sources were used in obtaining data for this report, including,

- Existing in-house knowledge
- Archive material and historical records
- Industry contacts by telephone and e-mail
- Internet searches

Obviously, it is not always possible to fully define some of the more informal contacts but, where specific documents are available, these are listed in the references section.

3 PRESENT SITUATION IN THE UK

3.1 Performance requirements as-new

The following table lists performance standards in the UK for as-new domestic gas appliances, the limits of CO or CO/CO_2 ratio allowed, and the required accuracy of the instrumentation used.

Appliance type	Relevant documents	CO and/or CO_2 limits	Instrumentation accuracy
INSTANTANEOUS WATER HEATER	BS EN 26:1998	CO ≤0.1% DAF, SEE NOTE (1)	RAPID RESPONSE TO ±6% FULL SCALE
COOKER	BS EN 30-1-1:1998 BS EN 30-2-1:1998	EACH BURNER CO ≤0.1% DAF ALL BURNERS CO ≤0.2% DAF	CO: 0.005% v/v CO_2: ≤6%
FANNED OVEN COOKER	BS EN 30-1-2:1999 BS EN 30-2-2:1999	AS BS EN 30-1-1 1998 WITHOUT FAN	CO: 0.005% v/v CO2: ≤6%
TYPE B CENTRAL HEATING BOILER	BS EN 297:1994	CO ≤0.1% DAF	±6% FULL SCALE FOR CO AND CO_2
TYPE C CENTRAL HEATING BOILER	BS EN 483:1999	NORMAL CONDITIONS: CO ≤0.1% DAF ADVERSE WIND: CO ≤0.2% DAF	±6% FULL SCALE FOR CO AND CO_2
RADIANT CONVECTOR GAS FIRE	BS 5258-5:1989 BSI 98/708846 DC BS 6332-2:1983	CO/CO2 ≤0.02 CO ≤0.1% DAF	CO: 0.001% v/v CO_2: 0.05% v/v NOTE (4)
GAS FIRE/BACK BOILER	BS 5258-8:1980 BSI 95/717426 DC	CO/CO_2 ≤0.02	CO: 0.001% v/v CO_2: 0.05% v/v NOTE (4)
AIR HEATER/CIRCULATOR	BS 5258-9:1989 BS 6332-4:1983	CO/CO_2 ≤0.02	CO: 0.001% v/v CO_2: 0.05% v/v

FLUELESS HEATER	BS 5258-10:1980 BS EN 449:1997	FREE AIR AND VITIATED STATE $CO/CO_2 \leq 0.01$ $CO \leq 0.008\%$ v/v AT $CO_2 = 2.1\%$	NOTE (3) CO: 0.005% v/v AND CO_2: 0.05% v/v
CONVECTOR HEATER	BS 5258-13:1986 BS 6332-4:1983	$CO/CO_2 \leq 0.02$ NOTE (2)	CO: 0.001% v/v CO_2: 0.05% v/v
COMBINATION BOILER	BS 5258-15:1990 BS EN 625:1996	$CO/CO_2 \leq 0.02$	CO: 0.001% v/v CO_2: 0.05% v/v NOTE (4)
DECORATIVE FUEL EFFECT INSET GAS FIRE	BS 5258-16:1991 BS EN 509:2000	$CO/CO_2 \leq 0.02$ $CO \leq 0.1\%$ DAF	CO: 0.001% v/v CO_2: 0.05% v/v NOTE (4)
TUMBLE DRYER	BS EN 1458-1:2000 BS EN 1458-2:1999	$CO \leq 0.1\%$ DAF	NOTE (3)
INSTALLATIONS IN CARAVANS AND NON-PERMANENT DWELLINGS	BS 5482-2:1977	APPROPRIATE PARTS OF BS 5258	AS ABOVE, ACCORDING TO APPLIANCE TYPE

Notes:

(1) In the European Standards, combustion is said to be “complete” if there are no more than trace levels of combustible constituents (hydrogen, hydrocarbons, carbon monoxide, carbon, etc.) in the combustion products. Conversely, combustion is said to be “incomplete” if at least one combustible constituent is present in significant proportions in the combustion products. The amount of CO in the dry, air-free (DAF) combustion products is used as the criterion to distinguish between “hygienic” and “non-hygienic” combustion.

(2) These appliances usually have balanced flues. The sampling point in the flue is taken to be one diameter in from the end of the flue terminal and the probe is as described (and shown) in BS 6332-4:1983.

(3) For flueless heaters, BS 5258-10:1980 states no instrument accuracies. In general, all standards within the BS 5258 group require 0.001% v/v for CO and 0.05% v/v for CO_2.

(4) BSI document 98/708846 DC and BS EN 509:2000 require that CO is measured by an instrument capable of determining between $5x10^{-5}$ and $100x10^{-5}$ parts of CO by volume. In the range used, the method is to be selective and accurate to $\pm 2.x10^{-5}$ parts of CO by volume. Instruments that currently correspond to these requirements are of the infrared absorption type. The CO measuring apparatus is to be designed and installed so that it is not affected by the presence of CO_2 in the products of

combustion. CO_2 content is measured by a method accurate to within ±5% and infrared absorption instruments are recommended.

3.2 In-service diagnostic checks

British Gas Services currently has a policy whereby measuring the combustion products in the flues of central heating boilers is used as an indicator of the need for servicing the appliance. Prior to implementation of the policy, extensive surveys carried out on central heating boilers around the time of an annual service (see Reference 1) showed that 94% of appliances had a CO/CO_2 ratio less than 0.01 prior to servicing, and 86% were below 0.004. After servicing, 0.6% of appliances still had a CO/CO_2 ratio greater than 0.01.

The procedure entails the service engineer using a portable analyser as a diagnostic aid, and the CO/CO_2 ratio of the combustion gases in the secondary flue are used as a measure of combustion efficiency. It was shown that CO/CO_2 in the flue is influenced by internal cleanliness, but is largely independent of the model of appliance. The practical conclusion was that an improvement in service could be achieved, with no reduction in safety, if unnecessary stripping and cleaning could be avoided. The servicing policy works as follows,

> A lower trigger level of the instrument is used to determine the necessity for cleaning the burner, heat exchanger and primary flue. After the appliance has been cleaned, an upper trigger level is used to assess if the appliance is safe to be left for another year. If the reading is above this level, then action must be taken to further reduce the CO/CO_2 ratio. The values determined for these lower and upper trigger levels were 0.004 and 0.008, respectively.

4 COMPARISON OF REQUIREMENTS

The following table lists the known present position for servicing of domestic gas appliances, and any changes expected in the future, where such information is available or has been obtained.

Country	Present situation	Future situation
UK	As detailed in section 3.2.	Possible move to absolute CO instead of CO/CO_2 ratio.
AUSTRALIA	No mandatory checks; the onus for regular appliance servicing lies with the consumer.	Continued debate.
AUSTRIA	Austrian Standard M 7535-3 refers.	To be reviewed.
BRAZIL	Response awaited.	Not known.
DENMARK	Response awaited.	Not known.
FRANCE	Response awaited.	Not known.
GERMANY	Federal Act 1.BlmSchV (Appendix A).	No change.
ITALY	Italian Standard UNI 10389 (Appendix B).	To be reviewed shortly.
JAPAN	No national regulation.	Not known.
NETHERLANDS	Response awaited.	Not known.
SWITZERLAND	Ordinance RS 814.318.142.1 (Appendix C).	No change.
USA	No federal regulation, but guidance levels in individual states (Appendix D).	Continued debate.

Note: Information has not been received from all the sources contacted.

5 COMPARISON OF METHODOLOGIES

The following table lists procedural requirements enforced by relevant national legislation, for initial installation and subsequent routine servicing of domestic gas appliances, as detailed in Reference 2.

Country	Mandatory flue inspection	Mandatory CH boiler inspection	Random flue inspection (periodicity)	Inspection agency	Inspection responsibility
UK	Yes	Yes	No	CORGI (1)	Landlord (2)
AUSTRALIA	N/K	N/K	N/K	N/K	N/K
AUSTRIA	Yes	No	Yes (one year)	Chimney Sweep	Chimney Sweep
BRAZIL	N/K	N/K	N/K	N/K	N/K
DENMARK	Yes	Yes	No	Gas Supplier	Gas Supplier
FRANCE	Yes	No	No	None	-
GERMANY	Yes	Yes	Yes (one year)	Chimney Sweep	Chimney Sweep
ITALY	No	No	No	Installer	Installer
JAPAN	N/K	N/K	N/K	N/K	N/K
NETHERLANDS	Yes	Yes	Yes (two years)	Gas Supplier or Local Authority	Local Authority
USA	Yes	Yes	No	Gas Supplier, Local Authority, Installer or Fire Service	Local Authority

Notes:

(1) Confederation of Registered Gas Installers.

(2) For rented accommodation only.

N/K indicates that the current situation is not known.

6 DISCUSSION

From the information that has been obtained during the course of this part of the programme, it seems that the United Kingdom is the only country that uses flue gas CO/CO_2 ratio as a measure of gas appliance combustion performance in service. However, this should not necessarily be surprising, considering the much greater usage of gas for domestic heating, over a much longer period, than in other countries. In addition, the uniquely monopolistic position of the former British Gas Corporation within the UK enabled generation of the extensive data that were needed, before such a system could be justified.

In fact, the system described in section 3.2 has now been in operation within the UK for many years, and experience has shown it to be remarkably robust. It has the practical advantage of being simple to implement, whilst obviating much of the variability that had been apparent between individual measurements of CO and CO_2 made on nominally identical appliances under laboratory conditions. In service, these variations could be expected to become even more significant, with differences in installation and usage, as well as geographical factors.

However, the current British Gas Services system was devised specifically for central heating boilers, and the validity is not so well proven when used on other appliances. The table in section 3.1 indicates that performance requirements for some appliances (notably fires) are given in terms of CO/CO_2 ratio, whilst others (notably cookers) depend only on CO. In a few cases, combined limits apply when different sources are considered. It should be noted that the CO levels are specified as dry air-free measurements, which might be difficult to achieve outside the laboratory.

The information in sections 4 and 5 on emissions requirements for other countries indicates a picture that, at best, can be described as patchy. It is unfortunate that definitive details have not been forthcoming from some countries in the time available, but it is clear that much interest is being shown in many parts of the world. In a few cases (Australia and the USA, for example) this takes the form of open debate whilst, elsewhere, there seems to be a reticence to confront what may be considered a politically sensitive issue. The routine inspection of gas appliances and flues in service is certainly not considered to be a high priority at present by a significant proportion of respondents.

Based on this study, it seems that flue gas CO/CO_2 ratio can be a useful measure of combustion performance for gas-fired central heating boilers in service. Its usefulness for other gas appliances is not yet so apparent, although investigations are in hand (Reference 29) to make comparisons with measurements of CO alone.

7 CONCLUSIONS

7.1 Full details on present and future emissions legislation for gas appliances outside the UK have unfortunately not been forthcoming from all the likely sources in the time available to the project.

7.2 Flue gas CO/CO_2 ratio is apparently used as a measure of combustion performance for domestic gas appliances in service only within the UK.

7.3 In-service emissions requirements for domestic gas appliances are not generally seen as a high priority in many countries worldwide.

8 RECOMMENDATIONS

8.1 The use of flue gas CO/CO_2 ratio as a measure of in-service combustion performance for domestic gas appliances, other than central heating boilers, should be investigated in depth and compared with measurements of CO alone.

8.2 Attempts to obtain detailed information for other countries should be continued.

REFERENCES

1. IGE Communication 1397, May 1989. Servicing – right first time.

2. Report to IGE Subcommittee E1, April 1996. Field Experience: Collection of data to improve gas installations and gas appliances.

3. BS EN 26:1998. Gas-fired instantaneous water heaters for the production of domestic hot water, fitted with atmospheric burners.

4. BS EN 30-1-1:1998. Domestic cooking appliances burning gas. Safety. General

5. BS EN 30-1-2:1999. Domestic cooking appliances burning gas. Safety. Appliances having forced convection ovens and/or grills.

6. BS EN 30-2-1:1998. Domestic cooking appliances burning gas. Rational use of energy. General

7. BS EN 30-2-2:1999. Domestic cooking appliances burning gas. Rational use of energy. Appliances having forced convection ovens and/or grills.

8. BS EN 297:1994. Gas-fired central heating boilers. Type B_{11} and B_{11BS} boilers fitted with atmospheric burners of nominal heat input not exceeding 70 kW.

9. BS EN 483:2000. Gas-fired central heating boilers. Type C boilers of nominal heat input not exceeding 70 kW.

10. BS EN 1458-1:2000. Domestic direct-fired tumble dryers of types B22D and B23D, of nominal heat input not exceeding 6 kW. Safety.

11. BS EN 1458-1:2000. Domestic direct-fired tumble dryers of types B22D and B23D, of nominal heat input not exceeding 6 kW. Rational use of energy.

12. BS 5258-1:1986. Safety of domestic gas appliances. Specification for central heating boilers and circulators.

13. BS 5258-2:1975. Safety of domestic gas appliances. Cooking appliances.

14. BS 5258-5:1989. Safety of domestic gas appliances. Gas fires.

15. BS 5258-8:1980. Safety of domestic gas appliances. Combined appliances: gas fire/back boiler.

16. BS 5258-9:1989. Safety of domestic gas appliances. Specification for combined appliances: fanned-circulation ducted-air heaters/circulators.

17. BS 5258-10:1980. Safety of domestic gas appliances. Flueless space heaters (excluding catalytic combustion heaters) (3rd family gases).

18. BS 5258-11:1980. Safety of domestic gas appliances. Flueless catalytic combustion heaters (3rd family gases).

19. BS 5258-13:1986. Safety of domestic gas appliances. Specification for convector heaters.

20. BS 5258-15:1990. Safety of domestic gas appliances. Specification for combination boilers.

21. BS 5258-16:1991. Safety of domestic gas appliances. Specification for live fuel effect gas fires (2nd and 3rd family gases).

22. BS 5482-1:1994. Domestic butane- and propane-gas burning installations. Specification for installations at permanent dwellings.

23. BS 5482-2:1994. Domestic butane- and propane-gas burning installations. Installations in caravans and non-permanent dwellings

24. BS 6332-1:1988. Thermal performance of domestic gas appliances. Specification for thermal performance of central heating boilers and circulators.

25. BS 6332-2:1983. Thermal performance of domestic gas appliances. Specification for thermal performance of gas fires.

26. BS 6332-3:1984. Thermal performance of domestic gas appliances. Specification for thermal performance of combined appliances: gas fire/back boiler.

27. BS 6332-4:1983. Thermal performance of domestic gas appliances. Specification for thermal performance of independent convector heaters.

28. BS 6332-6:1990. Thermal performance of domestic gas appliances. Specification for thermal performance of combined appliances: fanned-circulation ducted-air heater/circulator.

29. To be issued. Comparison of measurements of absolute CO and CO/CO_2 ratio as a combustion performance indication.

Appendix A – Performance Requirements in Germany

Combustion analysis of small heating appliances is covered in Germany by law in the "Federal Emission Control Act" (Small Furnaces Order – 1. BImSchV).
All appliances >4 kW (gas and oil) or >15 kW (solid fuels) have to be tested once per year by a chimney sweep as an official measurement.

Small appliances have to achieve flue gas heat losses lower than the values in the table below.

Legal requirements for maximum waste gas loss

Appliance size	Installation until 31.12.1982	Installation after 1.1.1983	Installation after 1.10.1988	Installation after 1.1.1998
4-25 kW	15	14	12	11
25-50 kW	14	13	11	10
>50 kW	13	12	10	9

Flue gas heat losses are calculated from measured oxygen content according to the relationship

$$q_A = (t_A - t_L) * \left(\frac{A2}{21 - O2} + B \right)$$

Flue gas heat losses are calculated from measured carbon dioxide content according to the relationship

$$q_A = (t_A - t_L) * \left(\frac{A1}{CO_2} + B \right)$$

q_A= *flue gas heat loss*, %
t_A = *flue gas temperature*, °C
t_L= *inlet air temperature*, °C
CO_2= *volume ratio of carbon dioxide in the dry flue gas*, %

The parameters A1, A2 and B are taken from the following table.

Parameters for calculation in Germany

Fuel type	Light Oil	Natural gas	Town gas	Coking oven gas	Liquified gas and lpg/air mixture
A1	0.5	0.37	0.35	0.29	0.42
A2	0.68	0.65	0.63	0.60	0.63
B	0.007	0.009	0.011	0.011	0.008

The fuel specific CO_2 max values for CO_2 calculation from O_2 -measurement are:

Natural gas	12,0 Vol.% CO_2
LPG	13,7 Vol. % CO_2
Light oil	15,4 Vol.% CO_2
Coal	18,5 Vol.% CO_2

Appendix B – Performance Requirements in Italy

Combustion analysis in Italy is requested by law 10/1991 and regulated by decree 551/1999, for appliances included in heating plants, with power > 4 kW and supplied with gas or liquid fuel. They have to achieve a minimum efficiency $\eta \geq$ (see tables below). An official inspector tests the appliances, as follows:

Every two years, if power < 35 kW
Every year, if 35kW < power < 350 kW
Every six months, if power > 350 kW

Legal requirements for minimum efficiency η of heating appliances

a) Hot water plant

Appliance power (P)	Installation until 29.10.1993	Installation after 30.10.1993
4 – 400 kW	$\eta \geq (84 + 2\log P) - 3$	$\eta \geq (84 + 2\log P)$
> 400 kW	$\eta \geq (84 + 2\log 400) - 3$	$\eta \geq (84 + 2\log 400)$

b) Hot air plant

Appliance power (P)	Installation until 29.10.1993	Installation after 30.10.1993
4 – 400 kW	$\eta \geq (83 + 2\log P) – 6$	$\eta \geq (83 + 2\log P) – 3$
> 400 kW	$\eta \geq (83 + 2\log 400) - 6$	$\eta \geq (83 + 2\log 400) - 3$

The inspector shall only assess the combustion performance but, if the appliance shows a safety or environmental problem, he shall inform the competent authority and switch off the appliance. The procedure of combustion analysis is contained in Italian Standard UNI 10389, which is due to be revised in the near future. The calculation formula for combustion efficiency is:

$\eta = 100 – Qs$ where Qs = flue gas heat losses

Qs is calculated from the measured oxygen content, according to the relationship:

$$Qs = (Tf - Ta) * \left(\frac{A_1}{21 - O_2} + B \right)$$

Qs is calculated from the measured carbon dioxide content, according to the relationship:

$$Qs = (Tf - Ta) * \left(\frac{A_2}{CO_2} + B \right)$$

T_f = flue gas temperature (°C)
Ta = combustion air temperature (°C)
O_2 = volume ratio of oxygen in the dry flue gas (%)
CO_2 = volume ratio of carbon dioxide in the dry flue gas (%)

The parameters A1, A2 and B are taken from the following table.

Parameters for calculation in Italy

Fuel	Natural gas	LPG	Light fuel oil	Heavy fuel oil
A1	0.66	0.63	0.68	0.68
A2	0.38	0.42	0.50	0.52
B	0.010	0.008	0.007	0.007

In all appliances with gaseous or liquid fuel, the maximum concentration of carbon monoxide allowed in the dry flue gas is 1000 ppm. In plants with liquid fuels, the measured smoke spot number shall be <2 for light fuel oil and <6 for heavy fuel oil.

The fuel-specific maximum CO_2 values for the fuels distributed in Italy are indicated in UNI 10389, as:

Natural gas	11,7 Vol.% CO_2
LPG	13,9 Vol.% CO_2
Light fuel oil	15,1 Vol.% CO_2
Heavy fuel oil	15,7 Vol.% CO_2

Appendix C – Performance Requirements in Switzerland

The use of "Portable Electrical Apparatus Designed to Measure Combustion Flue Gas Parameters of Heating Appliances" is legally regulated[1] only for official measurements (inspections) on domestic appliances run on "extra light" fuel oil or natural gas.

Combustion installations run on "extra light" fuel oil

1) The flue gas losses from heating boilers with forced draught burners shall not exceed the following limits:

a)	with single stage burner operation	7%
b)	with two-stage burner operation	
	(i) during operation of first burner stage	6 %
	(ii) during operation of second burner stage	8 %

2) In the case of heating boilers with oil vaporization burners, the limit indicated on the type-approval plate for the permitted flue gas losses shall not be exceeded.

3) The limits for flue gas losses laid down in Paragraphs 1 and 2 shall apply to installations that are marketed after 31 December 1992.

4) The authorities may lay down less stringent limits in the case of heating boilers where the temperature of the heat carrier fluid is over 110 °C and where the requirements laid down in Paragraph 1 cannot be complied with because technology and operating conditions do not allow or because it is economically unacceptable.

5) In the case of heating boilers with forced draught burners where the temperature of the water is no more than 110 °C and which are marketed before 1 January 1993, the flue gas losses shall not exceed the following limits:

a)	installations with a heat input of up to 70 kW	10 %
b)	installations with a heat input of over 70 kW	9 %

Gas combustion installations

1) In the case of heating boilers with forced draught burners run on gas fuels, the flue gas losses shall not exceed the following limits:

a)	with single stage burner operation	7 %
b)	with two-stage burner operation	
	(i) during operation of first burner stage	6 %
	(ii) during operation of second burner stage	8 %

2) The limits for flue gas losses laid down in Paragraph 1 shall apply to installations that were marketed before 31 December 1992.

[1] Ordinance on air pollution control (RS 814.318.142.1)

3) The authorities may lay down less stringent limits in the case of heating boilers where the temperature of the heat carrier fluid is over 110 °C and where the requirements laid down in Paragraph 1 cannot be complied with because technology and operating conditions do not allow or because it is economically unacceptable.

4) In the case of heating boilers with forced draught burners run on gas fuels where the temperature of the water is not more than 110 °C and which are marketed before 1 January 1993, the flue gas losses shall not exceed the following limits:

a) installations with a heat input of up to 70 kW 10 %
b) installations with a heat input of over 70 kW 9 %

5) In the case of heating boilers and circulation heaters with atmospheric gas burners and with a heat input of up to 350 kW, where water is used as the heat carrier and the temperature of the water is no more than 110 °C, the flue gas losses shall not exceed the following limits:

a) for installations marketed after 31 December 1992, the q_A limit indicated on the type-approval plate;

b) for all other installations, the limit $q_A = 14.5 - 2 \log Q_{Nmax}$, but no more than 12.5 %.

Where:

q_A = limit for the maximum permitted flue gas losses in percent (%)
$\log Q_{Nmax}$ = logarithmic value of the maximum boiler nominal output in kW

6) The requirements laid down for forced draught burners shall apply to heating boilers and circulation heaters with atmospheric gas burners with a heat input of over 350 kW.

Calculation of flue gas losses

The flue gas losses are calculated using the following formula:

$$q_A = (t_A - t_L) \times \left\{ \frac{A}{21 - O_2} + B \right\} \text{ with}$$

q_A = flue gas loss in %
t_A = flue gas temperature in °C
t_L = combustion air temperature in °C
O_2 = volume content of oxygen in the dry flue gas given in %
A, B = constants having the values:
for “extra light” fuel oil: A = 0.68, B = 0.007
for natural gas: A = 0.66, B = 0.009

Appendix D – Performance Requirements in the USA

Emission standards for new appliances

Document reference	Appliance type(s)	CO limit
ANSI Z21.1	Household gas cookers	800 ppm
ANSI Z21.10.1	Storage water heaters (<75000 BTU)	400 ppm
ANSI Z21.11.2	Un-vented room heaters	200 ppm
ANSI Z21.13	Low-pressure steam & hot water boilers	400 ppm
ANSI Z21.47	Gas-fired central heating furnaces	400 ppm
ANSI Z21.60	Decorative gas appliances for installation in solid fuel burning fireplaces	400 ppm

Note: Flue gas CO measurements are air-free.

Emission guidelines for used appliances

Source location	Appliance type(s)	CO limit
Chicago protocol	Gas-fired furnaces, boilers, water heaters, vented space heaters, fireplaces and flame-effect fires	50 ppm (as measured)
	Gas cookers and ovens	800 ppm (air- free)
Ohio state	Furnaces, boilers and hot water heaters	400 ppm
	Un-vented appliances and cookers	100 ppm
Iowa state	Unspecified	400 ppm