SNAP CODES:	**050601** **050603** **010506**
SOURCE ACTIVITY TITLES:	**GAS DISTRIBUTION NETWORKS** ***Pipelines*** ***Distribution Networks*** ***Pipeline Compressors***
NOSE CODE:	**106.06.01** **106.06.02**
NFR CODE:	**1 B 2 b** **1 A 3 e i**

1 ACTIVITIES INCLUDED

This chapter considers emissions from the transmission of gaseous fossil fuel from terminals to consumers via pipelines, compressor stations and networks. Most of the information in this chapter is based on data for natural gas.

Emissions from gas terminals are covered in the chapter on Extraction and first treatment of liquid and gaseous fuels (50200/50300).

2 CONTRIBUTION TO TOTAL EMISSIONS

Methane and NMVOCs are the pollutants that are likely to be emitted from gas distribution networks in significant quantities.

Table 2.1 refers to the UK only and to the year 1992. Data are from the UK Digest of Environmental Protection & Water Statistics 1994. The NMVOC component of natural gas was calculated using the UK species profile given in Section 9.

Table 2.1 - UK emissions from gas distribution networks (1992)

	Methane	**NMVOC**	**Total**
Emission due to natural gas leakage (kt)	375	42	417
Total emission (kt)	4736	2556	7292
Natural gas leakage as % of total emission	7.9	1.6	5.7

Table 2.2: Contribution to total emissions of the CORINAIR90 inventory *(up to 28 countries)*

Source-activity	**SNAP-code**	**Contribution to total emissions [%], (including emissions from nature)**							
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Gas distribution networks	050600			0.5	6.0				

0 = emissions are reported, but the exact value is below the rounding limit of 0.1 per cent
- = no emissions are reported

3 GENERAL

3.1 Description

Natural gas is a combustible gas that occurs in porous rock of the earth's crust and is often found with or near accumulations of crude oil. It may also occur alone in separate reservoirs. Gas wells exist on land and offshore. Some countries may also use gas derived from coal. Coal gasification has been practised since the early nineteenth century and can be done using a number of different processes.

The main use of natural gas is heating buildings and processes and as a chemical feedstock, for example in the manufacture of ammonia and fertilisers. Also, it is increasingly being used as a fuel for power generation.

Natural gas is transferred from the well to a processing plant where it is separated by cryogenic distillation to give 'sales' gas of the required specification as well as possibly other products such as liquid hydrocarbon fractions. After this it is transferred via a network of pipelines and networks or 'mains' to consumers ranging from large factories to small dwellings. Natural gas may also be transported in liquefied form by ship, in which case it is loaded and unloaded at specially designed marine terminals.

A gas transmission network covering a country or region consists of pipelines and mains of a variety of different sizes, materials, and pressures. It will also contain storage facilities, pumping stations and pressure reduction stations. Pipes will also make use of different types of joint.

Transmission systems

Gas transmission systems can conveniently be divided into two interconnecting systems; the national transmission system, which consists of large diameter high pressure pipelines spanning distances of hundreds of kilometres, forms the backbone of the network and takes gas from the terminals to each of many regional supply systems, which consist of smaller diameter intermediate and low pressure pipelines and mains.

Pipelines & mains

Pipelines and mains are made from the following materials:

- Welded steel
- Cast Iron
- Ductile Iron
- Polyethylene

Pipelines and mains are operated under a variety of different pressure regimes, usually classified as follows:

- High pressure - up to 75 bar
- Intermediate pressure - 2 to 7 bar
- Medium pressure - 2 bar to 75 mbar
- Low pressure - < 75 mbar

Service pipes, which transfer gas from a main to a customer's meter, are always at low pressure.

Pipelines and mains can also be classified as jointed or unjointed. Jointed pipes have joints which consist of flanges bolted together or similar arrangements. In unjointed pipes the sections are welded together.

Storage

The gas transmission system incorporates a number of different types of storage elements. These include high pressure liquid storage, underground salt cavities and gas holders.

Losses

Losses can occur in many different ways from the network. For example, losses due to leakage and losses due to the purging of sections of pipe and items of equipment during commissioning, decommissioning and maintenance. Leakage can be further classified according to whether it is due to some malfunction, such as a crack in a pipe or a failure of a joint, or whether it occurs in fully functioning equipment as a direct consequence of its design and operation.

Emissions from gas transmission networks arise from a large number of small sources spread over a large area (fugitive). It is estimated that up to 20% of the gas escaping from leaky pipelines and mains is oxidised in the soil by micro-organisms.

3.2 Definitions

Compressor stations

These are pumping stations designed to either raise or maintain the pressure in the pipeline or main.

Distribution System
The term ‘distribution’ usually refers to the low pressure part of a country’s gas supply network rather than describing the system as a whole.

High pressure LNG storage
Large vessels in which natural gas is stored in liquid form under pressure.

Mains
Transmission pipes on a local level. Typically the sort of gas pipes found under the streets. Classified as low, medium or intermediate pressure.

Pipeline
The term pipeline is generally restricted to the large diameter, high pressure pipes used in national transmission systems and the high pressure parts of regional transmission systems. The smaller pipes branching off from these are referred to as mains.

Ports
A facility at which liquid natural gas is loaded onto and off ships.

Service mains
Also referred to as service pipes or ‘services’. These are the narrow, low pressure pipes leading directly to a customers premises.

STP
Standard Temperature & Pressure - refers to a temperature of 373.15 K and a pressure of 101325 Pa.

Terminals
A facility for storing and processing gas at the end of a pipeline from a well. The well can be either on shore or offshore.

3.3 Techniques

The technology which forms part of a typical gas transmission network is described in Sections 3.1, Description, and 3.2, Definitions, above.

3.4 Emissions

The pollutants emitted by the various parts of a typical gas transmission network are described in Section 9, Species Profiles, below and the various emission sources within a gas transmission network are described in Sections 3.1, Description, and 3.2, Definitions, above. As mentioned in Section 3.1 above it is estimated that up to 20% of the gas escaping from leaky pipelines and mains is oxidised in the soil by micro-organisms. However, since it is not possible to measure how much of the gas gets oxidised in this way it is recommended that this phenomenon is ignored in the estimation of emissions.

3.5 Controls

End of pipe techniques are inapplicable because the emissions cannot be collected together in a pipe or duct, instead they arise from a geographically diverse array of small sources emitting directly to the atmosphere. Consequently the only way is to reduce emissions by:

- the use of better materials for pipes, joints and seals
- the quicker detection and rectification of leaks
- improved maintenance
- measures to collect gas purged during commissioning, decommissioning & other maintenance activities

4 SIMPLER METHODOLOGY

In the absence of data characterising the transmission network, an emission can be estimated from the total sales of gas in the region or country. Emission factors can be expressed either as a percentage of total gas sales in tonnes or using an emission factor in tonnes per PJ of energy.

5 DETAILED METHODOLOGY

The detailed methodology requires much greater information on the gas transmission system. This information is normally available from the distribution company.

The first step is to divide the pipeline network of the country into categories. The categories should be chosen so that data on the installed length (i.e. number of km) of each category of pipeline is available and also so that pipelines in each category have common emission characteristics. Table 5.1 lists a suggested scheme of pipeline categories and Table lists a suggested scheme of point sources.

Equation 1 is a calculation to estimate the emission. It refers to m different categories of pipeline and p categories of point source, e.g. gas holders, compressor stations etc. In the rest of this document m = 7 and p = 3. However, these numbers may differ for different countries according to the choice of categories of pipeline and point source. Examples of the allocation of suffixes in equation 1 are shown in Table 5.1 and Table 5.2.

$$E = \sum_{i=1}^{m} l_i p_i f_i + \sum_{k=1}^{p} n_k F_k \qquad (1)$$

Where: l_i = the length, in km, of pipeline of type i

p_i = the pressure, in mbar, of the gas in pipeline of type i

f_i = an emission factor, in tonnes per year per km per mbar

n_i = number of point sources of category i

F_i = leak rate in tonnes per year

Table 5.1 - Pipeline Types

Suffix	Pipeline Category
1	high pressure pipeline
2	jointed low pressure and service mains
3	unjointed low pressure and service mains
4	jointed medium pressure mains
5	unjointed medium pressure mains
6	jointed intermediate pressure mains
7	unjointed intermediate pressure mains

Table 5.2 - Point Sources

Suffix	Point Source
1	high pressure LNG storage facilities
2	compressor stations
3	gas holders

6 RELEVANT ACTIVITY STATISTICS

For the simpler method, only the energy value of the gas consumed is required.

For the detailed method, the activity statistics that appear in equation 1 are needed.

For breaking down the emission into individual compounds the local composition of the natural gas is also required.

7 POINT SOURCE CRITERIA

Storage facilities and processing plants should always be treated as point sources.

Compressor stations may be treated as point sources if sufficient data are available.

Further geographical disaggregation is discussed in Section 12 below.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Method

Table 8.1: Default Emission Factors for Simpler Method

Compound	**Emission factor** (tonnes per PJ of energy)	**Data Quality**	**Abatement type**	**Abatement efficiency**	**Fuel type**	**Country or region**	**Reference**
Methane	14.8 - 27	E	NA	NA	NA	Western Europe	4
Total emission	19 - 35	E	NA	NA	NA		†
Methane	39.6 - 104	E	NA	NA	NA	US & Canada	4
Total emission	51 - 130	E		NA	NA		†
Methane	218 - 568	E	NA	NA	NA	Former USSR, Central & Eastern Europe	4
Total emission	280 - 730	E	NA	NA	NA		†
Methane	40 - 96	E	NA	NA	NA	Other Oil Exporting Countries	4
Total emission	51 - 120	E	NA	NA	NA		†
Methane	40 - 96	E	NA	NA	NA	Rest of World	4
Total emission	51 - 120	E	NA	NA	NA		†

† derived from methane figures by assuming that the gas is 78 wt% methane

Error limits: ± >100% of emission estimate.

8.2 Detailed Method

8.2.1 High pressure storage facilities, F_2

The preferred way to estimate the emission factor is to carry out ambient concentration measurements and calculate the source strength from these. Alternatively a component-emission factor may be used. If this method is used the error limits on the emission factor will be ± 10% of the emission factor.

There is currently no default emission factor to propose for this source

8.2.2 Compressor station, F_3

Determine by ambient concentration measurements as for 8.2.1 above. If this method is used the error limits on the emission factor will be ± 10% of the emission factor
Default emission factor: 71.5 t/y (from reference 1)

8.2.3 Gas holder, F_4

This can be determined by isolating a gas holder and measuring its loss in height over a given time period. If this method is used the error limits on the emission factor will be ± 100% of the emission factor

Default emission factor: 4 t/y (from reference 1)

8.2.4 High pressure pipeline, f_1

Only determine if the high pressure pipeline system is old and considered to be leaky. Emission factors can be estimated by carrying out pressure decay experiments on isolated sections of pipeline. The technique for doing this is described in Section 16.1. If this method is used the error limits on the emission factor will be ± 10% of the emission factor.

Default emission factor: 0 t/y (from reference 1)

8.2.5 Medium & intermediate pressure pipeline & main, f_4, f_5, f_6 & f_7.

Determine by pressure decay experiments on isolated sections of pipe as described in Section 16.1.

Default emission factors 0.04 m^3/km/mbar/year for jointed pipes and 0.00004 m^3/km/mbar/year for unjointed pipes. Calculate tonnages using the ideal gas equation and the average molecular weight of the gas determined from its composition (from reference 1).

8.2.6 Low pressure main & service pipes f_2, f_3.

Determine by pressure decay experiments on isolated sections of pipe. This should be carried out as described in Section 16.1.

Table 8.2: Default Emission Factors for Detailed Method

Compound	Source	Symbol	Value	Unit	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
methane	high pressure storage facilities	F_2	no data	t/y	E	NA	NA	NA	UK	1
methane	high pressure pipeline	f_1	0	t/y/km	E	NA	NA	NA	UK	1
methane	jointed intermediate pressure main	f_6	0.04	m^3/km/mbar/year	E	NA	NA	NA	UK	1
methane	unjointed intermediate pressure main	f_7	0.00004	m^3/km/mbar/year	E	NA	NA	NA	UK	1
methane	jointed medium pressure main	f_4	0.04	m^3/km/mbar/year	E	NA	NA	NA	UK	1
methane	unjointed medium pressure main	f_5	0.00004	m^3/km/mbar/year	E	NA	NA	NA	UK	1
methane	jointed low pressure main & service pipes	f_2	88	m^3/km/year/mbar	E	NA	NA	NA	UK	2
methane	unjointed low pressure main & service pipes	f_3	88	m^3/km/year/mbar	E	NA	NA	NA	UK	2
methane	compressor station	F_3	71.5	t/y	E	NA	NA	NA	UK	1
methane	gas holder	F_4	4	t/y	E	NA	NA	NA	UK	1

9 SPECIES PROFILES

Species profiles can be estimated by assuming that the composition of the emission is the same as the composition of the gas, although in practice for some types of emission, e.g. leaks from underground pipes, some components of the gas may get adsorbed, e.g. by the soil. However, we recommend that these effects are ignored because they cannot be quantified. Table 9.1 lists typical species profiles for a number of countries:

Table 9.1: Typical species profiles for emissions from gas distribution networks

	UK*	Netherlands†	Germany††	France††
Carbon Dioxide(CO_2)	0.5	5.0	2.2	0.9
Nitrogen(N_2)	2.5	6.1	7.6	4.5
Methane(CH_4)	92.5	84.7	85.5	88.6
Ethane(C_2H_6)	2.9	3.8	3.3	4.7
Propane(C_3H_8)	0.9	0	0.9	0.8
2-methylpropane (C_4H_{10})	0.2	0.1	0	0
Butane(C_4H_{10})	0.2	0.1	0.4	0.2
2,2-dimethylpropane(C_5H_{10})	0.1	0	0	0
2-methylbutane(C_5H_{12})	0.1	0.1	0	0
Pentane(C_5H_{12})	0.1	0.0	0.1	0.3
Hydrogen Sulphide (H_2S)	0	0.1	0	0
Total mole %	100	100	100	100

* reference 5
† reference 6
†† reference 7

The data in Table 9.1 are mole percentages.

The following default profile has been derived from the above profiles by taking the average and rounding to the nearest whole percent:

Table 9.2: Default species profile for emissions from gas distribution networks

	mole %	**wt %**
Carbon Dioxide(CO_2)	2	5
Nitrogen(N_2)	5	8
Methane(CH_4)	88	78
Ethane(C_2H_6)	4	7
Propane(C_3H_8)	1	2

In the absence of any other data this profile should be used.

10 UNCERTAINTY ESTIMATES

10.1 Simpler method

For the simpler method the only available way of estimating the degree of uncertainty is by intuition based on experience. The uncertainty limits for the estimates derived using the simpler method are about a factor of 2.

10.2 Detailed method

The detailed method requires the determination of emission factors for various sources within the gas transmission network and the error in the final emission estimate will depend on the way in which these factors are determined. Section 8.2, suggests error limits for each of the methods discussed. However, in practice the error limits may differ from these if the techniques used to estimate the emission factors are not identical to those described in Section 8.2. Section 8.2 also gives error limits for the default emission factors.

The error limits for the emission factors should be combined with the error limits for the activity statistics (which should be available from the source of the statistics) according to the usual rules of the propagation of errors to give an error limit for the total emission.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHOD

11.1 Simpler method

This method depends on the default emission factor. However, better estimates of the emission factor can only be obtained by using the detailed method.

11.2 Detailed method

The main weakness of the detailed method is that it can be quite effort intensive to determine accurate emission factors.

12 SPATIAL DISAGGREGATION

The gas transmission system can be divided into two, the two parts being the national transmission system consisting of a relatively small number of high pressure pipelines covering distances of hundreds of kilometres, the second part being the rest of the transmission system. Data on the locations of the various pipelines which form the national transmission system should be readily available for most countries. These can then be regarded as line sources. Emissions from the rest of the system can be broken down into a mixture of area sources, proportional to population density, and point sources corresponding to the locations of major installations such as terminals, storage, processing plants and larger compressor stations.

13 TEMPORAL DISAGGREGATION CRITERIA

Leakage rate is a function of pressure rather than throughput. It is therefore safe to assume that the leakage rate is constant.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

No supplementary documents are required.

16 VERIFICATION PROCEDURES

The emission factors for the detailed method can be checked by carrying out pipeline leak tests as described in Section 16.1.

16.1 Pipeline Leak Tests

Identify a representative sample of pipes to test. The best way of doing this is to compile a table such as the figure below dividing up the national network into a number of categories based on pipe diameter and material:

Table 16.1: Example table for pipeline leak tests

Diameter	**Steel**	**Pit Cast**	**Spun Cast**	**Ductile**	**PE**
≤8cm					
10-13cm					
15-18cm					
20-28cm					
≥30cm					

The categories described in the above figure are for illustration only. Different diameters and materials may be more appropriate in different countries.

Start by entering into the table the number of kilometres of pipe of each category in the entire distribution system. Next, decide how many sections of pipeline from each category should be chosen for the experiments. The aim is to identify a sample of experimental pipeline sections which are representative of the network as a whole. The number of test sections in each category should generally be proportional to the number of kilometres in the network and to the expected variability of leakage rates. The leakage rates from PE pipes are expected to be less variable than those from cast iron pipes and so fewer tests are required for a given size of population for PE pipes than for cast iron to establish the leak rate to the same level of uncertainty.

For each section of ‘main’ identified agreement will be needed from the customer supplied by that main to allow interruption of their supply for the duration of the test. Each section of pipe to be isolated should be approximately 1km long. The service pipe should be capped on the customer’s side of the meter isolation valve.

Two pressure decay experiments are required for each isolated section of pipe. In one test a leak of known magnitude is introduced into the pipeline under test and a pressure decay curve plotted. In the other the control leak is stopped. From the two pressure decay curves it is possible to calculate the rate of gas leakage from the test section without prior knowledge of the internal volume of the section.

Leak rates should be determined in this way for a number of different pressures, both above, below and at the normal operating pressure of the main.

The leak rate should also be determined with the service pipe disconnected from the main. This allows separate leak rates to be calculated for the service pipe. Service pipes are made of a number of different materials and the sample of test mains should include service pipes of all the materials used.

Default emission factor: 88 m^3/km/year/mbar including leakage from service pipes. The emission factors f_{Lj}, and f_{Lu} can be calculated from these figures using the pressure in the pipe and the composition of the gas (to estimate the weight of $1m^3$ of gas), (from reference 2)

17 REFERENCES

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19 RELEASE VERSION, DATE AND SOURCE

Version	2.1
Date:	1 February 1999
Source:	H. J. Rudd AEA Technology Environment UK

20 POINT OF ENQUIRY

Any comments on this chapter or enquiries should be directed to:

Haydn Jones

AEA Technology Environment
E6 Culham
Abingdon
OX14 3ED
UK

Tel: +44 1235 463122
Fax: + 44 1235 463574
Email: haydn.h.jones@aeat.co.uk