TECHNICAL ASSOCIATION
OF THE EUROPEAN NATURAL GAS INDUSTRY

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GAS INFRASTRUCTURE
POSITION PAPER ON BAT

24TH JULY 2012

MARCOGAZ is the Technical Association of the European Natural Gas Industry.
- MARCOGAZ chief mission is to serve its Members as the European window for any technical issues regarding natural gas.
- As the representative organisation of the European Natural gas Industry, it aims at monitoring and taking influence when needed on European technical regulation, standardisation and certification.
- MARCOGAZ represents 28 members in 22 countries.

1. Introduction

This document has been prepared by the Working Group Air Emissions as part of the Standing Committee Sustainability. Our special envoy Mr Jürgen Vorgang of Open Grid Europe is participating in the BREF revision. MARCOGAZ have made an evaluation of the present use of Large Combustion Plants LCP in the Gas industry and the possible consequence for the gas industry when the Industrial Emissions Directive (IED) will be implemented.

The conclusion is that gas turbines used in compressor stations to push the gas through the tubes will be part of the IED. The gas system is designed to be able to deliver gas for industries and for heating of households under extreme severe winter conditions which will statistically occur only once in the fifty years. In addition delivery of supply is essential for gas (>99.9% is required by law) which implicates that there is a back-up system for all systems. Above implicates that the operating hours of the turbines are very limited during the year.

The best available technology to reduce NO_x emissions is replacing the burners of the existing turbines by Low NO_x burners (when available on the market).

We have calculated the cost for replacements of the existing burners in the gas turbines for Low NO_x burners according the latest technology. The cost of the emission saving per ton NO_x emission saved is between € 9.000,- and € 115.000,- when we calculate the cost with a payback period of the investments of 15 years. Even in an emission Trading System (ETS) system this kind of cost will never occur. Neither for society, nor for the environment, looking at the small amounts of NO_x reduced it is benefital to modify the existing gas turbines to achieve lower emissions.

MARCOGAZ has also participated in the revision of the “Integrated Pollution Prevention and Control document” which is the “Reference Document on Best available Techniques for Large Combustions plants. To read our comments on this 580 pages containing document is however more time consuming than to read this position paper.

2. Integrated Pollution Prevention and Control (IPPC)

Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control is a directive of the European Union. It replaces the Council Directive 96/61/EC of 24 September 1996 on the same subject matter; both are commonly referred to as IPPC Directive.

From 2005-2007, the effect of the directive was assessed. In 2010, a revised wording was published, integrated with 6 other European directives regulating large industrial sites, into the Industrial Emissions Directive, short IED.

The European IPPC Bureau has been founded to organize the necessary exchange of information and produces Best Available Techniques reference (short: 'BREF') documents which Member States are required to take into account when determining best available techniques generally or in specific cases.

Emission limit values, parameters or equivalent technical measures should be based on the best available techniques, without prescribing the use of one specific technique or technology and taking into consideration the technical characteristics of the installation concerned, its geographical location and local environmental conditions. In all cases the authorisation conditions should lay down provisions on minimising long-distance or trans frontier pollution and ensure a high level of protection for the environment as a whole.

In order to coordinate the permit process required under the Directive and the greenhouse gas emission trading scheme, a permit issued in compliance with the Directive is not obliged to contain the emission limit values for greenhouse gases if these gases are subject to an emission trading scheme, provided there is no local pollution problem.
In this document 'MARCOGAZ' is giving an overview of the nowadays used combustion techniques and the operating conditions for gas transport. To demonstrate this a survey, covering about 80% of the EU gas industry, was organised. 11 Countries participated in this survey with in total 32 engines and 515 gas turbines.

The main conclusions from this survey are:

- 40 % of TSO and storage turbines are running less than 500 hours per year
- Only 20% of the turbines are running more than 3000 hours/year.
- Security of supply of natural gas is essential. To cope with a continuously fluctuating demand a high flexibility is required resulting in important load variation impacting turbine efficiency.
- Operation: Energy efficiency is affected by several parameters depending on gas transportation nominated by the shippers and traders..
- Case studies show that dry premix low NO_x burners (DLN, DLE, SOLONOX...) are the best reference solution to be applied.
- Considering the specific operating conditions in the gas industry other technical options like SCR (Selective Catalystic Reduction) or water or steam injection are not economically and technically viable and therefore not used for gas turbines by the gas industry (See EN12583 :2001 and pr EN12583 : 2011).
- Existing turbines cannot always be retrofitted with new burner technology.
- Recent achieved results from gas turbines installed since 1996 operating in the gas grid show NO_x concentrations in the flue gas down to 60 mg/m³ at 15% O_2 at common load. Local conditions may differ from ISO conditions, so results vary. Gas turbines installed today can reach 50 mg NO_x/m³.

3. Introduction of the Gas industry

3.1 The gas industry transports 60 % of the primary energy in Europe.

In EU the natural gas High pressure grid in the 27 EU countries is approximately 235.000 km long. The high pressure grid delivers gas to a low pressure distribution grid which is 1.649.400 km long. Only in the high pressure grid are compressor stations (167 compressor stations in total). In total 120.682.000 customers are connected to the gas grid.
The gas market is open to all parties and is regulated. This means that shippers or traders order gas transport and the transmission system operators (TSO) must deliver the transport on demand.

In 2010 Europe imported 82 bcm of LNG from 13 different countries. This amount guarantees that the supply of the European gas market is not limited to the 6 gas suppliers who are transporting via pipelines to Europe and the 6 indigenous gas suppliers.

Due to the fact that gas is a main primary energy source there are high requirements for security of supply.

The global natural gas resource for conventional recoverable gas resources are equivalent to over 60 years of current global consumption. The potential of natural gas from shale and other newly recoverable resources such as coal bed methane is expected to extend current production to at least another 100 years.

Natural gas price is typically 1/3 of the price of electricity per kWh in Europe and is for that reason the preferred source for heating and hot water. Due to this the transported quantities of gas are partially temperature related. The European gas grids are capacity wise designed to supply the consumers even under severe winter conditions which will only occur once in the 50 years. Due to this and due to the capacity needs of a European integrated open market a well-functioning gas grid requires a lot of compressor stations which will run only for a few 100 hours a year.

3.2 Infrastructure

3.2.1 Compressor stations

Gas transportation is only possible when there is a pressure differential among the pipelines. For that reason gas compressors, which are located in compressor stations, are required.

One compressor station consist always of minimal 2 compressor units (due to the required security of supply there is always a redundant system) and at maximum 12 individual compressor units. By compressing the gas the volume is reduced and the diameter of the pipelines can be reduced. The gas compressors are mainly powered by gas turbines, and some piston type gas engines or electrical engines. (See addendum paragraph 6.5.4 for more details about compressor stations)

3.2.2 Gas storage

In 2009 there were 78 underground gas storages in the EU where gas turbines are used to compress the gas into the gas storage.

Throughout the year, natural gas is produced at a relatively constant level. However, there are significant differences between natural gas consumption in winter and summer. Historically storages were used to offset seasonal fluctuations in consumption. In spring and summer, natural gas suppliers import more natural gas than demand requires, and the surplus is stored. In winter, consumption exceeds the volume of gas imported, so the stored gas is used to cope with the demand. However, since the opening of the gas markets by the European directives, the operation of storage is less seasonable: storage can as well be emptied in summer, depending on the gas movements asked by shippers and traders. (See addendum paragraph 6.6 for more details about gas storage)

3.2.3 LNG receiving terminals

In 2009 there were 19 LNG (Liquefied Natural Gas) receiving terminals where gas turbines are used to pressurize the gas into the gas transport pipelines. (see addendum paragraph 6.7 for more detail about LNG receiving terminals).

3.3 Special conditions for the gas industry

High seasonal and temperature linked fluctuations

Coping the high demands of cold winter days and in parallel low demand at high temperatures in summer means: a high flexibility is needed, which leads to compressor stations with modular composition of different units which can be started and stopped depending on the varying demand. Most of the times the turbines are running under partial load. The utilization range is 50-100% of full load capacity.

Limited freedom regarding the localisation of compressor stations

The gas industry is transporting gas molecules physically and cannot shift compression work to other places: every 100 to 150 km a compressor station is required. Compressor stations are usually located in remote areas since the pipelines are routed across the country. In general the transported gas is used as fuel. Compared to power plants there is no steam or water used in compressor stations and so no existing water capture and treatment facilities. Therefore steam or water injection is not a suitable technology for NO_x limitation in the case of gas transport. Pre-mix low NO_x technologies are the only solution for gas compressors. However for older turbine models this technology is not always available and may not give the same results. As can be seen, technical options are limited and higher NO requirements can lead to complete replacement of turbines.

Controlled by the market

The TSO's are offering large transmission capacities, which can be booked and used by shippers and traders. Depending on their demand we have to increase and decrease the flow by starting and stopping compressor drives and/or run on less efficient part load (see § 6.4).

Historically built

The gas grid is mainly built between 1966 and 2010. The design is expanded every time when new industries, new cities new suppliers, new connections to Europe like Nord-stream and South-stream appear. Also by the opening of the markets in Europe, the grid is expanded and additional connections are made. In the EU it is normal to have every 2 years an open season where shippers and traders can buy new transport capacities. The TSO is then responsible that these new capacities are realised in the gas transport system.

4. Results from the MARCOGAZ survey

4.1 Statistical Survey

To give an actual overview of the todays techniques for natural gas fired turbines and engines used for gas transport, MARCOGAZ performed a survey among its members. 11 countries participated in this survey with in total 32 engines and 515 gas turbines. The results of this survey are presented in this paragraph

Gas turbines used for gas industry can vary much in age. The first turbines became operational at the end of the sixties. With the expansion of the transportation grid more gas turbines became operational. All of these older gas turbines are still operational and are still in good operational condition. The expected lifespan of these turbines is easily over 50 years.

Thermal capacity

Turbine size in MW fired	Number of turbines	Number of engines
0 < Turbine ≤ 15	67	29
15 < Turbine ≤ 50	309	3
>50	139	

Table 1: Number of turbines and engines versus turbine size

Table 1 demonstrates that the majority of the gas turbines and engines used in Europe for gas transportation have a small thermal fuel input. Although the thermal input may be small the number of turbines is quite large.

Operating time

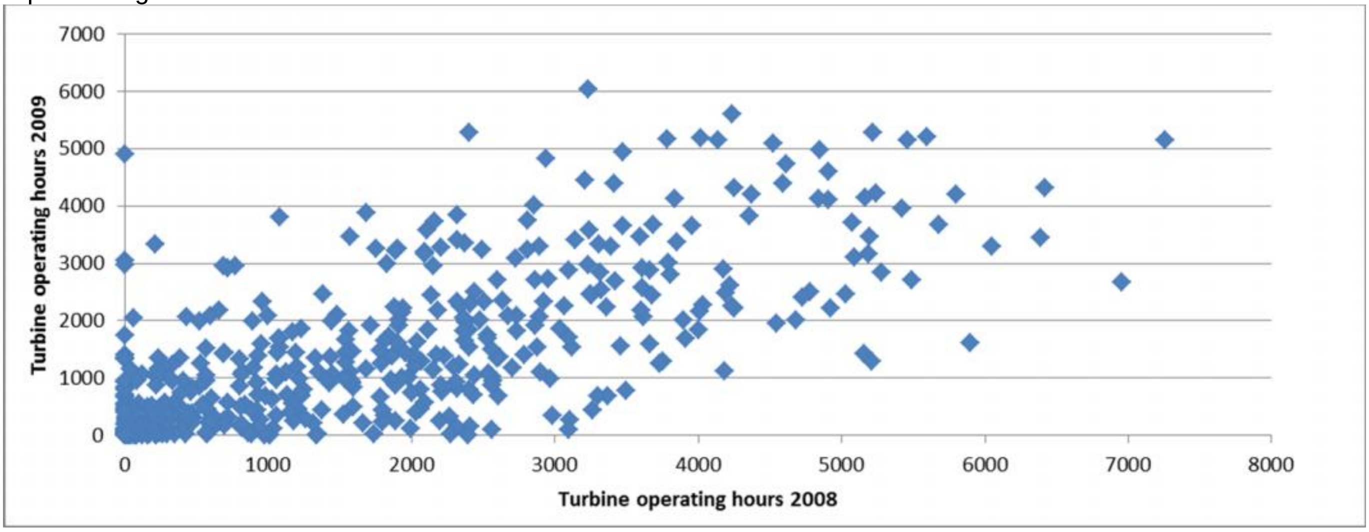

Figure 1: Operating hours of gas turbines in 2 adjacent years

When the operating hours in two adjacent years where comparable the figure would show one line through the crossing of the axis. The figure shows that depending on temperatures and request the operational hours fluctuate from year to year.

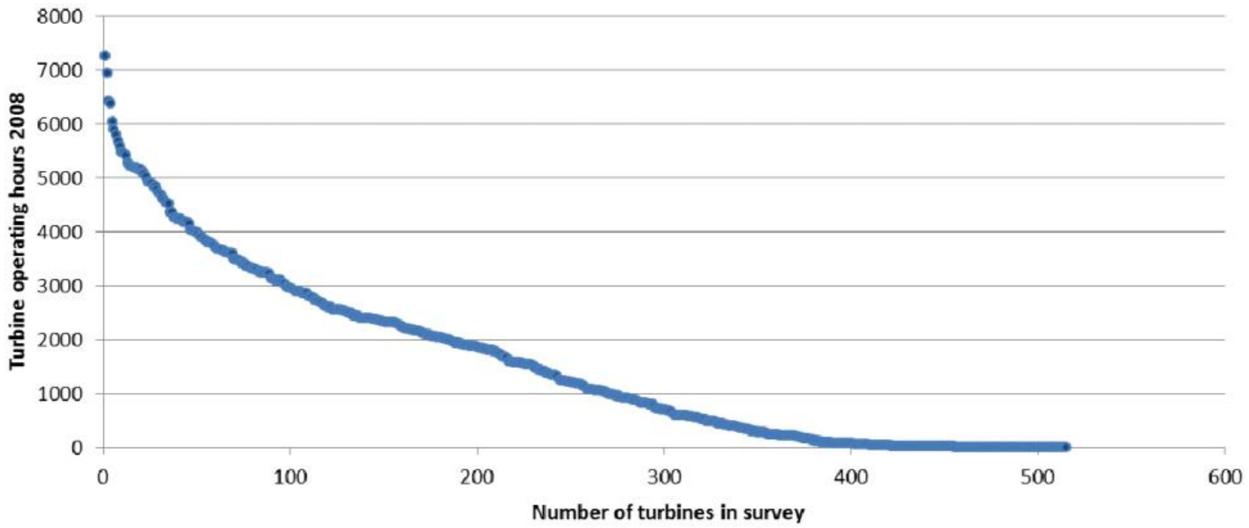

Figure 2: Operational hours per year

In figure 2 every dot represents a turbine. Depending on their operating hours they a placed in a decreasing sequence to obtain one clear line who represents the operating hours per turbine in the year 2008.

From Figure 1: 1 and 2 it can be derived that:

- 40% of the turbines and engines used in gas industry are running less than 500 hours per year.
- Approximately 20% of the turbines run more than 3000 operating hours per year.
- The operating time of the unit varies much from year to year because of different winter situations and different behaviour of the markets. This has an important impact on the NO_x and CO emissions and on turbine efficiencies which are indeed much varying with the load.
- TSOs and storage operators have standby units. They try to share the hours of operation, not always equally, in order to reduce the maintenance costs and to optimize their availability and emissions.

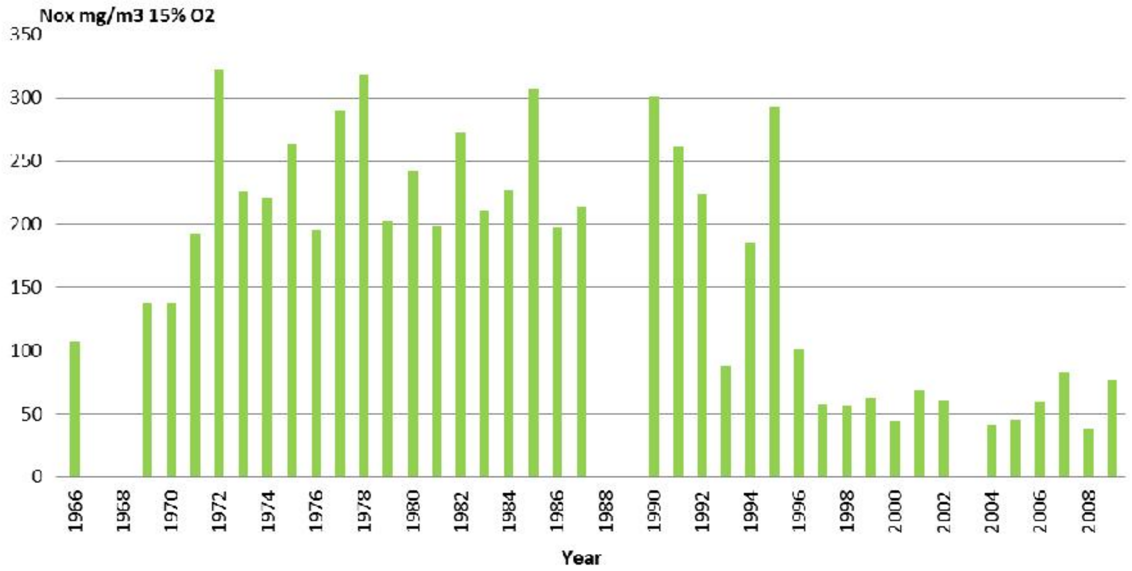

Figure 3: NO_x emission in mg/m^3, 15% O_2 versus age of turbines measured by year installed.

Figure 3 shows that recent achieved results from gas turbines installed since 1996 operating in the gas grid show NO_x concentrations in the flue gas down to 60 mg/m^3 at 15% O_2 at common load. Local conditions may differ from ISO conditions, so results vary. This survey covers 80% of the EU gas industry (turbines and engines). From 1996 on a clear trend can be seen demonstrating the effort done by TSO's to invest in the new (in 1996) Premix based Dry Low NO_x Emission technologies to lower the emission for NO_x. That technique is the BAT for new mechanical drive Gas Turbines; the fluctuation in the recent years emission is related to the sensitivity of that technique to load variation linked with the previously detailed variability of the gas transmission capacities demands.

4.2 Economical aspects of reducing NO_x emissions.

4.2.1. Retrofit of existing technology to DLN in gas industry

A study of the total costs of ownership and the cost per ton NO_x avoided is calculated for 5 existing conventional burners' system turbines to be retrofitted with DLN technology. The cost of the emissions saving over a 15 years period is calculated for some compressor station turbines in operation in the EU. The price is between 9 k€ and 115 k€ per ton avoided NO_x. The widespread in price varies with the total tons of NO_x emitted per year. It can be noticed that the replacement technique (DLN) mentioned are economically adequate only for machines with higher operating hours. However not for all gas turbines is this retrofitting technology available.

Compressor units	A	B	C	D	E
Nitrogen oxides (No_x/NO_2) (t/a) average / years 2002-2010	5,73	4,96	3,41	2,28	27,33
DLN-burner investment cost (based on rough estimations)	3 400 000 €	3 400 000 €	3 400 000 €	3 400 000 €	3 400 000 €
- technology		2 100 000 €	2 100 000 €	2 100 000 €	2 100 000 €
- installation etc		1 300 000 €	1 300 000 €	1 300 000 €	1 300 000 €
Estimated emissions after changes (t/a)	1,47	1,03	0,36	0,3	2,38
Estimated emissions savings after changes (t/a)	4,27	3,93	3,06	1,97	24,95
Cost of the emission saving 1 year period	796 869 €	865 990 €	1 111 695 €	1 721 940 €	136 257 €
Cost of the emission saving 15 years period (€/t/a)	53 125 €	57 733 €	74 113 €	114 796 €	9 084 €

Table 2: Cost of DLN retrofit technology on existing turbines

4.2.2. Cost analysis of NO_x Control for stationary gas Turbines

The U.S. Department of Energy performed a Cost Analysis of NO_x Control Alternatives for Stationary Gas Turbines (1999). In this analysis the costs of different techniques were compared to each other. In the next table an overview is given of this cost analysis.

NB : the considered DLN technology (25ppm = 50 mg NO_x/m^3 at 15 % O2) is still in the BAT widely used for recently installed Units

Turbine Output	5 MW Class		25 MW Class		150 MW Class	
Median value NO_X EMISSION CONTROL TECHNOLOGY	USD/ton	USDct/ kWh	USD/ton	USDct/ kWh	USD/ton	USDct/ kWh
DLN (Dry Low NO_x) (25 ppm)*	260	0,075	210	0,124	122*	0,054*
Catalytic Combustion (3 ppm)	957	0,317	692	0,215	371	0,146
Water/Steam Injection (42 ppm)	1652	0,41	984	0,24	476	0,152
Conventional SCR (Selective Catalytic Reduction) (9 ppm)	6274	0,469	3541	0,204	1938	0,117
High Temperature SCR (9 ppm)	7148	0,53	3841	0,221	2359	0,134
$SCONO_x$ ™ (Catalytic Absorption System) (2 ppm)	16327	0,847	11554	0,462	6938	0,289
Low Temperature SCR (9 ppm)	5894	1,06	2202	0,429		

* 9-25 ppm USD/kWh based on 8,000 full load hours/year

Table 3: Cost analysis different techniques for NO_x reduction of stationary gas turbines

From both studies it can be derived that – regardless of the technical feasibility of other options – premix dry low NO_x technologies are the best solution for NO_x reduction. Looking at the large differences between the results of both studies it can also be concluded that the retrofitting to premix dry low NO_x technology of the oldest conventional turbines is only economically conceivable for compressors with large yearly operating hours.

It has to be noticed that existing turbines cannot always be retrofitted with this new technology.

All compressor stations are located at remote locations, and do not use steam or water. Therefore steam and water injection is not a suitable technology for NO_x limitation.

This is confirming the conclusions stated in the EN12583 : 2001 reconfirmed in the pr EN12583 : 2011 "Gas supply systems - Compressor stations Functional requirements"

5. Conclusions

The main conclusions from this survey are:

- 40 % of TSO and storage turbines are running less than 500 hours/year.
- Only 20% of the turbines are used for more than 3000 hours/year.
- Security of supply of natural gas is essential. To cope with a continuously fluctuating demand a high flexibility is required resulting in important load variation impacting turbine efficiency.
- Operation: Energy efficiency is affected by several parameters depending on gas transportation nominated by the shippers and traders.
- Case studies show that dry premix low NO_x burners (DLN, DLE, SOLONOX…) are the best reference solution to be applied.
- Considering the specific operating conditions in the gas industry other technical options like SCR or water or steam injection are not economically and technically viable and therefore not used for gas turbines by the gas industry (See EN12583 :2001 and pr EN12583 : 2011).
- Existing turbines cannot always be retrofitted with new burner technology.
- Recent achieved result from gas turbines installed since 1996 operating in the gas grid show NO_x concentrations in the flue gas down to 60 mg/m3 at 15% O2 at common load. Local conditions may differ from ISO conditions, so results vary. Gas turbines installed today can reach 50 mg NO_x/m^3.

Addendum explaining the working of the Gas infrastructure

6.1 The main components of the gas grid

The gas grid is essentially composed of a transit grid, a transport grid and a distribution grid.
The transit grid contains, as the transport grid, an entry point (frontier of the country, LNG-terminal, storage plant) and compressor stations. It contains also an exit point at another frontier of the country.
The transport grid contains entry points or links to the transit grid, to LNG-terminals or a storage plants, and compressor stations. It contains also links to important gas consumption sites (electrical power plants, important industrial customers) and to the distribution grid.
The distribution grid has entry points linked to the gas transport grid (gas regulation stations, city gates), where the pressure of the gas is reduced from transport pressure to high pressure distribution pressure, which is further in this grid reduced to medium and final distribution pressure.
Technically the elements of the grids are:

- Entry station at the boundary, where the gas volume and quality is measured and monitored;
- LNG-plants, where the gas is stored in liquid cryogenic form, and eventually sent out in gaseous form after gasification and pressurization;
- Storage salt caverns, aquiferous layers and depleted gas fields, where the gas is stored under high pressure and eventually sent out in the (transportation) grid;

- Compressor stations, guaranteeing that the volume of gas needed is effectively transported by the grid or compressed into a storage;
- Pipelines transporting or distributing the gas. The greater the diameter the more gas can be transported by the pipe. However, in order to avoid huge diameters, gas is compressed. Gas distributed to the domestic clients has a gauge pressure of 20, 25 or 250 mbar. This pressure must be constant in order to obtain a safe and environmental friendly functioning of the appliances. The compression is also necessary because the transport of the quantities of gas needed at those distribution pressures would need gigantic pipes with for instance a diameter of 55 meter at 20 mbar instead 100 cm at 60 bar;
- Gas metering and pressure regulation stations, where the pressure is by steps lowered to the final distribution pressure;
- The gas metering and pressure regulation stations of power plants or important industrials consumers are generally not a part of the gas grid.

6.2 The main functions of the gas grid

The first function of the gas grid is to guarantee a default free supply of gas to all the gas consumers. The supply of gas cannot be interrupted. Indeed in case of an interruption, the restart of supply can lead to serious problems since it is not certain that every appliance is equipped with a reliable shut off valve forbidding the release of not ignited gas after the restarting of supply. As a result, a default in supply will need the shutdown of that part of the grid, followed by the resupply of each consumer, one by one, after checking that his appliances are well shut down and will not emit unburned gas. This takes a very long time.
As a result, the continuous supply is a matter of national health and safety. It is also for another reason a matter of national health and safety: in case of an interruption of the supply of gas, heating, cooking, production of warm water and a number of craftsmanship’s and commercial or service activities will be impossible. Finally, a problem of supply of the gas grid can jeopardize the production and supply of electrical power.
This security of supply is a must not only during normal operating days but also during the coldest winter periods, when the volume of gas consumed is huge compared to warm summer days.
This explains why the grid is configured on such a way that in all circumstances a 100 % security of supply is obtained: feeding from different ways, standby compression units, grid and equipment designed and maintained for the most heavy demand and circumstances.

6.3 Specific situation (remote locations)

While the goal of distribution lines is to distribute the gas in the cities, the transit and transport pipelines and storages are localized in country side. The public consultations realized in the framework of town planning or environmental legislation lead to routings and compressor sites which are disturbing as less as possible socio-economic life, populations and environment. Further, the different permits, public consultations and environmental effects reports needed in case of new investments, and even the legislation on public procurement, make it, compared to private projects located in industrial areas, impossible to realize investments in a normal time period.

6.4 The effects of the market opening

In the past, the maintenance and operation of the gas grid and its equipment could be organized in function of the seasons: during summertime maintenance and filling of storage, during the other seasons the grid and equipment must be ready for operation and the degree of operation was essentially function of the temperature.
Since the opening of the market this seasonal rhythm has disappeared: operation is now dictated by trading. As a result, the maintenance can no longer be realized on the way it has been programmed in the past, and the existence of spare or emergency equipment is essential during the whole year.
Another result of market opening is that the grid operators are now highly regulated business, with investment plans and operation budgets to be approved by the regulating authorities. This

leads to inflexibility in investments and operations policy which has to be taken into account during the design of the networks.
Finally, it is the goal of the European authorities to obtain a global gas market. In such a gas market the movements of gas can be unlinked to the local or even regional conditions regarding weather, economic conjuncture or electrical power production. As a result, gas movements, and thus the working regime of compressors, LNG-plants and underground storages, will be continuously changing in function of totally external factors.

6.5 Gas transmission

6.5.1 Summary

Gas pipeline transmission means high pressure transport of gas through pipeline systems. Large quantities of energy can be transferred over distances of several thousand kilometres. The operation is described for different technologies involved in that process, the emissions are characterised according to their occurrence and the regulations to limit emissions are mentioned.

6.5.2 General introduction

Transmission of natural gas is made by either pipelines or via shipping. In general the pipeline transport is cheaper at distances lower than 4000 km, but that depends on individual circumstances.

For the pipeline transmission the gas molecules need pressure to move, and during their way in the pipe they create friction, which results in a pressure drop. After 100 to 150 km the initial pressure has decreased so much that an increase is necessary to obtain a reasonable flow through the pipeline system. Pressure increase is made by compressor stations, which need energy to recompress the gas. This energy is usually taken from the natural gas flow inside the pipeline. Today there are also electrically driven gas compressors installed. This can be only efficient when a High Voltage line with sufficient capacity is in the vicinity of the compressorstation.

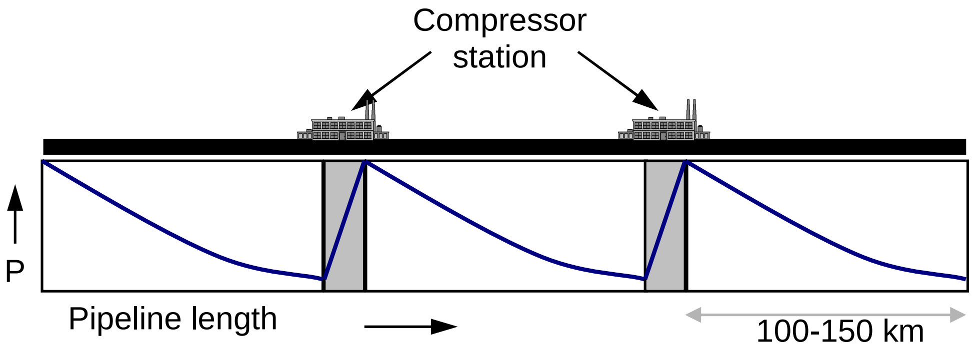

Figure 4: Winter situation Pressure decline

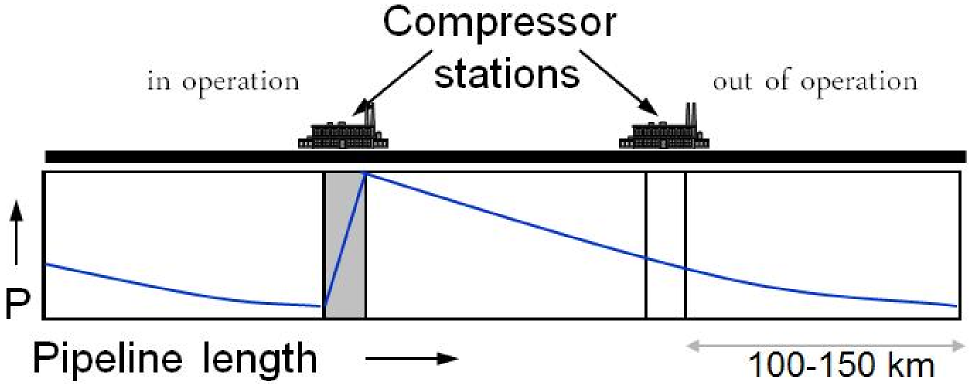

Figure 5. Summer situation. Pressure decline.

Transmission of natural gas is subject to seasonal fluctuation and to fluctuations driven by the market: industrial users and power stations are relatively constant consumers of gas during the year and have to be supplied also in warm seasons. For heating purposes during winter times plenty of gas is needed, but these consumers do not need gas during summer. . This has an effect on the use of compressors as well as on the flow of gas. Sometimes the gas in the pipelines moves at walking speed, as slow as 5 km/h, in other times the gas velocity can be at a level of 50 km/h or even higher.

Transmission of natural gas is the term usually for high pressure transport in big pipelines to bridge long distances. A higher pressure results in a higher energy flow, so the higher the pressure, the more gas can be transported. But it has to be taken into account that with doubling the pressure the need for compressor energy increases eight times. The pressure ranges up to 100 bar in onshore pipelines. In offshore pipelines the pressure can even exceed this value due to higher outside pipeline wall pressure caused by water depth.

The distribution of gas to consumers is also made in pipelines, only pressure and diameter of pipes are much lower. The limit between transmission and distribution depends on national or company definitions, but in general transport higher than 5 bar is called transmission, lower pressure means distribution.

6.5.3 Pipeline systems

Main transport pipelines are like a network of gas highways. The pipes range in diameter from DN 1400 down to DN 300 (56" down to 12") or smaller.(DN is standardised internal diameter in mm). They are made of various grades of steel and there is a cathodic protection system to prevent corrosion. For bigger flows sometimes parallel pipes are installed. This can be up to 10 lines in parallel. The gas highways have 'link roads' at various points along their length. Interlinking enables different parts of the system to be connected together or to substitute for each other in order to maintain the security of supply.

Valve systems allow to isolate sections of the line so that the gas flow can be shut off and diverted e.g. if a pipe section needs repair. It may also be necessary to close a link between two pipelines for other reasons. At long transmission pipeline systems there are valve stations at each 30 km, but in higher dense areas with more interlinking the distance can be smaller.

Shut-off valves are installed at switching points and other locations. The main shutoff valves in the pipeline incorporate smaller by-pass valves so that pressure differences can be equalized gradually before the main valve is opened.

The gas purchasing resp. transmission contracts require gas to be supplied in clean condition. Sand, water, condensate and other impurities are accordingly removed by the producers in gas conditioning installations before the gas is transferred to the main pipelines.

During operation the pipeline does not have any impact on the environment; only during the building phase it is necessary to remove all plants from the corridor needed to operate the building machines. After the renaturation often there is no remarkable difference.

Photo 1: Building phase Photo 2: Pipeline after one year

Equipment used for pipeline systems:
- pipelines of different size
- valves of different size

6.5.4 Compressor stations

The purpose of a compressor station is to restore the pipeline pressure to the desired level if it is decreased too much in the pipeline. The pressure loss depends on the distance from the previous compressor station, but also on the flow rate. To ensure the contracted gas flow the pipeline pressure has to be raised again after 100 to 150 km depending on the local and technical situation.

The compression is made by rotating machines (mainly centrifugal compressors) driven either by gas turbines, which are mainly used, or by electrical or gas motors. The advantage of gas driven machines is the availability of energy, whereas a connection to the power supply is often expensive and increases the danger of availability.


Photo 3: Gas compressor


Photo 4: Gas turbine as compressor drive

The number of compression unit and their single mechanical power is depending on the pipe usual flow profile. To react on a changing gas flow, a compressor station modular design has to be used to optimise the station global efficiency and capability to fulfil the compression needs. With increasing flow more and more compressor units are put into operation.
At a single pipeline the number of compressors can be at 2 to 3, but in large compressor stations a set of up to 6 parallel pipelines the number of compressors could reach up to 12 units.

The compressor unit mechanical power usually varies between 3 and 25 MW depending on the required power input to the pipe. To ensure the contracted gas flow, spare capacity is installed to switch to that machine and operate in case of a repair of a given compressor unit.

The main environmental impact of a gas turbine based compressor station is the composition of waste gases, which contain CO_2, NO_x and CO. As natural gas is cleaned from sulphur at the production stage, the emissions of SO_2 are negligible as well as the creation of particulates from burning natural gas. Another aspect is the creation of noise from the compressor drives, but usually the compressor stations are located in areas with low density of population.
The electrical drive based compressor stations are obviously not directly impacting air emissions. Indirectly their impact is related to the way the electrical energy used is produced (coal, gas, nuclear…). As NO_x and CO are varying in an opposite way in relation with flame temperature, the use at various load of a compression gas turbine is making it difficult to optimise both of these emission factors.

The efficiency of the compression units is varying a lot with the operating conditions:

- Concerning the gas turbines, their base load efficiency is varying for new units from 30% to 40%, according to their size (base load power) and their design.
- The specificity of turbines used in gas transmission is the flexibility they have to cope with resulting in a use at partial load.

- The use at partial load of a gas turbine has an important impact on the unit efficiency.

Photo 5: Compressor station in Germany containing 8 compressor units in total

6.6 GAS STORAGE

Throughout the year, natural gas is produced at a relatively constant level. However, there are significant differences between natural gas consumption for heating in winter and summer. Historically storages are used to offset seasonal fluctuations in consumption. In spring and summer, natural gas suppliers import more natural gas than demand requires, and the surplus is stored. In winter, consumption exceeds the volume of gas imported, so the stored gas is used to cope with the demand. However, since the opening of the market, the operation of storage is less seasonable: storage can as well be emptied in summer, depending on the gas movements asked by shippers and traders.

Natural gas storage is an industrial process where gas is generally injected into an underground porous rock system (or in salt cavern) which can store the accumulation and then supply the gas to meet the market's demand, in terms of hourly and daily flow rate.
The cap rock, , must have natural sealing properties so as to prevent vertical gas losses. Samples are collected and lab tests carried out to evaluate the maximum operating pressure limits for the reservoir.

Process
The gas storage stations include gas a compression plant and a processing plant suited for withdrawal.
Natural gas arriving from the transport system for injection in the storage reservoirs is compressed at the compressor plants, in order to inject it into the reservoir.

In particular, the compression plants connected to the transport system allow gas, arriving from the gas pipeline network at a maximum pressure of approximately 75 barg to be injected into the storage wells at a pressure of up to 150-180 barg using high head centrifugal compressors powered by gas turbines or reciprocating compressors powered by explosion engines or electric motors.

6.7 LNG TERMINAL

In order to be transported by LNG carriers, natural gas is subject to the liquefaction process. The liquefaction temperature of natural gas is -162 °C at atmospheric pressure: this is known as liquefied natural gas (LNG). Once liquefied, the volume is 600 times smaller, making it possible to transport large amounts of energy by ship.

The natural gas is liquefied and stored in tanks in the producing country before being loaded into an LNG vessel. It is then transported to the destination country.
During transportation by sea, the LNG is stored at -162 °C and at atmospheric pressure.
Once arrived at its destination, the LNG is unloaded at the import terminal where it is stored under the same conditions, and eventually heated by boilers and returned to a gaseous state and after having reached an appropriate pressure level, injected into the pipeline network.

The process of extracting natural gas from the deposits, its liquefaction for transport on-board ships and the subsequent regasification for use by users is known as the LNG supply chain.
In recent years, the regasification of natural gas, together with its transport and storage, has been a fundamental activity to ensure the necessary diversification of supply sources and the appropriate flexibility of infrastructure, in response to the growing demand for gas.

6.7.1 Plants areas

LNG receiving area of the plant has, in general, a berthing area for the LNG carriers, unloading arms and a transfer line to the tanks. The LNG is unloaded from carriers and sent through a pipeline.



The storage area consists of tanks in which submerged pumps are placed for the movement of LNG.

The regasification area is made up of pumps for the movement and pressurisation of the LNG and of the submerged combustion and/or seawater vaporisers. The liquefied natural gas is drawn from the tanks and sent through the pipeline to the vaporisation units where the LNG is heated to reach its gaseous state. The natural gas is then injected into the transmission network which transports it to end users.

In order to improve performance and safety in general there's the presence of a boil- off recovery system (i.e. the recovery of vapours which are continuously formed inside the tanks when the LNG is "boiling" and which tend to increase the pressure).
For the recovery of this boil-off gas, compressors are used to transport the gas from the tank to an absorption column where they are condensed and go back into the production cycle. Part of the boil-off vapours that are produced at this stage are sent back to the ship to compensate for the empty volume in the ship's tanks due to the progressive unloading of the LNG.