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R&D Activities as Driver of Efficient Pipeline Integrity Assessment

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Рабочая группа по политике в области стандартизации и сотрудничества по вопросам нормативного регулирования
ЕВРОПЕЙСКАЯ ЭКОНОМИЧЕСКАЯ КОМИССИЯ

R&D Activities as Driver of Efficient Pipeline Integrity Assessment

The European gas industry has always joined forces to develop new technologies and to keep the technical risk related to energy transportation via gas pipelines at a negligible level. Despite the statistically proven safety record in recent decades, it is today still a challenging task to increase the efficiency of pipeline operation including integrity management.

By Dr. Bernd GROH[1], Dr. Gerald LINKE[1], Alessandro CIGNI[2] and Daniel HEC[2]

1 Abstract

Due to the need to enlarge the capacities of existing gas transmission infrastructure and its capability to absorb energy generated from renewable sources (bio-methane) as well as the necessity to expand LNG regasification facilities, the European gas industry will face tremendous geopolitical and economic challenges in the next twenty years. Beside this issue mainly related to supply and energy sustainability, technical availability and reliability remain a prerequisite for trading and a stable, continuous gas supply via pipelines for Europe, a region with the world's third largest population after China and India. In this context, efficient integrity management focusing on modern technical developments is of key relevance to the industry. Therefore the European gas industry is investing in new technologies and R&D to find new ways to keep pipeline integrity and safety at the highest possible level. This includes means to assess aging phenomena as well as protection mechanisms against third-party interference, both of which might lead to unintentional loss of containment. Industry experience shows that interest in new technologies is valuable in that respect as they are best suited to provide environmental and safety benefits.

2 Evaluation of new technologies is most valuable for a sustainable energy policy

A reliable and safe gas supply is essential for modern societies. Over the decades, the gas industry in Europe has developed proven technical know-how of high-pressure gas systems design, construction and operation. It now has established specialist knowledge of pipeline safety, procedures and measures which form the basis of technical standards and state-of-the-art practices, maintenance and inspections.

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On safety issues, gas transmission system operators (TSOs) have always been pro-active in developing and applying high-level safety standards. This is a challenging task when considering that the energy gas network in Europe is very complex, as illustrated in figure 1, and characterised by the following (MARCOGAZ, 2006):

- Transmission network length: 222,548 km
- Cross-border points: 107
- Compressor stations: 154
- Underground storage facilities: 107
- LNG terminals: 13 in operation

In addition to these figures the European (EU-25) low-pressure distribution lines, with a length of over 1.5 million kilometres, distribute a total of over 450 BCM[3] per year today. Gas demand in the EU is likely to rise to 520 BCM in 2020. The European Commission expects the EU's dependence on gas imports to increase from about 57% today to 84% within the next 20 years [1]. Therefore, energy transport has become a global business.

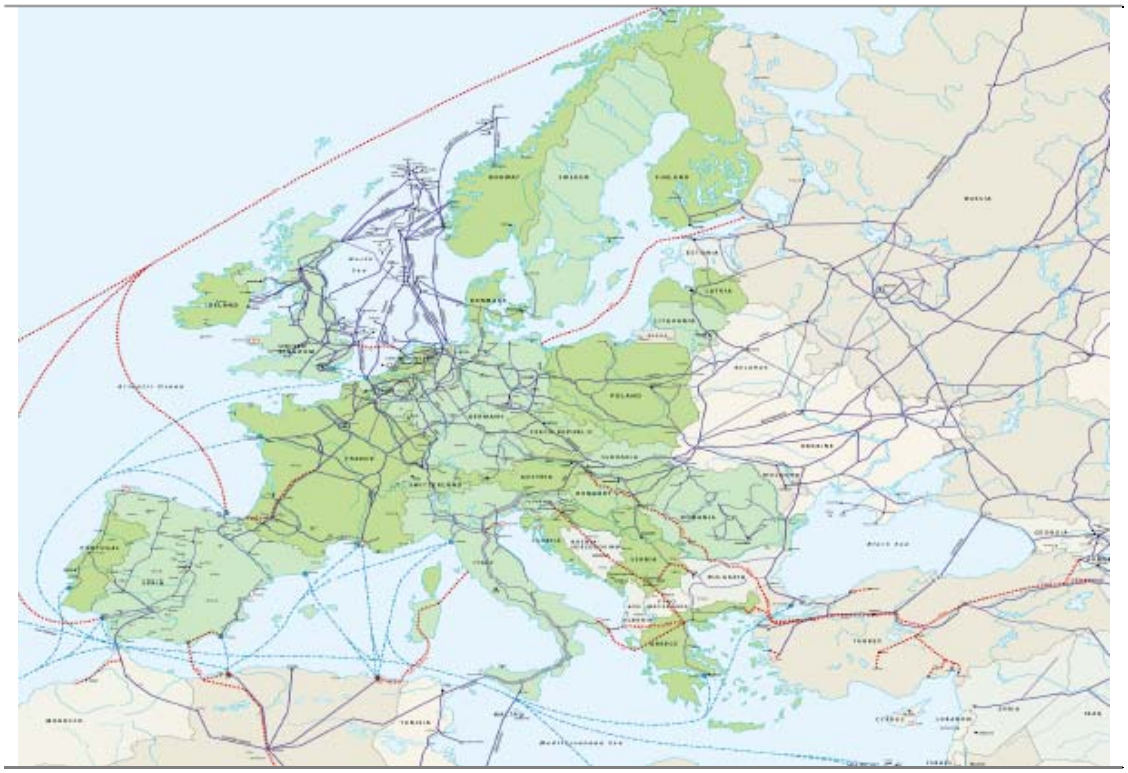

Fig. 1: European natural gas grids.

Apart from this geopolitical challenge of global competition, technical reliability is what attracts customers and what constitutes a crucial element of an efficient energy supply.

[3] BCM = billion cubic metre

In this sense, safety is a prerequisite for a sustainable energy policy for Europe. And technical availability is a key aspect of this function.
Besides technical availability, natural gas has received wide attention in recent discussions on developments related to renewable energy production (biogas) or focusing on energy efficiency. This is not only due to the fact that natural gas is the most environmentally friendly fossil fuel, but also because of its innovative strength in the area of gas utilization.

Bringing together technical safety and efficiency in the framework of risk assessment beside integration into a fast developing market and simultaneously promoting innovations has always been a high priority for the gas industry. Therefore this article gives a detailed survey of recent developments.

3 Different approaches to efficient safety management

The design and operation of pipelines in individual European countries follow different approaches, depending on the respective legal system:

- goal setting requirements,
- prescriptive requirements.

Some of them are risk-based, others deterministic. However, the different approaches are covered by European norms and standards, and all of them lead to a safe and reliable transport system. A major difference between the deterministic and risk-based approach is related to pipeline design, for example the determination of the wall thickness. Where the deterministic approach is applied, the precautionary principle, in conjunction with a traditional design and experience, will lead to pipeline design with a high safety margin against burst/rupture, depending generally on the pipeline material.

Particularly in some countries a homogeneous utilisation factor[4] of 0.62 is applied:

The use of a constant utilization factor has some advantages which offset the initial economic investment:

- a homogeneous safety level along the pipe with no need to modify operating conditions or even re-route the pipeline if built-up areas are approached,
- preventing sections with a lower wall thickness from being overstrained; pipelines with a higher wall thickness might not be stressed sufficiently to detect potential material or construction defects.

However, it is a stringent requirement to ensure stable external conditions during a pipeline's lifetime and if there are hints that they are changing – for example, due to interference from other construction activities crossing the route, due to additional stresses from

[4] The utilisation factor describes the maximum operating pressure in relation to the ultimate material yield strength.

soil load or due to stray current from high-voltage facilities – countermeasures need to be taken. Beside this issue one key principle of the deterministic concept is maintained with the judgement and the approval by independent experts. For example in Germany the so called TÜV[5] controls new pipeline projects including their design to be in compliance with the safety policy related to mechanical strength or functioning devices. Afterwards the commissioning the gas pipeline is monitored by means of several technical and organisational measures (see chapter 7).
In general the concept taken as a basis and the engineering experience is documented and each time updated in the technical rules and guidelines. It is commonly accepted that applying these rules will enclose a safe and reliable gas transmission operating. Therefore the compliance is maintained. In Germany the private so called DVGW[6] provides all technical documentation for the gas and pipelines service.

The deterministic approach encloses the definition of safety measures which are based on causal relations of any threats to pipelines (analysis of causes). The afore-mentioned precautionary principle comprises measures (so called primary safety or precautionary measures) to reduce any probability of any damage which might occur. Furthermore so called secondary safety measures are determined to minimise any consequences of unintended events called nevertheless incidents. In the frame of the deterministic safety concept decision are taken based on the used technology, not on the calculated and associated risk. The safety analysis (HAZOP) contains the determination of unintended events which could be within the bounds of possibility and for which (counter-) measures need to be taken to prevent their occurrence. The principle of prevention of any accident is superior to the minimisation of damages.

In contrast to this approach, in other European countries the pipeline operator will normally identify a “risk area” in the vicinity of a pipeline in a so-called risk assessment (RA). The utilization factor will then be chosen in connection with the determined risk [2],

$$R = C \times P \qquad (1),$$

where C relates to the consequence and P to the probability of an unintended scenario. The value of the utilization factor could then be up to 0.72 or lower than 0.62 when “sensitive areas” are crossed. During operation a re-assessment of the risk levels might become necessary, depending on the “gravity” of change of external conditions.

Possible consequences are limited to a defined technically worst case scenario, including a loss of containment with ignition. These consequences are subsequently converted into lethality in respect of virtual persons present in the vicinity of the pipeline but exposed to the expected physical effects (e.g. heat radiation) for a predefined period.
The UK's health and safety executive board [3] defines the individual risk as the likelihood of an individual being exposed to a specified level of harm for example receiving a dangerous dose of a toxic substance or heat or being subjected to blast overpressure. It

[5] Technical Supervising Council; German: Technischer Überwachungsverein
[6] German Association of Gas and Water Engineers

is common practice to try to limit the individual risk to a threshold value typically 1 x 10^{-6} p.a., this value could differ from country to country.

Quantitative risk assessment (QRA) is used to determine the risk resulting from hazardous sources in the vicinity of locations with equal individual risk levels which is demonstrated on maps that facilitate for example land use planning applications.
More relevant for gas transmission pipelines is the relation of collective so-called societal risk which allows the comparison of accidents affecting a number of individuals and to take account of different demographic density and distributions. Based on the risk methodology the afore-mentioned homogeneous safety level along the pipeline will then give rise to higher societal risks in highly populated areas and lower societal risks in rural areas.

Individual risk levels are used to decide on safety measures (technical and organizational) and/or on safety zones (distances), where the societal risk is used to decide on measures in case of an accident. In addition, by integrating the individual risk and the population density expected values of the number of fatalities or injuries can be determined. It is a common legal duty in European countries where the risk based approach is applied to demonstrate that risks are as low as reasonably practical (in countries where the probabilistic approach is applied this is called ALARP). Therefore measures to reduce the physical effects (e.g. reduction of the utilization factor) need to be implemented. Examples and the methodology will be presented in the next chapter.

The added and commonly accepted value of a QRA is well described in figure 2 where different bases of significance are related to the decision making process.

The decision context knows three levels of technical understanding, summarized by:
A: established practice
B: some deviation from standard
C: novel applications

The deterministic approach falls into decision context A. The QRA-concept, applied in the frame of the probabilistic approach, is used to deal with technical uncertainty and some deviation to the standard. It is commonly accepted as a secure tool to cover economic lifecycle risk of technical applications. Beside a qualitative risk assessment where a definition of the technical system and the scope, identification and description of the hazards, failure modes and scenarios are incorporated (this is called HAZID) the QRA will issue quantitative figures for both failure frequencies and consequences of failures. It is believed that both figures can only be proven reliable with historical data, so this approach is best used in cases for which some data is available.

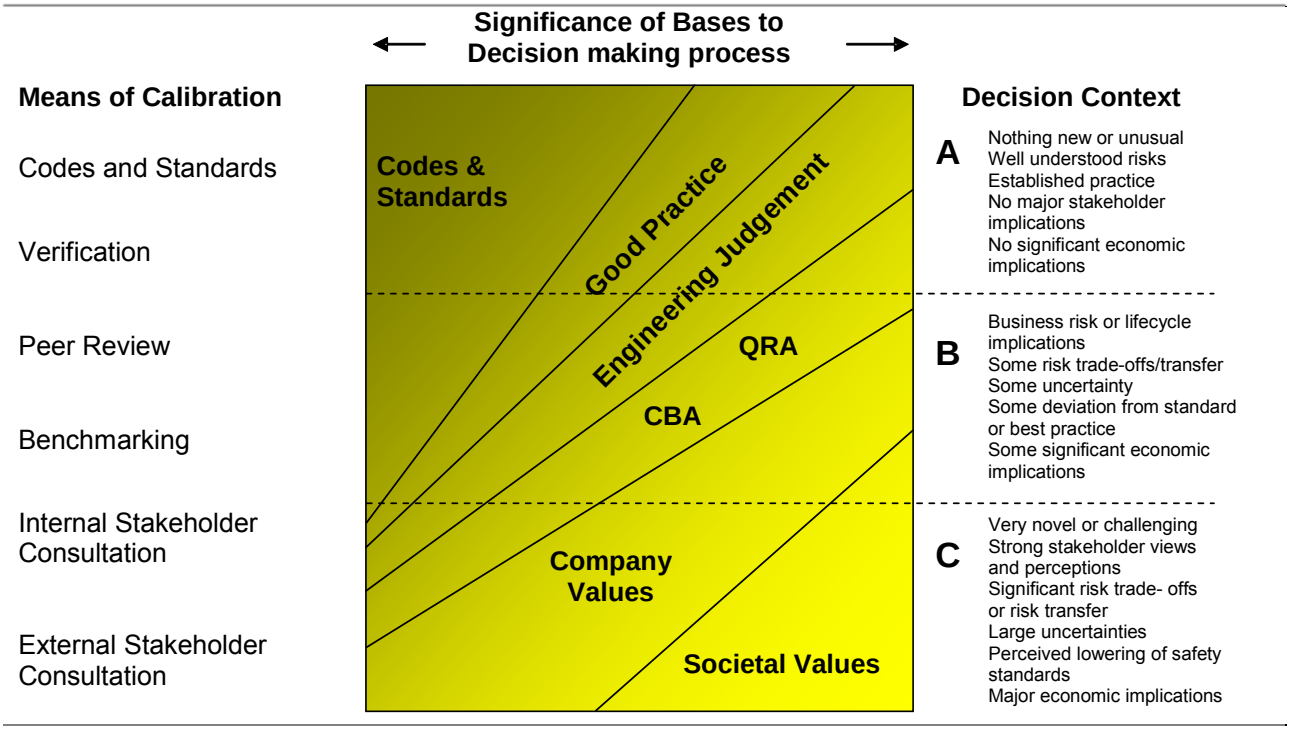

Fig. 2: Decision making process based on risk assessment (UKOOA).

Regardless of which safety approach is implemented and applied by companies, it is of common interest within the European gas industry to cooperate and to ensure an exchange of information to cover risks that are inherent to pipelines and threats that might endanger the assets, but can be tackled effectively through increased cooperation between the gas industry, involved external parties and authorities.

4 Management based on technical and organizational integrity: PIMS[7]

Within the framework of self-regulation of the European gas industry, TSOs designed and maintained their pipeline systems in accordance with recognised international and proven company standards (compare with the chapter before) which form an integral part of their technical pipeline management.

A major part related to this development was covered by the CEN/TC 234 committee work started in 1990. This work was concluded after six years with the series of CEN/TC 234 standards for the entire onshore gas chain. In 1996 MARCOGAZ promoted PIMS, which was included in the European norms TS 15173 [5] and TS 15174 [6]. PIMS is a part of the common company management system and a part of the safety management system (Fig. 3). To mention some in detail:

- Control raw hazardous materials to be stored
- Control of maintenance equipment
- Control of safety zones
- Control of noise, radiation in case of venting
- Education of personnel

1) Company Management System
2) Pipeline Integrity Management System
3) Integrity Management System
4) Safety Management System
5) Environment Management System
6) Quality Management System
7) Integrity Management System
Measurement & Regulating Stations

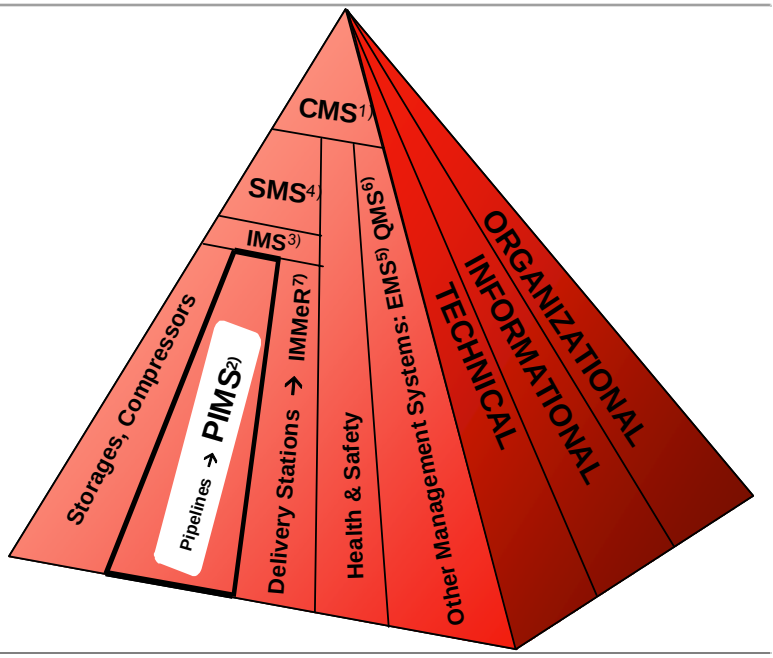

Fig. 3: PIMS is a part of the Company Management System.

Focussing on these issues and tasks important measures to ensure pipeline integrity in different lifecycle phases have been introduced (see table 1). However, PIMS specifies the complete process of pipeline integrity assessment. Depending on the prevailing methodology, PIMS is today fully integrated in each West European TSO.

[7] PIMS is an acronym for Pipeline Integrity Management System

The main objectives of this tool are the following:

- Systematic quality assurance and status documentation,
- High level of information on technical pipeline integrity,
- Access to primary safety data,
- Quality and in-time procedures,
- Standardised methods and procedures for status evaluation,
- Reports based on the integrity assessment,
- Support for decisions on maintenance measures,
- Technical infrastructure safety and economic asset preservation.

PIMS' characteristic features include (Fig. 4):

- Technical integrity,
- Organizational integrity,
- Data and informational integrity.

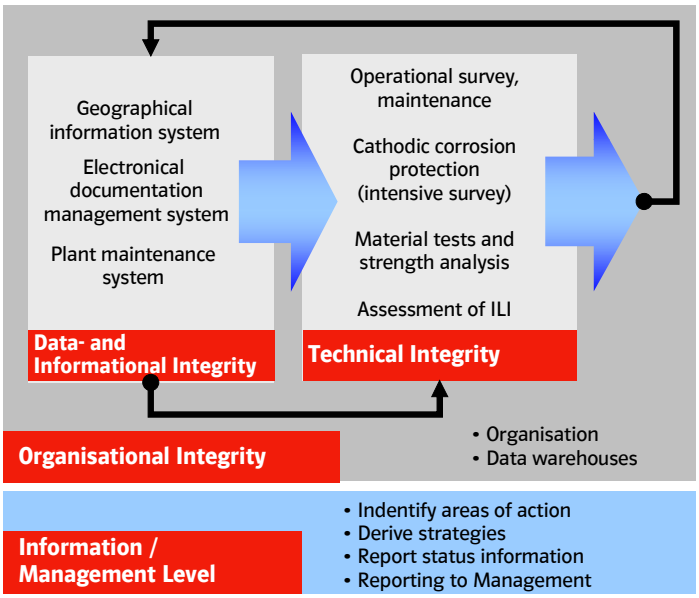

Fig. 4: Definition and characteristic features of PIMS.

E.ON Ruhrgas, a German TSO, introduced a workflow reducing the risk of system failures by laying down rules on which organizational or technical measures are to be taken to establish a continuous asset assessment process.

In general, such workflow tools can help to:

- Initiate and tackle assessment processes and measures,
- Process all measures systematically,
- Generate a action list for each operational unit or a list of to-dos per asset,
- Complete documentation and keep it up to date.

Table 1: General measures to ensure pipeline integrity.

Hazards	Overview of Measures: Intrinsic safety & protection measures	Overview of Measures: Operational safety & protection measures	Damage mgmt.
Third-party interference	Marker post, Warning tape, Depth of cover	Pipeline information, Training, Supervision, Walking/ mobile surveys	Response measures
Corrosion	Coating, CP	Intensive measurements, Pigging, Aerial surveys, Walking/ mobile surveys	
Construction/ materials	QA	Service life tests, Wöhler diagrams, Bending tests, Metallographic samples, SEM	
Hot tapping	As-built documen-tation	Documentation updates	
Ground motion	Strain gauge	Strain gauge monitoring	
Other	e.g. specification against longitu-dinal cracks	+ Make safe + Monitor + Repair + QA	

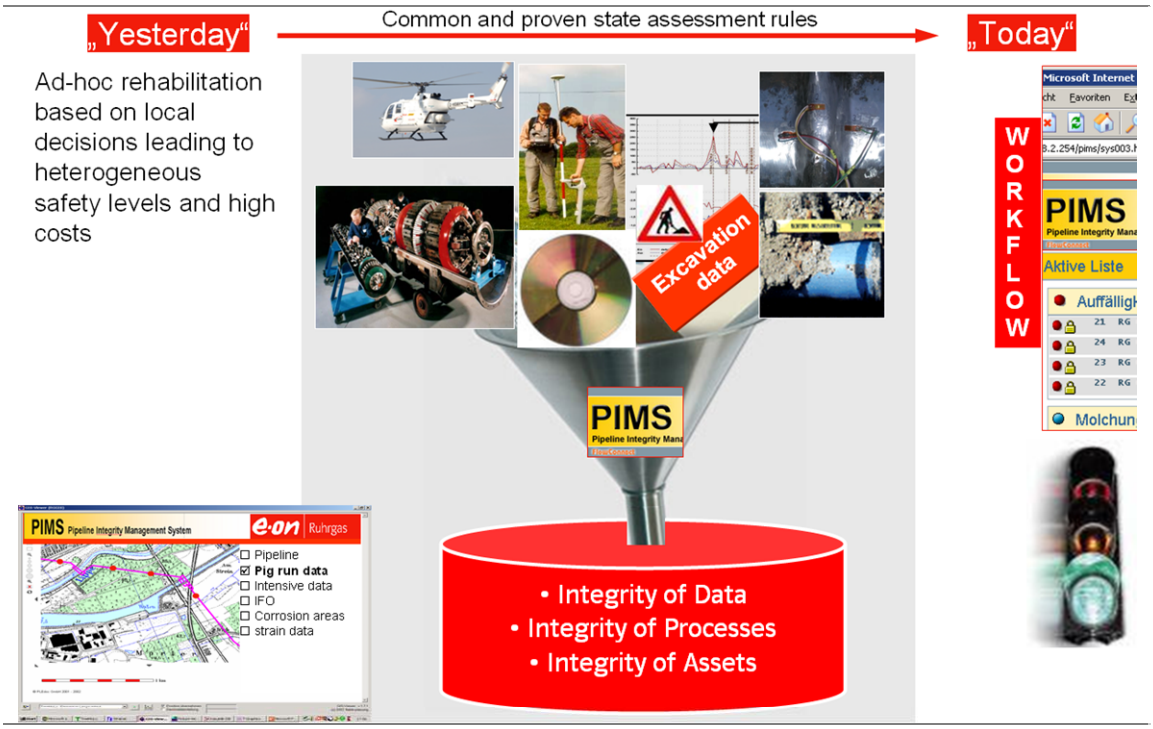

Fig. 5: Integrity management for pipelines.

At E.ON Ruhrgas, workflows are processed step by step on the basis of specific software. The user will be supplied with a mask with corresponding prompts. The inputs and the confirmed process will be stored including the relevant documents.

To sum up, PIMS combines safety-enhancing technology and integrity for management, organization and information. It is used to demonstrate that assets such as pipelines are capable of fulfilling their intended purpose safely and reliably even after decades of operation (Fig. 5).

5 Safety management is a part of the European and national legislation framework

Each European country has its own legal framework and specification where the particular accident history is reflected. The main purpose of the legislation is to regulate and reduce the risk and protect the people and the environment. Technical specifications related to the design of pipelines, the construction and operation of pipelines tend towards self-verification.

Because of the fundamental importance of safety of people in the vicinity of gas transmission pipelines, the European gas industry has always focus on corresponding safety standards for the gas infrastructure which is in sum a very robust and complete suite of functional standards covering all parts of gas systems from the input of gas in the transmission systems to the inlet connection of the gas appliances.

Prescriptions regarding safety can generally be found in the following hierarchy:
1. European legislation
2. Safety related national laws and regulations setting goals
3. European functional standards
4. National or company detailed codes of practices and operating manuals

The European standard EN 1594 [4] covering on-shore systems, adopted in 2000 and therefore included in the collection of standards in all European countries is the cornerstone of the standardization edifice for gas transmission pipelines. This standard is now more and more frequently given a compulsory status when revision of national safety regulations for gas pipelines occurs. All relevant technical safety aspects concerning the design, construction, operation and maintenance of transmission gas systems are covered in EN 1594.
Reference is also made to other specific functional or product European standards to be used when constructing a gas transmission system [7], [8], [9], [10], [11].
CEN standards are not mandatory for operators, unless a national legislation imposes them. According to CEN rules, each EN standard shall be examined after five years for eventual revision in order to take into account possible evolutions.

For on-shore gas transmission systems, the use of European standards is the preferred option comparing to International standards for the following reasons:

- EN standards form a high quality coherent and consistent system;
- EN standards are designed to fit with existing European and National safety regulations;
- EN standards shall be incorporated in National standard collections (it is not always the case for ISO standards);
- The influence of Public Authorities and stakeholders is sometimes limited in the elaboration of other International Standards, which can lead to reduce the quality of the standards.

Nevertheless, international standards are used when necessary, especially when European standards do not exist.

Particularly with reference to the management systems the CEN standardization body has therefore issued two normative documents, EN/TS 15173 [5] for Pipeline Integrity Management Systems and 15174 [6] for Safety Management Systems that can be used as framework for the TSO in order to design an effective system for facing up with safety aspects.

To sum up, this goal-oriented approach is best designed to fill existing gaps in the national pipeline legislation of the Member States and thus contribute to further improvement in pipeline safety, while not interfering with the developed legislative structures in certain Member States.
A regulatory framework including requirements on agreed performance measures for the Pipeline Safety Management System gathered the majority of preferences of EU competent authorities since 1997. The most important elements to be introduced and harmonised at community level are requirements relating to the control of external interference.

6 Lessons learnt from statistics: EGIG incident database

To show safety performance, six European TSOs took the initiative in 1982 to gather data on the unintentional releases of gas in their pipeline transmission systems. This co-operation was formalised by setting up EGIG (European Gas Pipeline Incident Data Group). Now EGIG involves 15 major gas transmission system operators in Western Europe. The objective of EGIG is to provide a broad basis for statistical use, giving a more realistic picture of the frequencies and probabilities of incidents than would be possible with the independent data of each company considered separately.
The collection of safety related data has grown in significance as a result of increasing interest shown by local, national and international responsible authorities for safe gas transmission. The total length of European gas transmission pipeline systems is constantly increasing. In 2007 the total length was 129,719 km (Fig. 6) which is now more than 50% of all gas transmission pipelines in Europe, which had a length of 222,548 km in 2006.

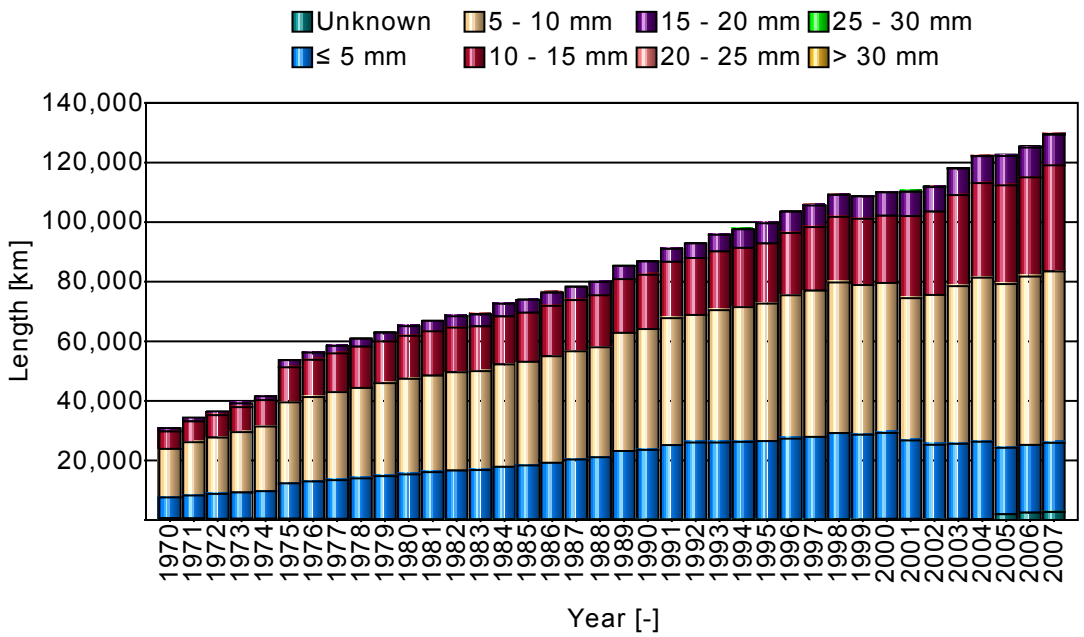

Fig. 6: Pipeline population and wall thickness distribution [12].

The EGIG database [12] stores information on natural gas transmission pipelines and incidents from 1970 onwards. Only onshore pipelines made out of steel with a maximum operating pressure higher than 15 bars and lying outside the perimeter of a gas installation are included in these statistics. Incidents are recorded for the following leak sizes:

- Pinhole/crack: the diameter of the hole is smaller than or equal to 2 cm.
- Hole: the diameter of the hole is larger than 2 cm and smaller than or equal to the diameter of the pipe.
- Rupture: the diameter of the hole is larger than the pipeline diameter.

The EGIG database (Fig. 7) shows the safety record of the European gas industry, i.e. that the number of incidents per km/year is still decreasing, currently down to 0.37 per thousand kilometres and year. Also shown in figure 7 is the primarily failure frequency based on the five year moving average. This trend documents that TSO operate pipelines safely due to their increasing efforts in the last few decades.

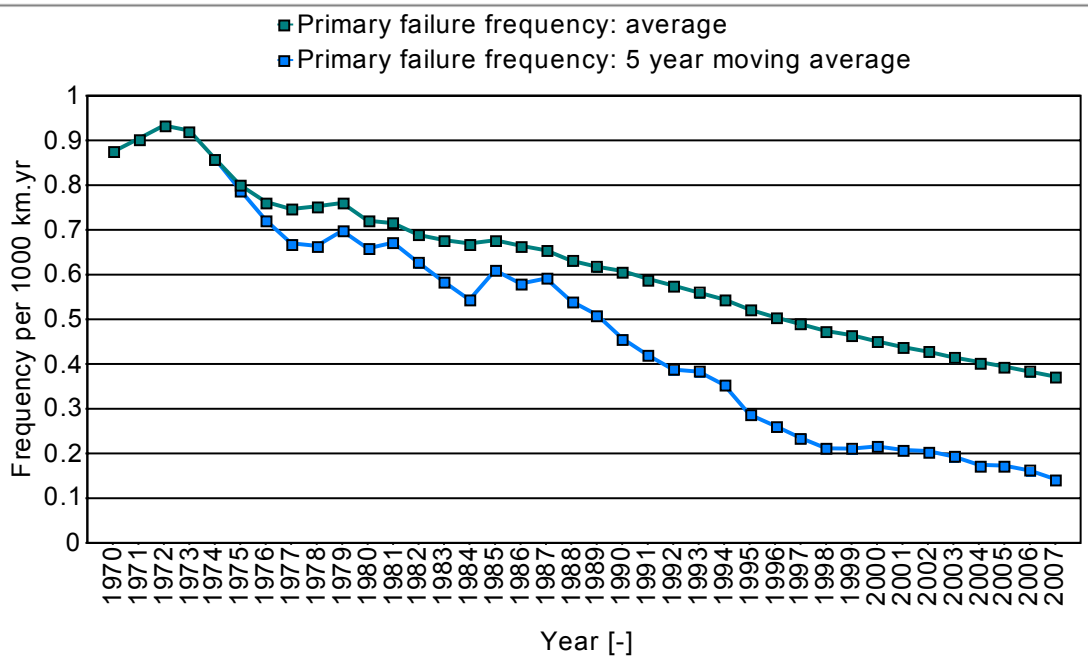

Fig. 7: Development of primary failure frequencies [12].

The remaining failure frequencies, which have reached a level of less than 0.2 per 1000 kilometres and year, are far lower than those for any other known means of energy transport.

Based on the leak sizing above, the following conclusions can be drawn from the collected data (Fig. 8):

- The main pipeline failure case is due to external (third-party) interference.
- Of minor importance are construction defects, material failure, hot tap made by error, corrosion and ground movements.
- The majority of leaks are minor holes or cracks.

However, some further conclusions can be drawn from figure 9. The first conclusion is that small-diameter pipelines are more vulnerable to external interference than large-diameter pipelines. This can be explained by the fact that smaller pipelines can be more easily hooked up during ground works than larger pipelines. The second reason is that their resistance is often lower due to thinner wall thickness.

Figure 9 in combination with figure 6 confirms that the wall thickness classes of ≤ 5 mm and 5 – 10 mm are the most commonly used. The exposure of the 5 – 10 mm wall thick-

ness class is much higher than that of the ≤ 5 mm class. Nevertheless, the failure frequency of the ≤ 5 mm class is much higher than that of the 5 – 10 mm class, which demonstrates that a larger wall thickness is an effective measure against third-party interference.

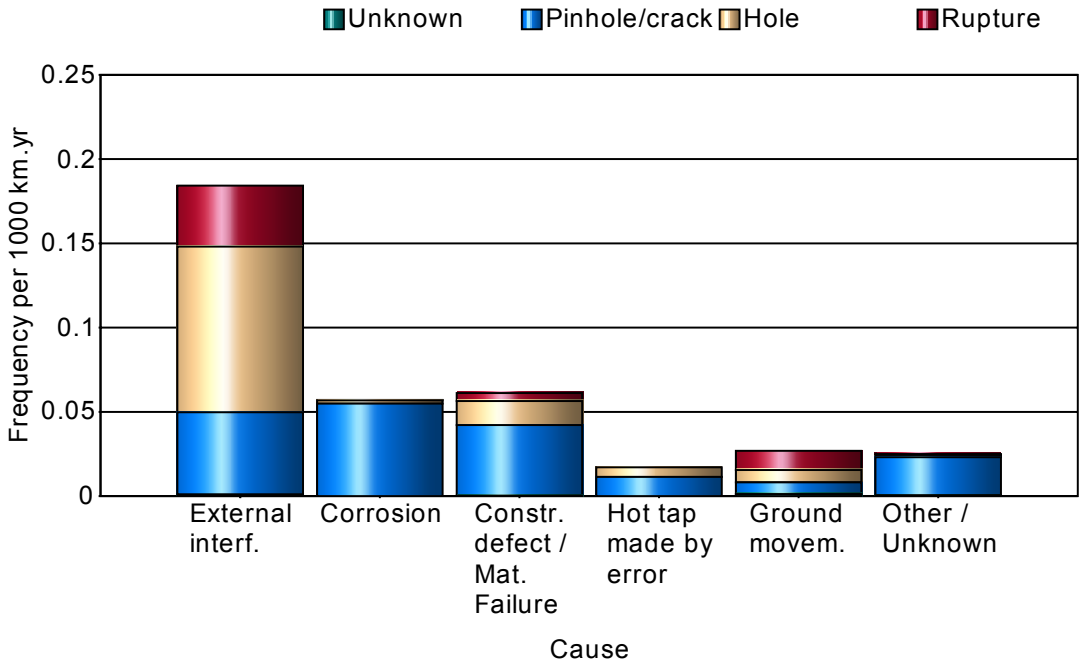

Fig. 8: Relationship between cause and size of leak, where the frequency is expressed in kilometre-years [km·yr] [12].

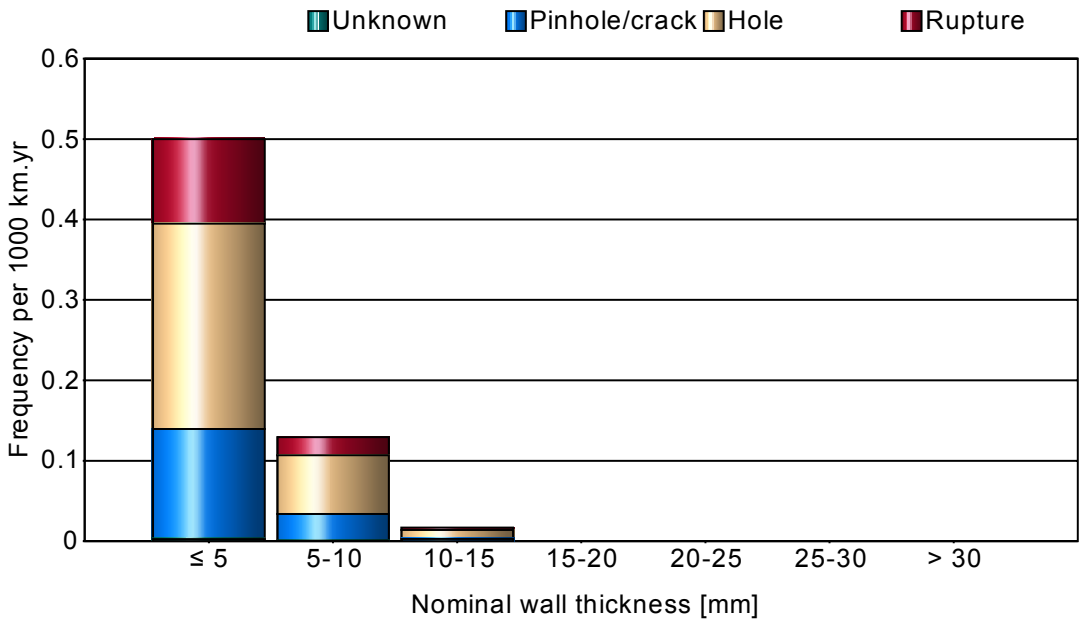

Fig. 9: Relationship between external interference, size of leak and wall thickness, where the frequency is expressed in kilometre-years [km·yr] [12].

7 Preventive and mitigation measures addressing the issue of external interference

Nowadays 50% of all leakage incidents are caused by third-party interference (Fig. 10). The causes of these third-party interference events are most of the time beyond the control of the gas pipeline operator. Therefore new organisational measures have been introduced by the European gas industry. For example in Germany, construction companies are required to ensure that prior to any excavation work the legal obligation to contact effected cable and pipeline operators is fulfilled. The German gas industry supports this in a simple way by ensuring access to the relevant pipeline location data or coordinates via so-called on-call systems or internet solutions.

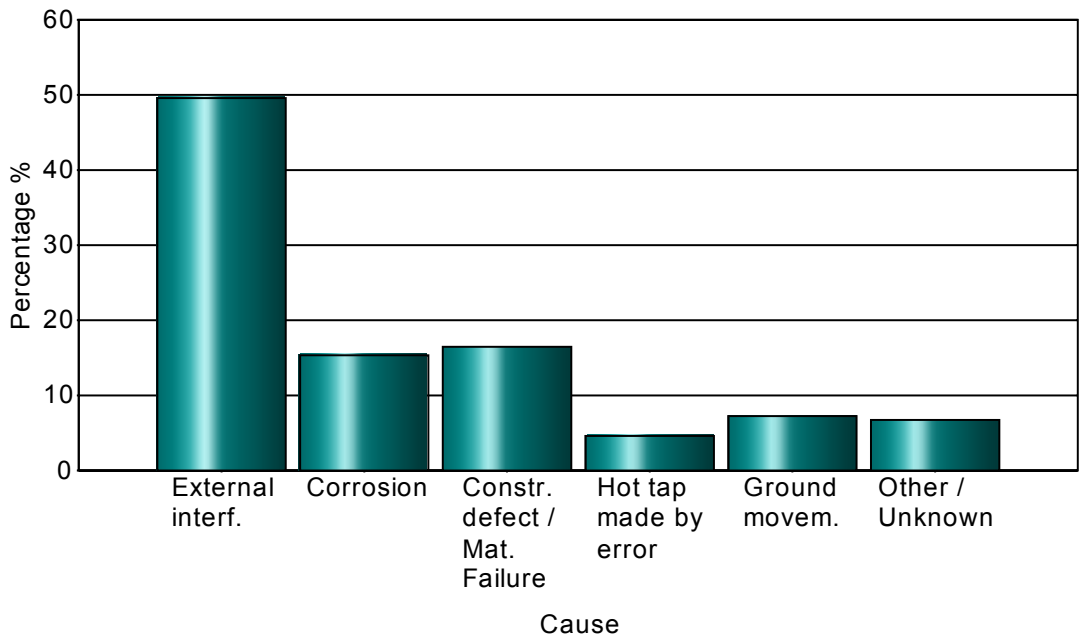

Fig. 10: Distribution of incidents per cause [12]

In addition, pipeline operators take particular measures over the whole life cycle of the pipeline system - in the design and construction phase as well as in the operation and maintenance phase - to prevent incidents caused by third parties and to mitigate their possible consequences.

According to [13] there is a whole range of mitigation measures and preventive actions:

1. Preventive measures in the construction phase
   - Route markers*
   - Steel quality with a high notched impact strength*
   - Right of way: definition of a restricted zone*

* mandatory in Germany

- Application of a minimum depth of cover*
- Pipeline route selection
- Utilization of warning strips
- Special pipeline protection measures on crossings (concrete protection, geotextile, etc.)
- Use of modern tools for exchanging information on any pipeline routes which may cross any planed excavation activity: internet platforms
- Proactive communication (informing third parties about legal prosecutions and costs, learning sessions

2. Consequence mitigation or reactive measures in the construction phase:
   - Specific line valve spacing*
   - Remote monitoring and control of plants and installations

3. Preventive measures in the operating phase:
   - Obligation to give notice of any activities in the vicinity of pipelines*:
     Excavation companies have to investigate site-specific information before starting excavation work.
   - Surveillance* on foot, by car or by helicopter
   - Building supervision*:
     During all excavation activities the presence of a formal supervisor is required by most gas system operators.
   - On-call systems
   - Public and contractor awareness campaigns
   - Standard procedures for accessing buried pipelines
   - Training of excavator drivers (certified sessions of the excavation company)
   - Intelligent pigging

4. Consequence mitigation or reactive measures in the operating phase:
   - Installation of a central emergency office* (24h duty)
   - Emergency preparedness*
   - Pressure and flow control
   - Remote valve control
   - Communication with local authorities and fire brigades
   - Record/report tracking of any incident details
   - Testing of the TSO emergency plan at certain intervals with a focus on organizational aspects

Although gas pipeline operators can contribute to tackling the problem of third-party interference through the aforementioned measures, a large part of the activities occurring in the vicinity of pipelines are beyond their control. Therefore, additional legislation could proactively target contractors and subcontractors to ensure that they are aware of the risks from buried gas utility infrastructure (compare with chapter 4). In addition, there are best-practice codes to reduce the occurrence of third-party interference [14].

Despite the above recognised measures, damage due to third-party interference continues to occur. Some explanations can be put forward:

- Legal requirements for contractors and subcontractors are sometimes insufficient.
- Work procedures are not well known or not always carefully followed by contractors or subcontractors.

One of the key issues concerning third-party interference is, apart from the establishment or reinforcement of legal requirements, the development of new technologies, which will be presented in the next chapter, giving gas operators immediate feedback on any hitherto undiscovered external activity in the vicinity of a gas pipeline.

8 Preventive and mitigation measures: New technologies

Gas transmission pipelines are operated according to the legal system as well as best-practice codes and norms existing in individual European countries. Compliance with the given state of the art ensures a high level of inherent safety.
However, as described in the last chapter and beside all the efforts described, external effects which can damage a pipeline or even cause a leak cannot be fully excluded. So there remains the risk of damage caused by third-party interference, mainly related to ground works involving excavators, drilling equipment, trench cutters or other heavy machinery.

According to the experience of gas suppliers and network operators, contractors and subcontractors occasionally fail to comply with their obligation to obtain information on any buried pipeline within the range of an excavator. Or damage to a pipeline occurs, even though they are aware of its existence, or they simply fail to report any damage caused.
Facing these known threats related to third-party interference, industry experience shows that investing in new technologies to find new alternatives to improve pipeline integrity and safety against third-party interference is a worthwhile task.

Some of these new projects under development in the gas industry are related to:

- <u>optical waveguides</u> or fibre-optic systems installed alongside pipelines, which make use of different physical phenomena including
  - optical interferometer, i.e. interference effects of two monochromatic light signals in neighbouring fibres to detect strong vibrations or deformations caused by a change in length of the light paths,
  - optical interference produced by temperature abnormalities caused by leaking substances
- <u>acoustic methods</u> designed to analyse signals picked up by microphones (so-called hydrophones) which "eavesdrop" on the gas flow at distances of 5 to 15 km,
- <u>spectral methods</u>
  - with laser systems (CHARM®)
  - based on infrared spectroscopy (Gas Camera)

The above mentioned methods have been developed under the European GERG[8] committee (i.e. fibre-optic systems, acoustic methods, Gas Camera).

An electric method which uses the existing measuring points of cathodic protection (CP) systems to detect a "short circuit" caused by an excavator, drilling equipment or a trench cutter etc. coming into metallic contact with the pipeline. The electric excavator detection method, also known as Remote Potential Monitoring (RPM), promises a range of benefits (Fig. 11):

- Compared with fibre-optic and acoustic systems, the likelihood of false alarms due to the measurement principle is very low.
- Compared with acoustic monitoring systems, even slight scratches or minor knocks with comparatively low-impact energy (as in the case of drilling) is safely detected.
- Installation costs are far lower because the system dovetails with CP and remote potential monitoring systems already in place.

Field tests will show how far the innovative idea now turned into a prototype is still away from market maturity.

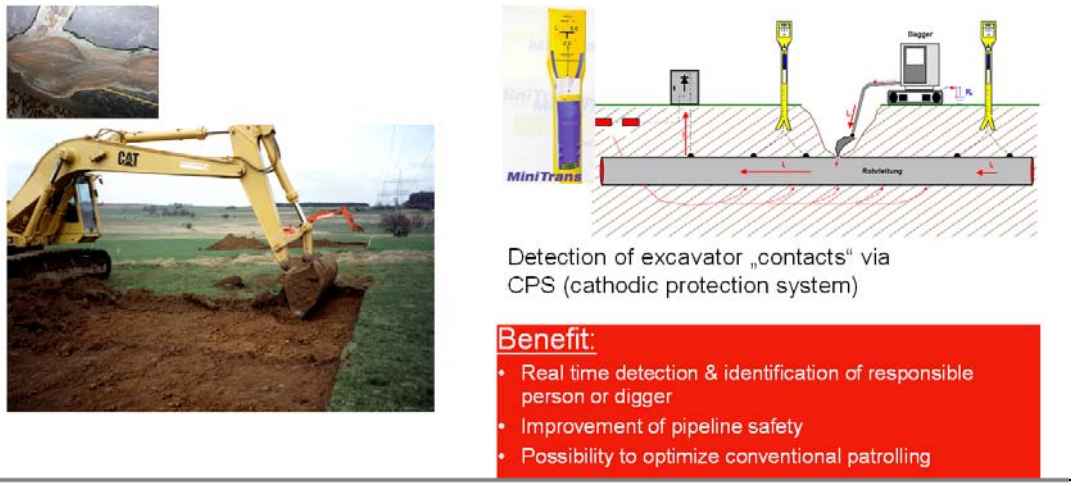

Fig. 11: Development of excavator detection systems.

Regarding gas leak detection systems commonly applied today, flame ionization detectors or semiconductor gas sensors are used for detecting leaks on gas transport facilities. These highly sensitive detection systems locally collect and analyse samples of air that may contain traces of methane. The samples have to be taken close to the surface of a facility in order to localise any leaks (Fig. 12). This is made even more complicated if light breezes dilute the gas clouds that originate from leaks.

A new technology called Gas Camera (GasCam®) has revolutionised this kind of gas leak detection at sites by making natural gas visible though what appears at first glance

[8] Groupe Europeen de recherches gazieres

to be a very simple method for the user but is in fact a very sophisticated process based on infrared spectroscopy (Fig. 13). The system allows small traces of methane at process plants to be detected quickly and reliably.

The Gas Camera is a remote detection system that provides video images of gas clouds displayed in front of a picture of the target (leak). The newly developed optical device employs an infrared-sensitive focal plane array for detecting gas clouds in air. It analyses infrared radiation that propagates from the background of the field of view through the gas cloud to the optical receiver and the sensing element.

Fig. 12: Chronology of gas detection;
Left picture: 1926; right picture: today.

Methane gas clouds which are detected at a distance between the background and the camera sensor modify the captured background radiation. Particularly designed software evaluates these modifications in real time and returns the information gained on the distribution of the methane traces in the area observed.

The Gas Camera works in front of almost any background including clear or cloudy skies. It is capable of safely detecting gas clouds with column densities as low as 150 ppm·m.
The Gas Camera was mainly developed at Hamburg University of Technology on behalf of industry with support by E.ON Ruhrgas AG, Gasunie, Fluxys and Snam Rete Gas. The prototype was finished at the end of 2007 and since then it has been tested at facilities of all project partners. During the measurement campaign it exhibited outstanding detection capabilities and proved to be particularly easy to use [15].

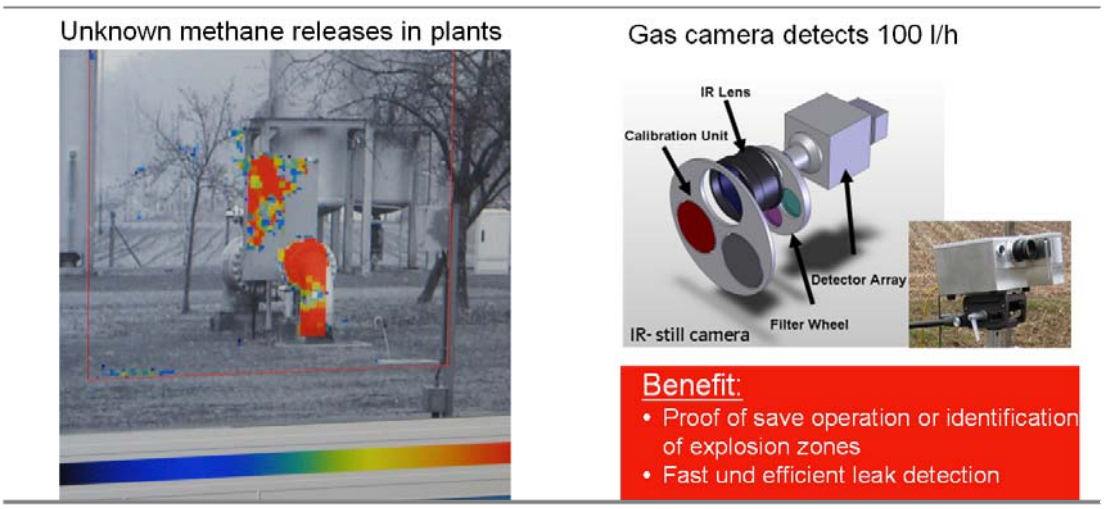

Fig. 13: Recent development of a Gas Camera (GasCam®)

Beside this infrared based gas detection system, recently a new technology has received wide attention in the European gas industry. It is know as CHARM®. This name stands for CH4 Air Remote Monitoring, i.e. helicopter-borne infrared laser-based remote gas detection system.

The technology is based on the Differential Absorption LIDAR (light detection and ranging) measurement principle, which has been used with considerable success for analysing trace gases in the earth's atmosphere throughout the world. It involves transmitting a laser light in the ultraviolet, visible or infrared spectral range and detecting and analysing the light back-scattered by the atmosphere or a solid target object. Trace gas concentrations can be determined by tuning the laser wavelength to the spectral signature and absorption characteristics of the gas to be detected.

Fig. 14: Efficient natural gas leak detection by helicopter.

CHARM® is securely installed on a helicopter and protected from vibrations. Control systems compensate for the effects of movement and target the measurement beam precisely onto the pipeline. Differential GPS[9] allows the position of the helicopter to be determined very precisely. In combination with an inertial measurement system for accurate position determination, the measurement beam can be targeted at the pipeline corridor automatically and extremely precisely (Auto Tracking). At an altitude between 80 m and 140 m the measuring points of the infrared laser have a diameter of about 1 m on the ground. The beam scans a corridor along the pipeline route, which can have a width of at least 7 and up to 12 metres. Any natural gas detected is visualised directly – a red dot appears at the appropriate point on the monitor of the CHARM® operator. The CHARM® system includes automated documentation of pipeline inspection and real time reporting of incidents (Fig. 14).

Even the slightest traces of natural gas can be identified during routine air patrols at a speed between 50 – 90 km/h. The operational detection limit is less then 25 ppm·m at a high detection resolution. During a measurement campaign CHARM® exhibited its outstanding performance, which was also accepted by the DVGW. CHARM® will in future replace conventional pipeline patrols with its advanced technology.

Summary

New technologies provided by the European gas industry like the GasCam® and the airborne gas detection system CHARM® illustrate the gas industry's extensive strength regarding innovation activities in the transportation sector. These innovations will – as established safety measures have in the past - guarantee the full technical availability of all transmission system functions, preserving the value of the infrastructure as a prerequisite for the security of energy supply in the future.

[9] Global Positioning System

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