Guide Providing Performance Indicators for PIMS "Pipeline Integrity Management System"

INTRODUCTION

The companies' PIMS "Pipeline Integrity Management System" constitutes the key element to ensure and maintain pipeline safety and pipeline integrity. The purpose of this guide is to establish a methodology to assess the adequate performance indicators to check the effectiveness of the companies' PIMS covering natural gas transmission pipelines.

It completes and put into concrete form the Marcogaz PIMS document "A framework document encompassing the key activities carried out by European Natural Gas Industries to provide safe and continuous natural gas supply system on shore" published in May 1996.

AIMS AND OBJECTIVES OF THE PRESENT GUIDE

To assist the Pipeline Operators/Owners in drafting their pipeline PIMS "Pipeline Integrity Management System" part of the companies overall SMS "Safety Management System" the present guide defines the basic elements of the transmission pipeline PIMS together with core performance indicators, respectively performance elements to check the effectiveness of the company PIMS. The key performance indicators are derived from EN 1594 (Ref. 1) drafted by CEN/TC234 and the Arthur D. Little study ordered by DG Environment (Ref. 2)

BACKGROUND

Throughout the report distinction has been made between pro- and reactive measures under the control of the pipeline operator/owner and obligations under the responsibility of National Authorities.

1. Pro-active measures under the control of the pipeline owner

In this area five pro-active "technical" indicators have been identified on the basis of existing good industry practices and standards across the EU concerning natural gas transmission pipeline systems these are:

- prevention of damage;
- detection of damage;
- control room response time;
- design, construction and testing part of the inspection declaration;
- block valves.

In each of these domains, potential pipeline failure causes have been identified using the EGIG incident database (Ref. 3) and analysed in pipeline root failure cause diagrams (see Annex 1). An example for integration of the performance indicators/performance elements into the "Pipeline Integrity Management Circle" is given in Part 2. The likelihood of occurrence of each of the individual pipeline failure cause shall be judged and evaluated, case by case, with the aim to achieve the appropriate overall safety and integrity level of the whole pipeline system.

2. Re-active actions under control of the pipeline operator/owner

In this area two re-active performance indicators have been identified:
- incident frequency;
- loss of containment.

Both indicators are seen as "reference indicators" to tune and review the companies' management system, in particular the individual performance indicators/elements.

3. Measures under the control of National Authorities

In this area three performance indicators have been identified:
- land use planning
- information to the public;
- emergency planning.

SCOPE

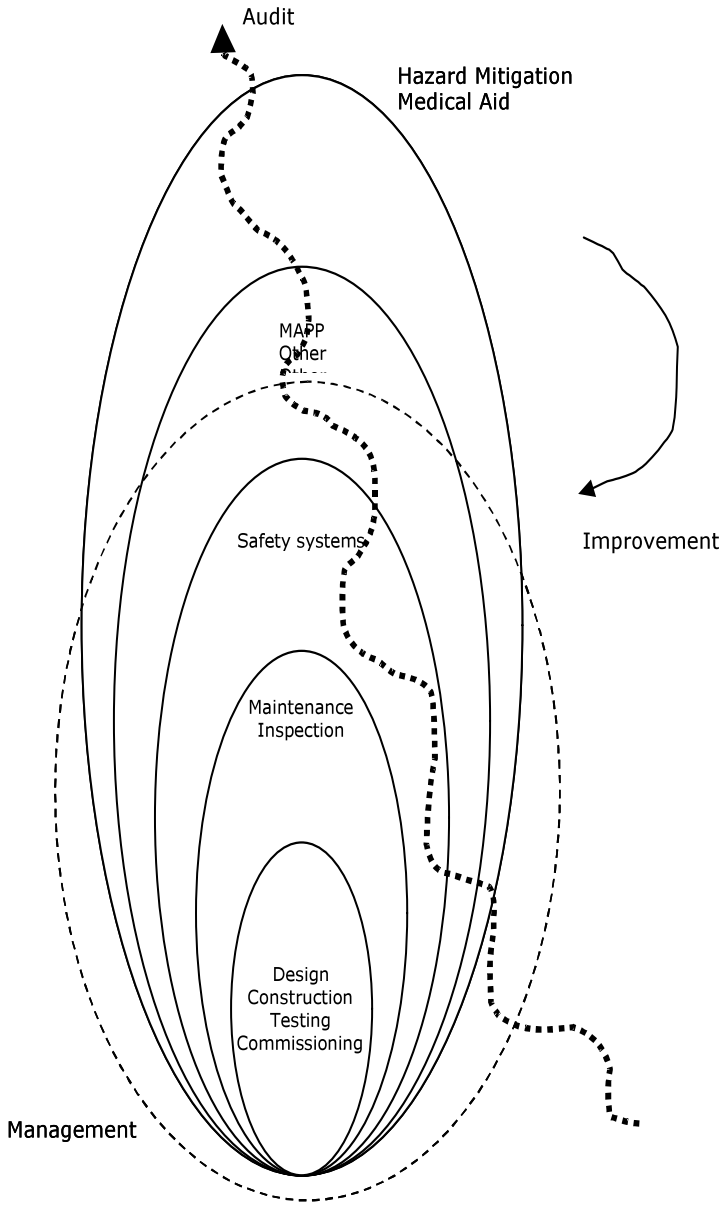
The scope of the subject Marcogaz guide setting out the performance indicators to assess the effectiveness of the company's PIMS "Pipeline Integrity Management System" is restricted to on shore gas transmission pipelines, excluding their stations defined as follows:
- processed, non-toxic and non-corrosive natural gas
- maximum operating pressure (MOP) over 16 bar;
- not located within industrial premises.

SCHEME FOR A COMPANY PIPELINE INTEGRITY MANAGEMENT SYSTEM AND BASIC DOCUMENTS

The basic elements to establish the companies' PIMS "Pipeline Integrity Management System" are given in chapter 10 "Operation and Maintenance" of the European standard EN 1594 (Ref. 1) which has been transposed into national standards and implemented, as a minimum requirement, by all gas transmission companies throughout the EU, to construct, maintain and operate a safe and integer transmission pipeline system. The present standard is currently benchmarked against national legislation covering transmission pipeline systems to identify potential gaps and needs for improvement.

The performance indicators/performance elements have been derived from the Arthur D. Little study, contracted by the EC Commission (see Ref. 2.). The latter report makes a clear distinction between re-active and pro-active criteria with basic elements to improve and complete chapter 10 "operation and maintenance" of EN1594.

An example for a company PIMS scheme is given below.

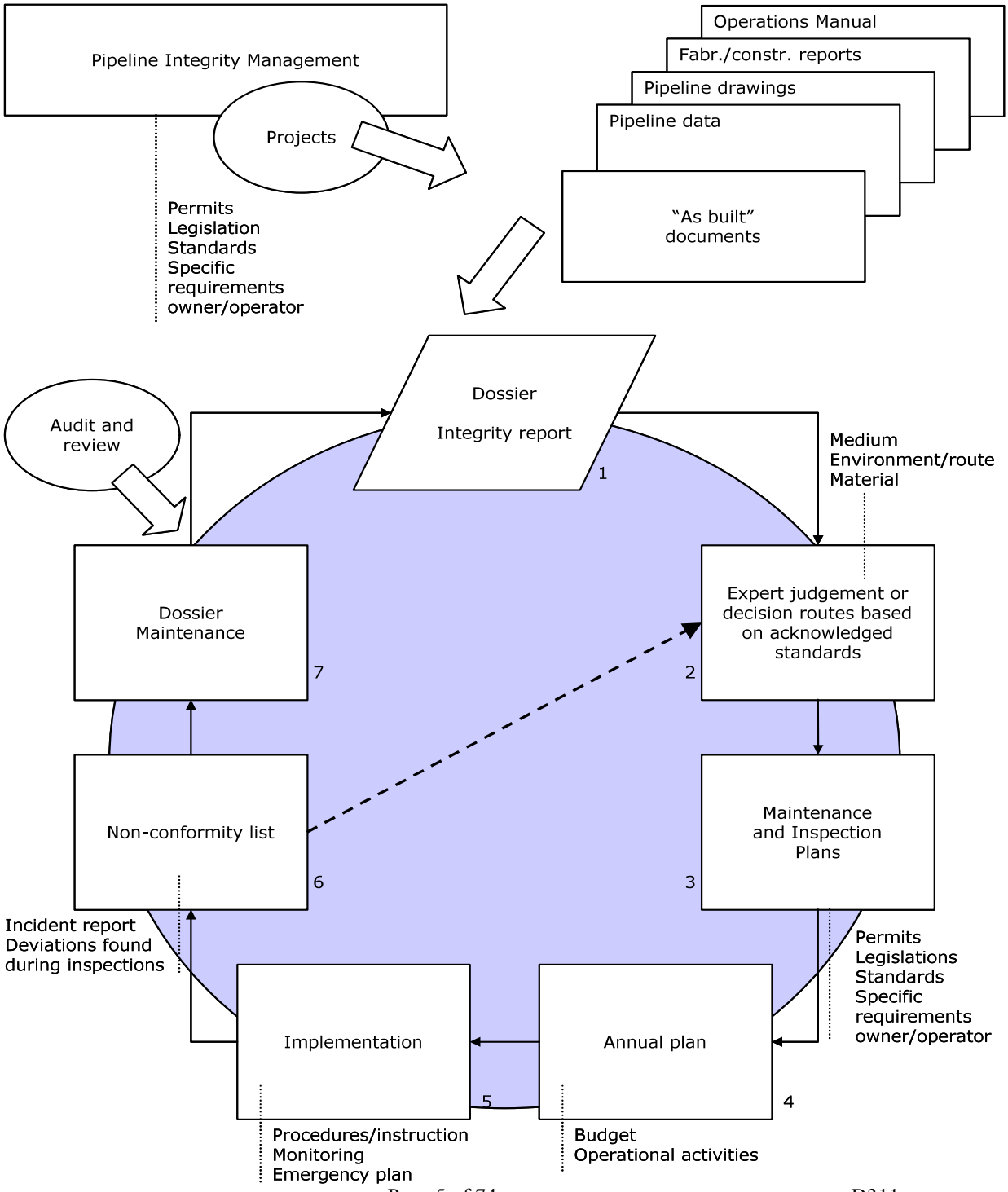


"ONION MODEL"

PIPELINE SAFETY MANAGEMENT

PIPELINE INTEGRITY MANAGEMENT CIRCLE

The Pipeline Integrity Management Circle with several steps to monitor and manage the individual measures to construct, operate and maintain pipeline safety and integrity constitutes the key issue of the companies' PIMS.



The "Integrity Management Circle" which effectiveness is checked against the relevant performance indicators and performance elements covers 7 steps, these are:

1. Dossier Integrity Report;
2. Expert Judgement;
3. Maintenance and Inspection Plans;
4. Annual Plan;
5. Implementation;
6. Non-conformity List;
7. Dossier Maintenance.

The "Pipeline Integrity Management Circle" is subject to audit and review.

An important step is "Expert Judgement". The "Integrity Management Circle" with required key expertise and competences of personnel has to be integrated into a transparent and effective organisational structure as outlined in this guide.

For the sake of consistency and clarity each step under the "Pipeline Integrity Management Circle" is individually assessed below. However it should be noted that in practice the individual steps are integrated in several ways into the company PIMS, depending on the company practices and/or national specifications.

Dossier (Integrity Report) (1)

The dossier contains all the data and references to standards, company codes and other documents which have been applied for design, construction and commissioning of the pipeline system. In addition it will also include other data such as:

- information concerning the physical location of pipelines;
- pipeline data, material used and their respective certificates;
- inspection and control reports;
- safety systems;
- permits.

Expert Judgement (2)

On the basis of the "Non-Conformity List" and in addition to the "Dossier", expert judgement is required on issues such as:

- to evaluate the importance of the non- conformity issue;
- to define corrective actions;
- to activate the subsequent actions.

Alternatively acknowledged roots and standards also lead to step 3 or provide for recommendations to step 4.

Maintenance and Inspection Plans (3)

The objective of the maintenance and the inspection step is to balance adequate pipeline integrity against optimal business operations (fitness for service) during the planned operational life-cycle compatible with the overall pipeline integrity policy. Optimal business operations have to take into account potential failure mechanisms, relevant legislation, permit requirements, relevant standards and codes as well as the basic requirements of the pipeline owner.

At each stage of the individual activities the adequate integrity performance level must be determined.

Annual Plan (4)

The Annual Plan determines the actions that should be undertaken within the available budget, this may include among others following issues:

- the pipeline integrity maintenance plan over the year;
- the one-off activities that are required;
- the co-ordination with and the planning of operational activities and shut-downs;
- the control of the material required to perform operational activities;
- the control of the conveyed substances with regard to correct composition and conditions.

Implementation (5)

The implementation of the annual plans is the next step in the process.

It lays down procedures and (work) instructions to implement the annual plans as well as the way these activities will be monitored together with dedicated equipment and manpower. In addition the 'normal' process monitoring and processing of breakdowns and defects must continue to function. It also includes an emergency plan with procedures and internal organisation for emergency preparedness which is regularly tested and reviewed. The emergency plans must be properly instructed and trained.

Non-conformity List (6)

Deviations from normal procedures during maintenance and inspection must be registered. Incident data must be collected, recorded and analysed to avoid recurrence of such incidents.

Dossier Maintenance (7)

The collected data and results of inspection mentioned under the previous steps are all part of the pipeline integrity dossier. The pipeline manager must compare the actual data with data from earlier inspections and must evaluate the technical safety and integrity of the whole system with the benefit of hindsight to determine the quality control operations that should be carried out in the future.

Audit and Review (8)

The whole pipeline integrity circle and each of the individual steps are subject to audit and review.

Note
Each of the above-mentioned individual steps under the "Pipeline Integrity Circle" have been compared with the functional requirements of EN 1594 (see table below). From this exercise gaps are identified and further documented in this report.

Subject	**EN 1594**
Organisation and personnel	Par. 10.2
Failure cause identification and expert judgement	-
Operational control	Par. 10.3, 10.6, 10.7, 10.8 and 10.9
Management of change	Par. 10.9
Planning for emergencies	Par. 10.4
Monitoring performances	-
Audit and review	-

Conclusion

EN 1594 fully covers:

- the deterministic aspects of the "Pipeline Integrity Circle" to design and construct safe and integer pipeline systems part of the companies' PIMS
  and
- internal management and organisation, competences of personnel, operational control, management of change and planning for emergencies.

Missing parts

The missing parts in EN1594 with respect to root failure cause analysis, monitoring performances, audit review are described in the following items of this report.

ROOT FAILURE CAUSE ANALYSIS - A METHODOLOGY TO IDENTIFY THE PIMS PERFORMANCE INDICATORS/PERFORMANCE ELEMENTS

1. Potential failure causes

All potential pipeline failure causes that can lead to an incident have been derived from the "European Gas Incident Data Group EGIG" report (Ref. 3.) and classified into 4 sub-groups:

1. external interference (third party damage);

2. corrosion:
   - external;
   - internal;
   - SCC/HCC/others;

3. construction defects/material defects;

4. others:
   - overload;
   - overpressure;
   - welding on pipeline in operation;
   - fatigue;
   - settlement/mining subsidence/crossing of faults (earthquake);
   - erosion;
   - pipeline moving;
   - temperature;
   - lightening impact.

It should be noted that not all mentioned failure causes are applicable to the whole pipeline system, because some failure causes are irrelevant for that particular pipeline segment or it presents a very low failure frequency. A case by case approach is therefore recommended.

2. Root analysis of potential failure causes

For each of the potential failure causes mentioned above, root cause analysis diagrams have been established following a methodology commonly used in the gas industry. (see Annex 1.) The cause failure scenarios do not take into account the likelihood of occurrence. It should also be noted that the occurrence of some of the failure causes is extremely low.

Following the root failure diagrams, a cause failure scenario can only lead to an accident when different "gates", called "defences" (to defend the pipeline in a static manner) and "controls" (to control the management tools) have been passed. When the "gates" are "closed" the accident cannot occur. The individual "gates" are called "Performance Indicators". While the prevention measures contributing to the "closing" action of the "gates" are called "Performance Elements".

3. Main performance indicators for the company PIMS

According the root cause failure diagrams and considering the individual "gates" which may lead to loss of containment, following pro-active performance indicators have been identified:

1) Pro active "Performance indicators" directly under control of the pipeline operators:

- prevention of damage;
- detection of damage;
- control room in view of quick response;
- design, construction and testing;
- line valve (block valve/isolation).

These performance indicators are considered as "technical measures".

2) Reactive "Performance Indicators" under the control of the pipeline operator

- incident frequency
- loss of containment

The latter re-active "Performance Indicators" are final tools to measure the integrity grade of the pipeline system and where needed to improve the "performance indicators-defences and controls" of the companies' PIMS for that particular area.

3) Pro active "Performance Indicators" under control of the National Authorities:

- land use planning
- information to public;
- emergency services.

4. Further Evaluation

To evaluate the pipeline performance a clear distinction should be made between responsibilities of the pipeline owner/operator and National Authorities

The "Performance Indicators" for design, construction and testing may consist in an inspection declaration. Evaluation through the procedure "Expert Judgement" or/and the application of acknowledge standards are also considered "Performance Indicators" in the area concerned.

Prevention of damage is the most important performance indicator, during operation and maintenance phase whereby the "Performance Indicator - Loss of Containment" is pre-dominant. Material toughness behaviour is an important issue to limit the consequences (leak before break).

5. Performance elements

The root cause schemes mention both, key performance elements and alternative solutions. Reliability of Individual "Performance Elements" can be improved, for example higher frequency of survey, and is part of the "Expert Judgement"

It is not required to apply in front of each of the "Performance Indicators" all listed "Performance Elements" and not all failure causes are applicable to the whole pipeline system. It is up to the pipeline operator to assess the adequate "Performance Elements" for each pipeline segment, respectively the whole pipeline, to achieve the pre-set level of safety and integrity.

Depending on the failure frequency and the probability of occurrence, it is allowed to deviate from the "Performance Element(s)" in question. For each of the "Performance Elements" the probability of occurrence can be calculated provided the relevant parameters are known.

For certain "Performance Elements" it may be more appropriate to apply a binary approach which can be an inspection declaration or an expert judgement.

6. Incorporation of the "Performance Elements" in the "Pipeline Integrity Circle"

The gas company should set up a coherent and transparent procedure to link the "Performance Elements" with the several steps under the "Pipeline Integrity Circle". An example is given in Annex 2 using the Tripod model developed by both, the Leiden and Manchester University.

Some of the "Performance Indicators" may be combined because covered in a similar manner, e.g. the "Performance Indicator" defence for design (material toughness) is linked to the P.I. for internal corrosion, material defects etc.

All aspects concerning operation, maintenance and overall system management shall be documented through transparent company procedures and management principles together with a system for audit and review.

INTERNAL ORGANISATION FOR OPERATION AND MAINTEANNCE UNDER THE COMPANY PIMS

Policy

The pipeline operator is responsible for establishing its policy with regard to pipeline operation and maintenance activities. The aim is to ensure that the system carries the gas safely, economically and without interruption.

The integrity of the pipeline system can be influenced by the reliability of the individual items of equipment and/or by the operation and the maintenance of pipelines. In order to meet good performance standards, all necessary precautions and provisions shall be taken :

- to ensure safe operation of the pipeline system;
- to monitor its condition;
- to carry out maintenance safely and effectively;
- to deal effectively and responsibly with incidents and emergencies.

These precautions and provisions shall be incorporated into the management system.

Chapter 10 of EN 1594 covers adequately all aspects mentioned above regarding operation and maintenance (for detail see the relevant standard).

Organisation

The minimum requirements concerning organisation with respect to the operation and maintenance of a pipeline system are:

- organisation chart;
- responsible persons;
- personnel and training;
- standby organisation.

Operating and maintenance instructions

The pipeline operator shall express the tools needed for safe operation and management of the pipeline system in the form of rules, guidelines and procedures and translated in operating instructions. These instructions are part of the overall management system and shall be checked at regular intervals to ensure maximum effectiveness and amended as necessary.

Commissioning

Commissioning shall be carried out in accordance with EN 12327. In addition, particular attention should be given to the need to dry the pipeline prior to the "Commissioning" of the pipeline.

During "Commissioning" any gas/air mixture shall be removed safely and no air shall remain inside the pipeline. Afterwards the pipeline pressure shall be increased to the operating level in a controlled manner.

After construction and sufficient time to allow polarisation of the pipeline, the effectiveness of the cathodic protection, protecting the pipeline, shall be tested to ensure acceptability.

Decommissioning

Decommissioning shall be carried out in accordance with EN 12327. Pipeline sections which are taken out of service for an extended period of time shall, if necessary, be decommissioned.

Recommissioning

Recommissioning shall be carried out in accordance with EN 12327. Before or during the recommissioning of a pipeline, it is essential to verify that the work has been correctly

executed and tested. Special attention shall be given to welding, tightness, coating integrity and cathodic protection.

Maintenance, modification and repair

The pipeline operator shall establish procedures for maintenance, repair and modification of the pipeline system.

Pipeline work shall only be carried out by trained personnel or under the supervision of personnel authorised by permits to execute the work.

During the work on the pipeline care shall be taken to ensure that no hazardous gas mixtures are created. If this cannot be guaranteed, appropriate precautions shall be taken to prevent hazard to persons and the surrounding area.
Welding, cutting, grinding and similar works may be performed on an in-service pipeline provided the pipeline design, the pipe material and the established techniques permit such work to be carried out safely.
After completion of the work, the corrosion protection (coating, cathodic protection) shall be carefully reinstated.

Before cutting the pipeline, appropriate technical precautions shall be taken to ensure that there is no possibility of an uncontrolled gas ignition.
Before starting work the section of pipeline shall be isolated, depressurised and if necessary, purged. Care shall be taken to ensure that no gas can enter any section of pipeline which has been purged.

When working on in-service pipelines, including work involving the generation of heat, suitable precautions shall be taken to prevent the escape of gas and other hazards.
If the chosen procedure cannot be carried out on the pipeline at its normal operating pressure, the pressure in the pipeline section in question shall be reduced in a controlled manner to the required level and shall be maintained in that state while the work proceeds.

Emergency plan
An emergency planning including internal and external emergency procedures with the availability of trained personnel and necessary resources shall be established, tested and reviewed. In the event of an emergency, all necessary measures shall be taken to restore the pipeline and/or surrounding area under safe conditions.

INCIDENT REPORTING AND EVALUATION

Pipeline accidents and incidents shall be reported to Company Management level.
Reports shall be registered, verified and evaluated. Evaluation can lead to actions for improvement.

AUDIT AND REVIEW

The companies' PIMS "Pipeline Integrity Management System" shall be periodically audited and reviewed by the companies' management team. Inputs for review are inter alia:

- the audits on performance indicators to check the effectiveness of the relevant procedures and instructions under the individual steps of the "Integrity Management Circle",

- lessons learnt from incident reporting, and information world-wide, etc.

The results of the review shall be tested against both the current "Performance Elements" and the overall pipeline safety level. From this evaluation concrete actions may be put into place and a review report shall be established.

REQUIRED COMPETENCE WITHIN A GAS TRANSMISSION COMPANY

The required technical competences within a gas transmission company are determined by both, the performance elements mentioned under the pipeline root failure cause schemes and the expert judgement, key element under the "Pipeline Integrity Circle".

The key competences regarding operation and maintenance are adequately covered by chapter 10 of EN1594 "Maintenance and Operation" and assessed at engineer level. The additional requirements set out in this report, in particular the aspects mentioned below require specific competences and know-how and assessed by engineers with a university degree:

- incident investigation (lessons learnt from/expert judgement): mechanical, materials, joining, structural, instrumental, process, hazardous area, labour, statistical, requires a specialist in inspection techniques;

- monitoring: requires a specialist in monitoring systems techniques.
  from workshops or Internet (e.g. NTSB), etc.

The above-mentioned experts are integrated in a transparent and well documented management structure, implemented, improved and reviewed according to the basic principles defined in chapter 10 of EN 1594. The required competence needs to be kept at the required management level. A mechanism shall be in place within the company to maintain this level.

To avoid recurrence of accidents it is necessary to learn from incidents reported inside the company and world-wide in literature, from other gas transmission companies, from workshops or Internet (e.g. NTSB), etc…

The competences in relation to design and construction are not necessarily within the gas transmission company. Such competences can be with the engineering contractor and/or pipeline contractor.

The competences are:

- pipeline engineering/structural engineering;
- mechanical engineering;
- civil engineering;
- agricultural expertise;
- welding/NDT;
- electrical/instrumental;
- cathodic protection.

The level of competence is engineering level.

INCIDENT REPORTING AND EVALUATION

Accidents and incidents with regard to safety shall be reported at the companies' management level.

Reports shall be registered, verified and evaluated. Evaluation can lead to improvement of the company procedures.

REFERENCES

1. EN 1594 - "Gas supply systems - Pipelines for maximum operating pressure over 16 bar - Functional requirements", March 2000, CEN (European Committee for Standardisation").

2. "Development of Performance Measurement Framework for Controls of Pipelines", Report of the European Commission, February 1998, Arthur D. Little Limited, U.K.
Accident

3. EGIG data - 4th EGIG report 1970-1998 – "European Gas Pipeline Incident Data Group" Ref. EGIG 99.R.0074 – December 1999