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Identification, evaluation and minimization of industrial risks relating to gas pipelines

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Abstract. The security of the functioning systems represents, through the four specific components (security, availability, reliability and maintenance), a basic component of the processing requirement. Monitoring of all specific intrinsic and operating parameters of oil and gas pipelines can be technically detected and diagnosed by:
-existing defects;
-rapid and effective intervention to eliminate the damage, if they occurred.
To establish the maintenance programs that can ensure the proper functioning of the gas pipelines, it is necessary to establish their technical status. The research done helps reduce the risk of gas pipeline damage.

1 Introduction

Pipe systems are assemblies consisting of two or more pipes connected together for the transport and distribution of the same working agent (fig. 1.). Checking the technical condition of the pipes can be ensured using one of the following methods: the in-line inspection method, the pressure test method, the direct evaluation method [3,6].

The master pipes are the pipes, including the installations, equipments and related equipments through which the transport of fluids between the pick-up points and the delivery points is ensured. For a better picture of what the complexity of these constructions means we can say that the component elements of the fluid transport pipes are:
piping (pipes) - main element and various equipment, connecting parts, molded parts (fittings), fittings, measuring and control devices, expansion compensators, etc.

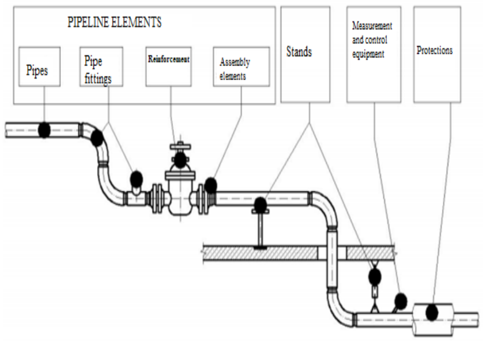

Fig. 1. Component elements of a pipeline system [37], [111].

2 Gas pipeline security

The emergence of new types of risks and the evolutions at international level generate increasingly complex needs in the field of risk management, as well as implications regarding their management at national or local level. In this context, it is necessary to use a common language in the field of risk management and a coherent and unique analysis process, so that it is possible to identify the risks with major impact at national level with international connotation, but also an integrated risk management [2,3].

The security of the functioning of the systems is, through the four specific components (security, availability, reliability and maintenance), a basic component of the processing requirements. In the case of gas pipelines, the fulfillment of this desire is essentially conditioned by the fulfillment of the following mechanical technical safety criteria:

➢ ensuring the mechanical strength of the structural components. This means avoiding reaching the limit states - critical, or last, of requesting the material put into operation; prevention of cracking and fracturing of the materials in the work; ensuring the mechanical stability, the rigidity of the structural components and maintaining the initial geometric shape of each component, during the service life under load and ensuring the tightness of the technological premises [3,7].

The wrong design, design, implementation, integration and processing of any system leads to an increase in the uncertainty level by exceeding the allowable threshold, following an accident. The source of danger in normal or abnormal processing situations, by nature of system components and the elements of entry / exit of the environment in which the system works. The exploitation of the technological installations, in conditions of technical security is accepted provided that

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they ensure the continuous operation within the limits of the design characteristics (fig. 2.). The load parameters of the component, respectively the strength of the material, are generally random variables [3,8].

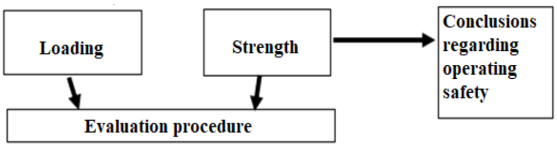

Fig. 2. Primary assessment of the safety in operation.[3,8].

If, however, the normal logarithmic distribution is assumed, it can be described in terms of the mean and standard deviation. In engineering practice, in addition to mathematically accurate description, the material or use characteristics of the components must be specified in statistical terms. A technical system is reliable if during the operating period it achieves the technical, technological safety, by observing the quality requirements of the technical and legislative norms. Reliability expresses the probability of the proper functioning of the technological equipment as a whole, but also of its components, within a time frame and under prescribed conditions. The exploitation of industrial plants implies a certain probability of failure, respectively a risk. In a practical sense, it can be identified with the potential loss of production in a certain period of time. The abnormal situations identified randomly materialize by technical and / or human accidents, failures of the components of the installations, disturbances of the technological cycle or of the environment. In the operation of a technical system, of the technological equipment, absolute technical security (S ›1) cannot be ensured, resulting in a zero technical risk (R› 0) [3,8].

Table 1. Risk matrix. [3,8].

Probability of occurrence	Risk level			
High				High risk
Medium			Medium risk	
Small		Low risk		
Null	No risk			

Consequences of degradation → in a practical situation, excluding the possibility of operating under real conditions of unreliable installations (F ›0), leads to a total reliability, presented in table 1. In such an objective context, the engineering has the obligation to provide answers based on the question: *how much is it worth to spend for the technical security to approach the unit and the corresponding risk to zero?*

The adoption of any technical-organizational measures aims to improve the technical security, the operational safety, through the competence and the involvement of the factors from the conception to the use of the installation. The measures adopted are limited by possibilities and / or rational limits. Thus, no great expense can be resorted to for increasing the technical security factor, such as additional investments. All of this can be found in the costs of production, the level of profit, which can have adverse financial effects over certain limits. The exploitation of the technological installations, under conditions of technical security is accepted as having to ensure the continuous operation within the limits of the design characteristics. To properly assess the risk, a definition is needed that includes all the possibilities of occurrence and the consequences of the defects in the structure of the technical system. In general, the risk function is represented in the graphic form of the "bathtub" (fig. 3).

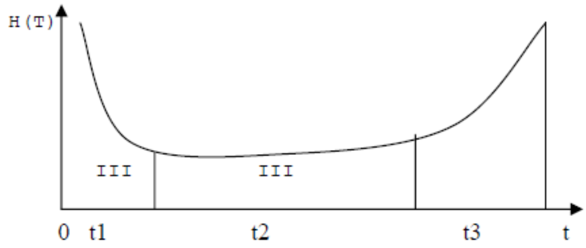

Fig. 3. Risk function [3,8].

In the initial period the intensity of H (T) yields is relatively high, but decreases with the passage of the use time. In the normal operating range the intensity of the yields is approximately constant. The objective of the user is to make this period as long as possible, so the speed of the intensity of the yields is as low as possible. Entering the period of use in the third area causes the intensity of the yields to increase rapidly.

3 Identification of risk scenarios Risk scenario: GAZODUCT Technical Damage - Total / partial exit from the National Natural Gas System (SNGN) function

The technical failure of the gas pipeline is given by succession of technical incidents / accidents at work; personal exploitation errors; total / partial exit from SNGN function; energy insecurity; economic insecurity; national insecurity; material damage / loss of human life and state of instability [1,3,4,5].

The causes and effects of the Pipeline Risk Scenario have been described in Table 2.

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Table 2. Description of the risk scenario (causes and effects).

RISK SCENARIO FOR PIPES: TECHNICAL FAILURE GAZODUCT → TOTAL / PARTIAL OUTPUT OF SNGN FUNCTION	
Causes - poor condition, lack of investment, lack of revisions, incorrect or outdated configuration at: • Major pipelines (thickness). • 45 GN - SRM measuring adjustment stations. • measuring stations - PM. • valve control stations - SC. • GN - SMG measuring stations. • GN - SCG compression stations. • PC stations - SPC. - wrong maneuvers performed by the operating personnel. - lack of specialized and / or trained operating personnel. - poor communication or communication with the National Natural Gas Dispatcher - DNGN. - DNGN personnel not specialized in times of crisis. - lack of working procedures during times of crisis. - lack / non-compliance / non-knowledge of national / European procedures in case of serious damage. - lack of training in the field of Risk Management.	Effects: - halting the natural gas market between Romania, ENTSO-G, NATO or other partner countries. - non-supply of natural gas to neighboring energy systems, from ENTSO-G, NATO or other partner countries. - the non-supply of natural gas to the major consumers and the main gas pipelines within SNGN.

Table 2. Description of the risk scenario (causes and effects) (sequel).

	huge material damage esulting from the lack of atural gas. huge material damage esulting from the nterdependence of other ystems with natural gas.

The calculation of the risk scenario for gas pipelines is done by following the steps:

➢ **Establishing the probability of failure:**

Due to the effects caused by the causes of the technical damage of the gas pipeline (the total / partial exit from the SNGN function) we have adopted an average level for establishing the probability, the event having a significant probability of occurring, according to the probability scale [3].

Table 3. Establishing the probability.

LEVEL/ ASSOCIATED SCORE		DEFINITION OF PROBABILITY	PERIOD
	1. Very low	It has a very low probability of occurring. Normal measures are required to monitor the evolution of the event.	after 13 years
	2. Low	The event has a low probability to occur. Efforts are needed to reduce the probability and / or attenuation the impact of the product.	10 – 12 years
X	3. Medium	The event has a significant probability of occurring. Significant efforts are required to reduce the probability and / or attenuation the impact of the product.	7 – 9 years
	4. High	The event is likely to occur. Priority efforts are needed to reduce the probability and / or attenuation the impact of the product.	4 – 6 years
	5. Very high	The event is considered imminent. Immediate and extreme measures are required to protect the target, evacuation to a safe location if the impact requires it.	1 – 3 years

➢ **Establishing the gravity of the consequences of the proposed scenario:**

The severity of the consequences is given by the unfavorable level of vulnerabilities and impact levels. Vulnerability and capabilities analysis are presented in Table 4 [3].

Table 4. Analysis of vulnerabilities and capabilities related to the Pipeline Risk Scenario.

RISK SCENARIO: GAZODUCT TECHNICAL FAILURE - VULNERABILITIES AND CAPABILITIES	LEVEL
1. Lack of energy infrastructure in the northern part of the country: - lack of investments (new gas pipeline constructions and regulation-metering stations, valve control, metering, compression and cathodic protection) and / or non-technologization of existing ones. - unpredictability of the political system. - the possibility of a natural, regional or national gas interruption, generating: • halting the natural gas market between Romania and ENTSO-G / NATO / partner countries. • stopping the production of electricity from power plants. • non-supply of natural gas to industrial and domestic consumers. - energy insecurity, generating economic insecurity, generating national insecurity.	Very low Low Medium High Very High
2. Incorrect or precarious configuration of energy infrastructures: - the incorrect or precarious configuration of the pipelines (thickness). - the incorrect or precarious configuration of the adjustment-measuring stations, valve control, measurement, compression and cathodic protection.	Very low Low Medium High Very High
3. The degree of specialization and periodic training of the personnel with responsibilities of restoring the process of natural gas supply: - the operative personnel within the National Natural Gas Dispatcher - DNGN. - the operative personnel from the stations of regulation-measurement, control of valves, measurement, compression and cathodic protection. - maintenance staff. - security personnel.	Very low Low Medium High Very High

➢

➢ **Impact study:**

The impact study is the analysis of the management at certain levels that identifies the impact of the loss of the resources of a European critical infrastructure (pumping station / national importance of natural gas pipelines). The severity of all the impacts of the scenario will be taken into account and then the level of severity of the consequences of the hazard / threat from the considered scenario will be established. The highest level will be chosen from the severity levels related to the impacts, according to table 5 [3].

Table 5. Analysis of the impact related to the Risk scenario.

IMPACT	LEVEL	
Huge damage caused by lack of natural gas.	1.Very low	temporary
	2.Low	significant damages
	3.Medium	medium damages
	4.High	big damages
	5.Very high	
Huge damage caused by the interdependence of the other systems with the natural gas.	1.Very low	0 – 10% of VCI
	2.Low	11 – 20% of VCI
	3.Medium	21 – 30% of VCI
	4.High	31 – 40% of VCI
	5.Very high	peste 41% of VCI
Potential environmental damage	1.Very low	0 – 20%
	2.Low	21 – 40%
	3.Medium	41 – 60%
	4.High	61 – 80%
	5.Very high	peste 81%
Strong social impacts	1.Very low	0 – 10% of IP
	2.Low	11 – 20% of IP
	3.Medium	21 – 30% of IP
	4.High	31 – 40% of IP
	5.Very high	peste 41% of IP
VCI - Volume of Invested Capital; CP - Confidence of the population.		

➢ **Calculation of severity of consequences:**

We calculated the severity of the consequences in table 6.

Table 6. Gravity of consequences.

	LEVEL/ ASSOCIATED SCORE	GRAVITY OF CONSEQUENCES
	1. Very low	The event causes a minor disturbance in the activity, without material damage
	2. Low	The event causes minor material damage and limited activity disruption
	3. Medium	Personal injury, and / or loss of equipment, utilities and delays in service provision.
	4. High	Serious personnel injuries, significant losses of equipment and facilities equipment, delays and / or interruption of service provision.
X	5. Very high	The consequences are catastrophic resulting in serious personnel deaths and injuries, major losses of equipment, installations and facilities and the cessation of service provision.

➢ **Calculation of risk level:**

Due to the strong impacts, we have chosen a very high level, which can cause huge damage, and the consequences can be catastrophic, leading to major losses of equipment, installations and cessation of service provision, but also to serious injuries, even deaths. The calculation of the risk level is given by the product between establishing the probability and calculating the severity of the consequences, being described in table 7 [3].

Table 7. Calculation of risk level.

P R O B A B I L I T Y	Very high 5					
	High 4					
	Medium 3					Scenario DAMAGE
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5
G R A V I T Y / C O N S E Q U E N C E S						
Note: The risk is given by the result of the probability of producing a hazard / threat and the severity of its consequences.						

The result of the risk of producing the chosen scenario is the following:

The calculated risk has the value 15 (probability 3 x gravity 5), therefore there is a HIGH RISK to produce the script chosen.

CALCULATED RISK LEVEL	
LEVEL	SCORE
Very low	1 – 3
Low	4 – 6
Medium	7 – 12
High	13 – 16
Very high	17 – 25

➢ **Risk management:**

To reduce the risk, measures are required to reduce the following vulnerabilities and / or improve the following capabilities, according to table 8 [3].

Table 8. Risk treatment for the Risk scenario [3].

VULNERABILITY AND / OR CAPABILITY	PROPOSED MEASURES
1. Lack of energy infrastructure in the northern part of the country: - lack of investments (adjustment-metering stations, valve control, measurement, compression, cathodic protection and existing pipelines - old). - unpredictability of the political system. - the possibility of a natural, regional or national gas interruption, generating:	- major investments in energy infrastructure: • new gas pipelines. • new regulating-measuring stations, valve control, measurement, compression and cathodic protection.
• halting the natural gas market between Romania and ENTSO-G / NATO / partner countries. • stopping the production of electricity from power plants. • non-supply of natural gas to industrial and domestic consumers. - energy insecurity, generating economic insecurity, generating national insecurity	• refurbishment of existing gas pipelines and regulating stations - measurement, valve control, measurement, compression and cathodic protection - old. - predictability (security) of the political system. - accessing European funds for securing European critical energy infrastructures.
2. Incorrect or precarious configuration of energy infrastructures: - the incorrect or precarious configuration of the pipelines (thickness). - the incorrect or precarious configuration of the regulating-measuring stations, valve control, measurement, compression and cathodic protection.	- technical assessments (thicknesses) on the thickness suitable for gas pipelines for the purpose of operating at normal parameters.
3. The degree of specialization and periodic training of the personnel with responsibilities of restoring the process of natural gas supply: - the operative personnel of the National Natural Gas Dispatchery - DNGN. - the operative personnel from the stations of regulation-measurement, control of valves, measurement, compression and cathode protection. - maintenance staff. - security personnel.	- training and training courses for operating personnel (DNGN / regulating-measuring stations, valve control, measurement, compression and cathodic protection), maintenance and security. - analysis of technical events, technical incidents and accidents at work, etc. - the control of the installations on line of operation and the preventive maintenance.

➢ **Recalculation of the gravity of the consequences:**

After treating the risk through the measures proposed for the vulnerabilities and / or the capabilities of the risk scenario, we reduced the level associated with the severity of the consequences from the medium to the low level, according to table 9 [3].

Table 9. Recalculation of severity of consequences.

	NIVEL / PUNCTAJ ASOCIAT	GRAVITATEA CONSECINȚELOR
	1.Very low	The event causes a minor disturbance in the activity, without material damage.
X	2.Low	The event causes minor material damage and limited activity disruption.
	3.Medium	Personal injury, and / or loss of equipment, utilities and delays in service provision.
	4.High	Serious personnel injuries, significant losses of equipment and facilities, delays and / or interruption of service provision.
	5.Very high	The consequences are catastrophic resulting in serious personnel deaths and injuries, major losses of equipment, facilities and the cessation of service provision.

➢ **Calculation of the risk level after the reduction measures are applied:**

Following the reduction of the risk and the recalculation of the severity of the consequences, the risk level of the scenario production was reduced, the value of the risk level after the reduction measures were applied is shown in table 10 [3].

Table 10. Risk level.

PROBABILITY	Very high 5					
	High 4					
	Medium 3		Scenario DAMAGE			
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5
	GRAVITY / CONSEQUENCES					
Note: The risk is given by the result of the probability of producing a hazard / threat and the severity of its consequences.						

The result of the risk of producing the chosen scenario is the following:[5]

The calculated risk has the value 6 (probability 3 x gravity 2), therefore there is a LOW RISK to produce the script chosen.

CALCULATED RISK LEVEL	
LEVEL	SCORE
Very low	1 – 3
Low	4 – 6
Medium	7 – 12
High	13 – 16
Very high	17 – 25

4 Conclusions

In order to establish the maintenance programs that can ensure the proper functioning of the gas pipelines, it is necessary to establish their technical status. Preventive and predictive maintenance systems that significantly reduce the risk of damage occurrence can be applied after finding out the technical state of the gas pipelines. These two maintenance systems are less expensive compared to corrective maintenance. The establishment of the gas pipeline maintenance plan is as follows:

- identification of the limit state for the intervention; the probability of reaching the limit state; the volume of fluid that can be released following an incident; number of population in the incident area.

Industrial practice has shown that no matter how much one invests in maintaining the high level of reliability of the technical / technological system, we will not reach the ideal reliability. Therefore, a system that does not degrade over time cannot be put into practice. The reliability of a technical / technological system is determined by all the factors involved in its implementation:

- design; implementation; system processing.

The security of the functioning of the technical / technological systems, in this case the gas pipelines, is a basic component of the processing requirements, through the four specific elements:

- security; availability; reliability and maintenance.

Mechanical technical security criteria ensure with high levels of reliability and technical security. Risk assessment is used to determine the identification of maximum risk areas. Investigations for the identification, evaluation and minimization of industrial risks related to gas pipelines involve high costs, approved equipment and authorized personnel. The results of the research can also be used in similar cases.

References

1. ASRO *SR ISO 31010:2010,* Managementul Riscului. Tehnici de Evaluare a Riscurilor,București, 2010
2. Băbuț, G., Moraru, R., *Environmental risk characterisation principles*, Proceedings of the 6th Conference on Environment and Mineral Processing, part. I, pag. 17-21, VŠB-TU Ostrava, Czech Republic, 27-29.06.2002
3. Bădică Marius Nicolae, *Identificarea vulnerabilităţilor şi riscurilor tehnogene asupra oleoductelor şi gazoductelor în scopul creşterii securităţii energetice*, Petroșani, Editura Universitas, 2020
4. ISO, *ISO/IEC 31010:2009 - Risk management – Risk Assessment Techniques,* International Organization for Standardization / International Electrotechnical Commission, Geneva, Switzerland, 2009
5. Ministerul Afacerilor Interne – Inspectoratul General pentru Situații de Urgență – IGSU *Metodologia de evaluare a riscurilor și de integrare a evaluărilor de risc sectoriale,* București, România, 2019
6. Norme tehnice specifice SNT mentenanţa conductelor de transport gaze naturale – NTMC, http://new.transgaz.ro/sites/default/files/uploads/users/admin/ntm_c_final_0.pdf
7. Riscul tehnic. Managementul riscului si utilizarea sa in activitatea decizionala, http://www.creeaza.com/referate/management/RISCUL-TEHNIC-MANAGEMENTULRIS543.php
8. T. Fleşer: *Mentenanţa şi reabilitarea sistemelor tehnice şi a componentelor mecanice* (2008, ISBN 978-973-8359-54-3)