RIGA TECHNICAL UNIVERSITY

Faculty of Building

Institute of Heat, Gas and Water Technology

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Student of the Doctoral Program "Heat, Gas and Water Technology"

METHODOLOGY OF ASSESSMENT OF THE TECHNICAL CONDITION OF DISTRIBUTION GAS PIPELINE SYSTEMS

Summary of the Thesis

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THE DOCTORAL THESIS HAS BEEN PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF THE DOCTOR OF ENGINEERING

The public defence of the Doctoral Thesis for obtaining the degree of the Doctor of Engineering is held on ______________ 2014 at._____ hours at Riga Technical University Faculty of Building Room 250 at Āzenes iela 16/20.

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CONFIRMATION

I hereby confirm that I have developed the present Doctoral Thesis that have been submitted for review to Riga Technical University for the promotion to the degree of the Doctor of Engineering. This Thesis have not been submitted to any other university in order to obtain any scientific degree.

Ilmārs Bode..(Signature)
Date...

The Doctoral Thesis are written in Latvian, there are 103 pages, they contain an introduction, 9 chapters, conclusions, the list of bibliography with 96references.

EXECUTIVE SUMMARY

Within the framework of the present Thesis, a methodology for assessment of the technical condition of distribution gas pipeline systems suitable for the Latvian conditions was developed.

Within the present Thesis the structuring of the technical operational process of distribution gas systems was carried out, the methodology for assessment of the technical condition of distribution gas pipeline systems was developed and tested at Bauska and Cēsis divisions of the Joint Stock Company (hereinafter JSC) "Latvijas Gāze".

The Thesis also contain elaborated unified methodologies for performing technical diagnostics (stray current, electrical protection, soil specific resistance measurements, insulation defects and adhesion, operational conditions of steel underground gas pipelines, etc.) and uniform forms for recording the above measurement results.

There is comparative assessment and recommendations for selecting equipment and measuring devices used for technical diagnostics of gas pipelines and their testing.

The data obtained in various regions of Latvia in the result of the research allow concluding that certain "risk areas" get formed in distribution gas pipeline systems and their condition can be assessed and measures can be implemented for minimising the risk of accidents.

The operational risk analysis of a gas pipeline contained in the methodology developed within the Thesis present a constituent of the industrial safety management and provides for a systematic use of all the available information for identification of danger and assessment of the risk of undesirable events.

In the course of the research the optimum values of the calculation were identified and necessary formulae for calculation and the criterion for assessment of the results was provided, i.e. the operational risk (Re) may not exceed the admissible risk (Rp).

Implementation of the methodology for assessment of the technical condition of distribution gas pipeline systems as developed within the Thesis and its inclusion in regulatory documents will ensure justified and operative assessment of the technical condition of gas pipelines.

The results of the Thesis were reported at 8 international conferences and reflected in 8 publications.

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INTRODUCTION

The organisation and technologies of the basic tasks of the technical operation of natural gas distribution pipeline systems (technical maintenance and repairs) are labour consuming and important processes that determine the lifetime of gas pipeline systems.

In Latvia, a certain proportion of gas pipelines of the natural gas distribution system have been in operation for thirty years and above. During the time period until the beginning of the1990-ies, the prevailing view regarding the operation of distribution gas pipeline systems was that the lifetime of gas pipelines was 40 years. No conditions for assessing the condition of gas pipelines if their lifetime exceeds this threshold were developed. Taking into account that the estimated lifetime of 40 years has been exceeded for a certain proportion of distribution gas pipelines and this proportion will increase within next years, there is an acute necessity of performing the assessment of the technical condition of these gas pipelines and to adopt operative decisions regarding the strengthening of supervision of such sites or discontinuation of operation of particularly unsafe parts of the system. Although regular technical service of these gas pipelines is performed in compliance with the standard LVS 445:2011, the assessment of these processes aimed at determining the technical condition of distribution gas pipeline system and the further procedure of operation, repair, reconstruction or replacement has not been studied in Latvia until now.

The assessment of the technical condition of natural gas transmission pipeline system (P > 16 bar) has been studied by A.Borodiņecs, A.Broks, A.Davis, A.Ješinska and A.Krēsliņš.

The research is based upon the internal diagnostics of a pipeline by means of placing a special diagnostics piston in the pipeline and using it for identification of the technical condition of the gas pipeline. However, this method cannot be applied in the distribution gas pipeline and the Consumers' gas supply systems (special chambers for starting and receiving of pistons are required, as well as long, specially prepared sections of pipelines with as few branches as possible).

The goal of the Doctoral Thesis - development of the methodology for assessment of the technical condition of distribution gas pipeline systems suitable for the Latvian conditions.

Tasks of the Doctoral Thesis:

1. Development of uniform requirements for organisation of the technical diagnostics of gas pipelines and relevant recording.
2. Development of a uniform methodology for assessment of the technical condition of a gas pipeline and identification of the possibility of further operation.
3. Performance of research regarding the selection of equipment used for diagnostics of gas pipeline systems.
4. Performance of experimental testing of the methodology for assessment of the technical condition of distribution gas pipeline systems as developed within the Thesis.
5. Drafting of proposals of necessary amendments to the National Standard LVS 445:2011 „Operation and technical servicing of natural gas distribution and Consumers' gas supply systems with a maximum operational pressure up to 1.6 MPa (16 bar)".
6. Drafting of proposals for development of a new industry standard LV NS GS that would including the methodology for assessment of the technical condition of distribution gas pipeline systems.

Methodology and means of research

Technical as-built documents of the JSC "Latvijas Gāze", technical passports of operation of gas pipelines and other documents related to the operation of gas pipelines were utilised in the present research.

Scientific novelty and main results of the research

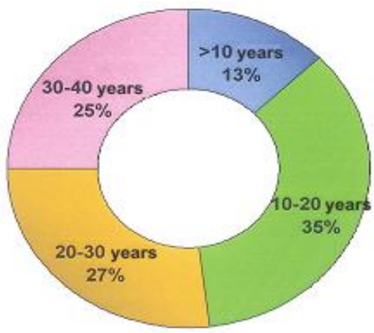
The research carried out during the development of the Thesis attest the necessity of developing, approbating and introducing a new and modern methodology for assessment of the technical condition of distribution gas pipelines. This methodology was developed within the framework of the Thesis and its has attested its usefulness in practice.

Practical application of the Thesis

According to the calculations, the practical application of the methodology would provide an opportunity of getting operative data regarding the technical condition of gas pipelines, of performing an evaluation resulting in identification of the most efficient and rational types of technical service and repair works, terms for performing the above works and further operation of the gas pipeline.

1. TECHNICAL DIAGNOSTICS METHODS OF NATURAL GAS DISTRIBUTION PIPELINE SYSTEMS

Steel gas pipelines have been installed in Latvia under various conditions since 1960. As steel gas pipelines were not installed all during the same year, they have been in operation for various terms (see Figure 1.1), their wear and other factors differ and the requirements regarding technical operation and renovation differ.



Above 10 years	- 382,76 km
10 to 20 years	- 1070,66 km
20 to 30 years	- 815,81 km
30 to 40 years	- 751,81 km

Fig. 1.1 Operational term of steel gas pipelines in operation

The technical operation of distribution gas pipeline systems is carried out by the territorial structural units, operational districts and specialised services of the system operator JSC "Latvijas Gāze".

The current procedure of technical service and repairs includes the following:

1) regarding gas pipelines - technical monitoring, auditing of the network devices, control of the technical condition, pressure and leakages, protective coating and repairs;
2) regarding gas control devices - technical survey, monitoring, auditing;
3) regarding anti-corrosion protection devices - measurement of potential, technical servicing of equipment.

The current technical operation of distribution gas pipeline systems is based upon performance of the measures provided for in the National Standard LVS 445:2011, however, it is not focused on identification of the causes behind the worsening of the technical condition of gas pipelines (damages) and forecasting of further safe operation.

Within the present Thesis, the current procedure of the operation and technical monitoring of distribution gas pipeline systems and its efficiency was analysed, resulting in the development of the scheme of the technical diagnostics of gas pipelines (see Fig. 1.2).

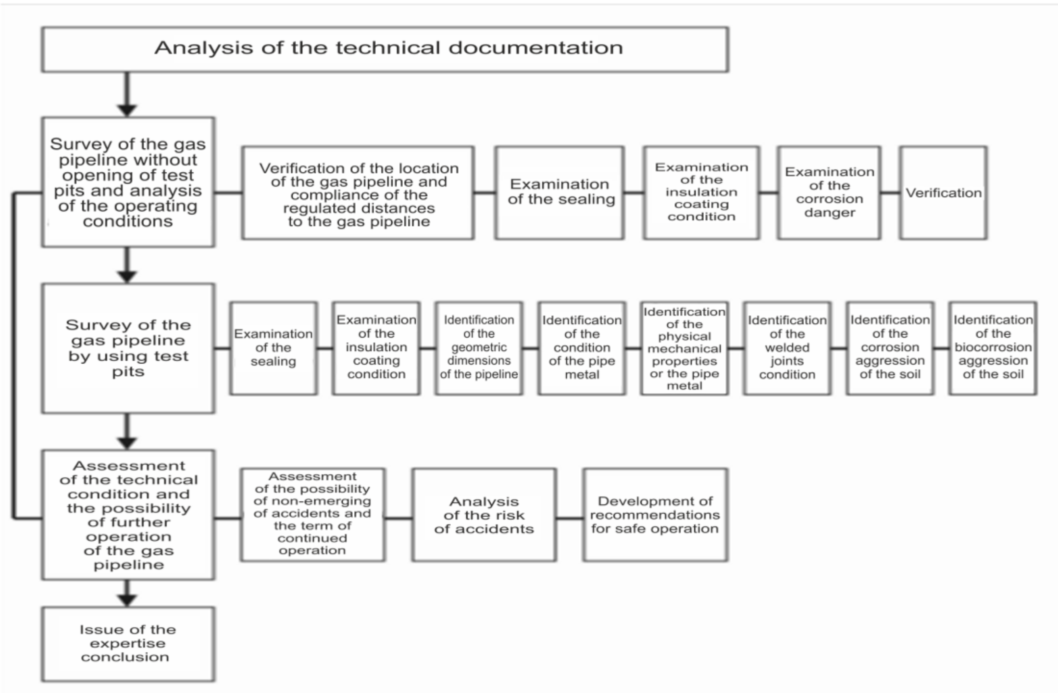


Fig. 1.2 Diagnostics scheme

The data obtained in the result of performing the diagnostics should cover the analysis of technical documentation, survey of pipelines without test pits and with test pits, assessment of operational conditions.

The diagnostics works should be performed in compliance with the algorithm presented in Figure 1.3.

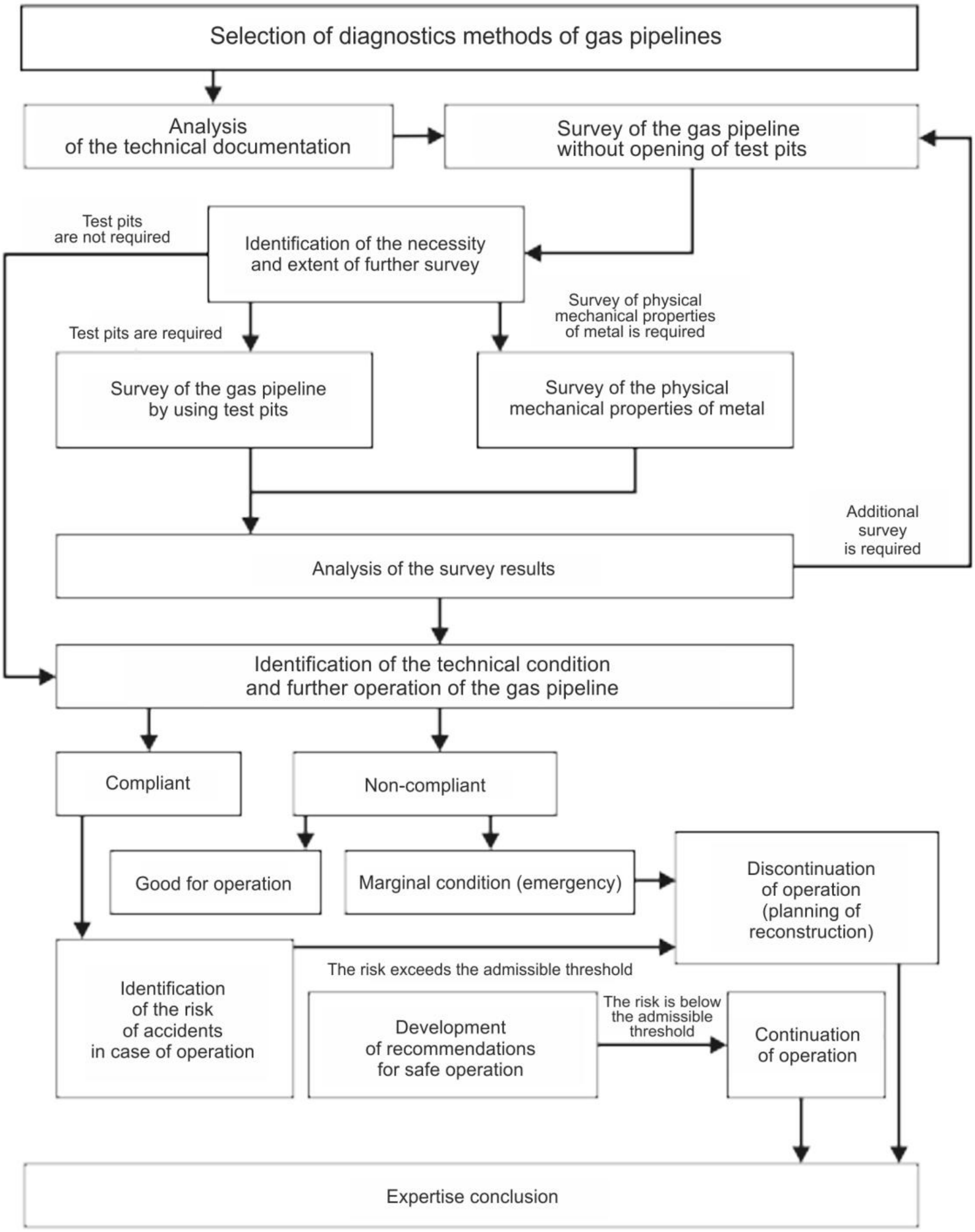


Fig. 1.3 Algorithm of performance of diagnostics works of steel underground gas pipelines

By means of diagnostics methods, the technical condition of underground gas pipelines is monitored, including measurements of polarisation potential values, identification of defects and damages of steel gas pipelines, defects of anti-corrosion coating, etc.

Fig. 1.4 Measuring of polarisation potential at a stationary control measuring point

Fig. 1.5 Measuring of the thickness of the wall of a metal pipe in a test pit

As the reliability of the mathematic results of the assessment of the technical condition of distribution gas pipeline systems, as developed within the Thesis, is heavily impacts by entered data, the uniform preparation of these data is also very important. Therefore, the tasks of the Thesis included also the task of elaboration of unified methodologies for performing technical diagnostics (stray current, electrical protection, soil specific resistance measurements, insulation defects and adhesion, operational conditions of steel underground gas pipelines, etc.) and uniform forms for recording the above measurement results.

2. ASSESSMENT OF THE TECHNICAL CONDITION OF A GAS PIPELINE AND IDENTIFICATION OF THE CONDITIONS FOR THE POSSIBILITY OF FURTHER OPERATION

The technical condition of a surveyed gas pipeline is determined in compliance with the algorithm presented in Figure 1.3.

For the purpose of the assessment of the technical condition, the possibility of non-emerging of accidents within the surveyed gas pipeline has to be assessed. Taking into account the technical condition of the gas pipeline, the possibility of non-emerging of accidents is assessed based upon the following relations:

1) The danger adjustment coefficient of defects and damages of the gas pipeline is determined in the result of the analysis of technical documentation – **Ki.** The recommended Ki values were calculated in the Thesis and these were obtained based upon statistics data, taking the coefficient equal to 1.0 as the basis:

Table 2.1

Values of the danger adjustment coefficients of defects and damages of the gas pipeline (Ki)

Characteristics of an underground pipeline		Ki eventual
Operational conditions		
Type	between the village	1.0
	distribution	1.05
	inlet	1.10
Pressure	low	1.00
	medium	1.05
	high	1.10
The route of the gas pipeline across natural and artificial obstacles	none	1.00
	a water obstacle	1.05
	a road or a railway	1.10
	a road and a railway	1.15
Regulated distances from the gas distribution network	complied with	1.00
	not complied with	1.05
The protection potential is ensured along the whole length or electrical chemical protection (EKA) not required		1.00

Table 2.1. (continued)

The protection potential is ensured not along the whole length at a high soil corrosion activity or if there is a dangerous impact of stray currents (DC and AC)		1.10
The protection potential is ensured not along the whole length at a high soil corrosion activity and if there is a dangerous impact of stray currents (DC and AC)		1.20
Interruptions in the operation of the electrical chemical protection device (EKI) exceed permitted terms		1.05
Development of the number of defects at this moment		
Damages of insulation coating not identified before		0.95
Damages of insulation coating were identified before, however, there was no development in the increase of their number		1.00
An increase in the number of locations of damages of insulation coating in comparison to a preceding survey		1.10
There is an increase in the number of penetrating insulation damage spots during the last 5 years in comparison to the preceding 5 years		1.90
There is an increase in the number of the spots of the loss of sealing of welds during the last 5 years in comparison to the preceding 5 years		1.90

2) The possibility of non-emerging of accidents at the surveyed gas pipeline ***Hj*** is assessed as follows As regards the technical condition of the gas pipeline, the possibility of non-emerging of accidents is assessed based upon the results of the diagnostics, taking into acocunt any found defects and damages:

$$Hj\ following\ diagnostics = \prod_{si=1}^{si} [1 - K_{\Sigma} * P\ (AS_j)]^{ms} \qquad (3.1.)$$

and following the elimination of all the defects and damages found during the survey, taking into account the defects and damages that may have been left unnoticed due to objective and subjective reasons:

$$Hj\ after\ repair = \prod_{si=1}^{si} [1 - K_{\Sigma} * P\ (As_j)]^{Ls} \qquad (3.2.)$$

where Π (pi) – multiplication sign of multiplicators;

si – number of types of defects and damages;

$\mathbf{K_{\Sigma}}$ – the danger adjustment coefficient of defects and damages (emerging of accidents) equal to the multiplication of individual coefficients Ki::

$$K_{\Sigma} = \prod_{i=1}^{n} K_i, \qquad (3.3.)$$

where n – the number of adjustment coefficients Ki;

3) The danger adjustment coefficient of defects and damages Ki allows taking into account the impact of the characteristics and operational conditions of the gas pipeline upon the degree of danger of defects and damages;

4) The maximum indices of the possibility of identification of defects and damages $\mathbf{P_{d\text{-}op}}$ are determined. These values were determined based upon the characteristics of tools and equipment as well as the parameters of the gas pipeline.

Table 2.2

The maximum possibility of identification of defects and damages of gas pipelines - $\mathbf{P_{d\text{-}op}}$ max

Description of the defect section	The maximum possibility of identification of the defect, $P_{d\text{-}op}$ max
Penetrating defects	
High pressure	0.98
Medium pressure	0.95
Low pressure	0.90
Low pressure d< 1 mm	0.85
Damages of insulation coating	
Within the territory of an inhabited location	0.70
Within the territory of an inhabited locations where there are no connected engineering communications	0.75
Outside an inhabited location	0.80
The lack of adhesion along the whole length of a gas pipeline	0.98
Destruction of the insulation coating along the whole section (the transitional resistance below the critical value), as confirmed for several times by means of test pit surveys	0.99

5) The criteria for assessing the degree of danger of defects and damages of the gas pipeline **P(Ai)** are determined based upon the statistics data of the operation of the distribution gas pipeline systems of the JSC "Latvijas Gāze".

Table 2.3

The criteria for assessing the degree of danger of defects and damages of the gas pipeline P(Ai)

Defects and damages of the insulation coating		P (Ai)
Mechanical and structural	damages	0.005
	Unsatisfactory adhesion in a test pit	0.0015
	The lack of adhesion along the whole length of a section	0.070
	Transitional resistance in a test pit below the critical value	0.003
	Destruction of the insulation coating along the whole length of a section (transitional resistance below the critical value)	0.020
Defects and damages of the pipeline metal		
Corrosion	penetrating, diam. >1 mm	0.250
	penetrating, diam. <1 mm	0.150
	Local (ulcer, point)	0.060
	General, the remaining thickness of wall below 70%	0.035
	General, the remaining thickness of wall between 99 and 70%	0.020
Structural	The loss of the pipeline strength $\sigma_t / \sigma_i > 0.9$	0.500
	Rupture of a welded joint	0.250
	Defect of a welded joint with the loss of sealing d<1 mm	0.150

6) The assessment of the technical condition is carried out based upon the criteria of the marginal condition - the possibility of non-emerging of an accident equals 0.95. Based upon the results of the diagnostics of the gas pipeline, its condition can be assessed as technically compliant, operational or marginal.

Depending on the possibility of non-emerging of accidents, the following extensions of the term of safe operation of the gas pipeline were arrived at and are recommended within the Thesis:

$Hj_{after\ repair}$ (the first criterion of the marginal condition of the gas pipeline)

Table 2.4

Recommended extensions of lifetime

The possibility of non-emerging of accidents , $Hj_{after\ repair}$	Recommended term of safe operation, years, up to
$1.000 > Hj \geq 0.990$	10
$0.990 > Hj \geq 0.980$	9
$0.980 > Hj \geq 0.975$	8
$0.975 > Hj \geq 0.970$	7

Table 2.4 (continued)

0.970> Hj ≥ 0.967	6
0.967> Hj ≥ 0.964	5
0.964> Hj ≥ 0.960	4
0.960> Hj ≥ 0.955	3
0.955> Hj ≥ 0.950	2
Hj ≥ 0.950	1

The operation of a gas pipeline whose technical condition has been assessed as marginal (Hj < 0.950) should be discontinued (reconstruction or renovation of the gas pipeline should be carried out).

A gas pipeline whose technical condition has been assessed as operational (Hj > 0.95) is declared as good for operation if all the measures of ensuring safe operation are implemented.

When, despite the identification of defects, in compliance with the results of the diagnostics and assessments, the possibility of non-emerging of accidents until their elimination exceeds 0.95 and the gas pipeline may be declared as good for operation, these defects should be eliminated.

It is recommended to perform calculations either by means of a special purpose computer software or by adapting, for example, the software for assessment of gas pipelines OPTINET developed in Germany.

3. ANALYSIS OF THE RISK OF ACCIDENTS AND ITS ASSESSMENT AS REGARDS THE OPERATION OF UNDERGROUND STEEL GAS PIPELINES

The analysis of the risk of accidents related to the operation of the gas pipeline (hereinafter referred to as the "risk analysis") is performed if the possibility of non-emerging of accidents due to the technical condition of gas pipelines after the performed repair is below 0.95, i.e. if the gas pipeline is declared as technically compliant or good for operation. The risk analysis of accidents related to the operation of the gas pipeline, which is a constituent of the industrial safety management, includes a systematic use of all the available information for identification of danger and assessment of the risk of undesirable events. The risk of accidents related to operation (Re) may not exceed the admissible risk (Rp). **This is the second criterion of the marginal condition of the gas pipeline.**

The performance of the risk analysis includes the following major stages:

- identification of the admissible risk criterion;
- identification of the degree of danger;
- evaluation of the risk of accidents related to the operation of the gas pipeline;
- development of recommendations for minimisation of the risk of accidents.

In order to ensure the quality of the risk analysis, the values of relations of emerging and development of accidents of gas pipelines should be used.

The economic usefulness of the operation of the gas pipelines is used as the admissible risk criterion of an accident:

$$R_p = E_r - C_\Sigma , \qquad (3.1)$$

where $$E_l = C_{jo} - \frac{C_{jo}}{(1+E)^s} \qquad (3.2)$$

$$C_\Sigma = \sum_{t=0}^{S} \frac{I_s^t - I_j^t}{(1+E)^t} \qquad (3.3)$$

$$I_s^t = C_{td}^t + C_r^t + C_{te}^t , \qquad (3.4)$$

where E_l – the economy secured by continued operation, Ls;

C_Σ – total operational expenditure, Ls;

C_{jo} – construction costs of a new site, Ls;

I_j^t – annual costs of a new site, Ls;

t – the current year of the term extension (t = 1, 2, 3, ... s);

E – the discount norm (as set by the owner of the gas pipeline system, it is assumed equal to 0.1 within the Thesis);

I_s^t – total annual expenditure, Ls;

C_{td} – costs of technical diagnostics of the gas pipeline, Ls;

C_r – costs of the repair-renovation works, Ls;

C_{te} – current operational costs, Ls.

The costs of diagnostics, repair-renovation works, the current operational costs were determined on the basis of the data of the JSC "Latvijas Gāze" for years - 2012.

The major tasks of the stage of determining the danger factors include the identification and description of the sources of danger and the ways of their implementation (scenarios), In the course of identification, the most dangerous sections of the gas pipeline have to be identified as characterised by various parameters of the technical condition of the gas pipeline, in particular, the operational conditions, the presence of the sources of danger and the presence of sites that may be damaged in case of an accident.

According to the analysis of the statistics data regarding accidents and incidents of gas pipelines:

- leakages of natural gas from gas pipelines present the sources of danger;
- the major causes of emerging of sources of danger include mechanical damage, corrosion damage, defects of welded joints, manufacturing defects, etc.;
- the major consequences of gas leakages include the emissions to the atmosphere, ignition of leaking gas, entry of natural gas to premises and an eventual explosion after formation of the explosive mix of the natural gas and the air resulting in destruction of a building causing harm to people, property and environment.

The main tasks of the risk assessment stage include the following:

- identification of the frequency of emerging of the initiating and all the undesirable events;

- evaluation of the consequences of emerging of undesirable events;

- summary of the risk assessment.

In order to identify the frequency of undesirable events, it is recommended to use the statistics data regarding accidents and safety of the gas pipeline, simulation models of emerging of accidents, experts' conclusions, taking into account the opinion of the industry experts.

Generally, the possibility of the harm caused by accidents **I** has to be determined in compliance with the following formula:

$$I = \sum_{i=1}^{n} P_1 * I_1 = P_2 * + P_2 * I_2 + ... + P_n * I_n \ , \qquad (3.5)$$

where I – the total expected harm caused by an eventual accident, Ls;

P_1 – i. the possibility of emerging of an undesirable event in case of an accident;

l_1 – expected harm caused by the undesirable event, Ls;

n – the number of undesirable events (types of harm).

In order to assess the possibility of emerging of accidents due to the technical condition of the gas pipeline (corrosion damages, defects of welded joints, damages of the insulation coating, etc.), the results of the technical diagnostics obtained by means of application of formulae 3.1 and 3.2, should be used, and for the assessment of emerging of accidents due to other causes (mechanical damage, manufacturing defects, etc.) statistics should be used.

The analysis of consequences includes the analysis of the eventual impact upon people, property and (or) environment. In order to assess consequences, it is necessary to evaluate the physical impact of undesirable events (failures, technical equipment, destruction of buildings and constructions, fires, explosions, emissions, etc.), to identify the sites that might be subject to the harm.

In order to assess the risk of accidents, the available data of the JSC "Latvijas Gāze" regarding the harm caused by accidents of underground gas pipelines were used.

The general risk analysis of accidents related to the operation should reflect the safety condition of steel underground gas pipelines, taking into account the risk indices of all the undesirable events which may emerge during the operation of a gas pipeline:

$$R_e = L * T * \sum_{j=1}^{m} P_j \sum_{i=1}^{n} P_i * I_i , \qquad (3.6)$$

where $\mathbf{R_e}$ – the risk of an operation related accident;
L – the length of a gas pipeline, m;
T – extension of the term of operation, years;
m – number of causes behind accidents;
P_j – the possibility of emerging of an accident

$$P_j = \sum_{j=1}^{m} P_j = P_{ts} + P_{mb} + P_{rb} + P_c \text{,} \qquad (7.7)$$

where P_{ts}, P_{mb}, P_{rb}, P_c – the possibilities of emerging of accidents in relation to the technical condition, mechanical damage, manufacturing defect and other causes accordingly.

The indices of statistic possibility of accidents of gas pipelines per 1/km per year are presented in Table 3.1.

Table 3.1

Statistical possibilities of accidents of gas pipelines

The cause of the accident	Denomination	Index, per 1/ km - annually
Mechanical damage	P_{mb}	0.00200
Manufacturer's defect	P_{rb}	0.00010
Other	P_c	0.00030

The decision regarding the possibility of further operation of the gas pipeline is adopted based upon the comparison of the risk of accidents with the admissible risk (see Table 3.2). In compliance with the obtained result, operation is only admissible if the assurance regarding non-emerging of an accident is not below 0.95 and the risk of accidents related to the operation **(Re)** does not exceed the admissible risk **(Rp).**

Table 3.2

Adoption of a resolution regarding the possibility of operation of the gas pipeline

Technical condition	Risk of accident related to operation	Decision regarding further operation
Hj after repair ≥ 0.95	**Re ≤ Rp**	admissible
Hj after repair ≥ 0.95	**Re > Rp**	not admissible
Hj after repair < 0.95	**Re ≤ Rp**	not admissible
Hj after repair < 0.95	**Re > Rp**	not admissible

The methodology for assessment of the technical condition of distribution gas pipeline systems as developed within the Thesis was tested in practice at sections of gas pipelines at Bauska and Cēsis divisions of the JSC "Latvijas Gāze" that were selected on random basis and constructed within a single project and having the same operational pressure, the as-built documents compliant with the same requirements or construction installation passports, compliant analogous commissioning. The results of the testing of the methodology are summarised in Tables 3.3 and 3.4.

3.3. Table

Results of assessment of the technical condition of distribution gas pipeline systems and calculations (Bauska division)

Stage		I.	II.	III.	IV	V	VI	VII	VIII
Danger adjustment coefficient	**K_Σ**	1.212	1.212	1.270	1.212	1.273	1.273	1.273	1.273
Following diagnostics	**Hj**	0.93528	1	1	0.81815	0.98731	0.98731	0.94414	0.99102
After repair	**Hj**	0.98341	1	1	0.95106	0.99575	0.99454	0.97566	0.99182
Recomm. (years)		**8**	**10**	**10**	**1**	**10**	**10**	**7**	**10**
Admissible risk criterion	**R_p**	1623	242	792	-23	6130	6989	8202	6879
Accident risk (operational)	**R_e**	123	0	1	8	162	230	846	314
Conclusions		**$R_e < R_p$**	**$R_e < R_p$**	**$R_e < R_p$**	**$R_e > R_p$**	**$R_e < R_p$**	**$R_e < R_p$**	**$R_e < R_p$**	**$R_e < R_p$**

3.5. Table

Results of assessment of the technical condition of distribution gas pipeline systems and calculations
(Cēsis division)

Stage		I.	II.	III.	IV	V	VI	VII	VIII
Danger adjustment coefficient	K_Σ	1.155	1.155	1.155	1.270	1.155	1.270	1.212	1.270
Following diagnostics	**Hj**	0.9547	0.9884	0.9884	0.9686	0.9827	0.932	1	0.9748
After repair	**Hj**	0.9884	0.9971	0.9971	0.9920	0.9942	0.9704	1	0.9891
Recomm. (years)		**9**	**10**	**10**	**10**	**10**	**6**	**10**	**9**
Admissible risk criterion	R_p	73168	38120	80327	101315	52985	36415	43025	33421
Accident risk (operational)	R_e	476	73	195	519	129	615	50	248
Conclusions		$R_e < R_p$	$R_e < R_p$	$R_e < R_p$	$R_e < R_p$	$R_e < R_p$	$R_e < R_p$	$R_e < R_p$	$R_e < R_p$

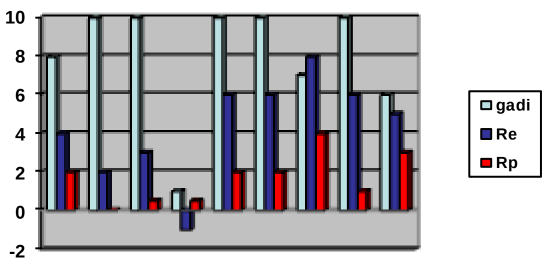


Fig. 3.1 Bauska division
(years of operation / R_e and R_p relation)

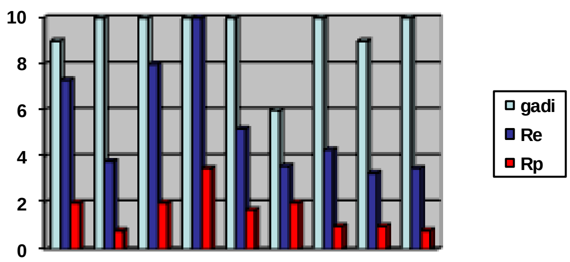


Fig. 3.2 Cēsis division
(years of operation/ R_e and R_p relation)

In compliance with Tables 3.4 and 3.5 and Figures 3.1 and 3.2 the following can be concluded:

1) the term of extension of the operational term of more than 50% of the selected sections of underground gas pipelines amounts to nine or ten years, which means that in these cases the mode of survey of gas pipelines, i.e. the periodicity of performance of complex survey by using tools, may be maintained unchanged;

2) for sections of gas pipelines where the extension of the operational term equals six or seven years, it is necessary to change the periodicity of performance of complex survey by using tools;

3) as regards the section of the underground gas pipeline at Bauska division where the permissible extension of the term of operation equals one year, repairs have to be implemented with no delay including the restoration of the insulation coating at places where defects were found and additional measures, i.e. the measures for improving the efficiency of electrical chemical protection.

As regards the gas pipelines where assuredness of non-emerging of accidents is at least 0.95 and the risk of accidents is below the admissible level, recommendations for securing safe operation and minimising the risk of accidents within the extension period were developed within the Thesis.

The recommendations for securing safe operation of the gas pipeline include the measures for minimising the risk based upon the results of the risk assessment and technical and (or) organisational by their nature, taking into account the costs of their implementation.

The recommendations include the following:

- the mode of survey of routes;
- measures of repair of gas pipelines including the restoration of the insulation coating at places where defects were found;
- the periodicity of performance of the survey by use of tools;
- measures for improving the efficiency of electrical chemical protection;
- measures for restoring the existing control measurement points and installation of new additional points;
- measures for strengthening the intersections with compatible engineering communications;
- measures for ensuring that the protection area of the gas pipeline is complied with;
- other measures that are required for ensuring safe operation of the gas pipeline.

CONCLUSIONS

1. In the territory of Latvia, as from the beginning of the 1960-ies until the beginning of the 1990-ies, distribution gas pipeline systems were constructed and operated in compliance with the standards of the former USSR by application of the materials, equipment, technologies and supervision methods typical for the period. It

was assumed that the conditional lifetime of gas pipelines equalled approximately 40 years, which is the term that has been exceeded for a certain proportion of gas pipelines by now and the number of such gas pipelines will increase during next years, resulting in the necessity of performing the assessment of the technical condition of such gas pipelines and adopting of operative decisions regarding the strengthening of supervision of such sites or suspension of operation of particularly unsafe sections of gas pipelines.

2. The methodology for identification of the technical condition of gas pipelines was developed within the Thesis, taking into account the works of assessment of the technical condition available within the operation of the Latvian distribution gas pipeline system and the accumulated engineering practice.

3. Within the framework of development of the Thesis, the examination of the technical condition of distribution gas pipelines was carried out on the basis of random selection by performing measurements and analysing obtained data.

4. The results of the Thesis attest that the technical condition of gas pipelines at different locations of installation of distribution gas pipeline systems with different soil and other construction and operational circumstances differs and requires different solutions.

5. Methods for assessment of the technical condition of gas pipelines based upon modern measurement and assessment technologies are proposed within the Thesis and approbated in practice.

6. During the research, modern measuring devices and equipment for gas pipelines were identified and tested, recommendations for their testing and assessment were provided.

7. The results of the Thesis can be used for amending Parts 1 and 2 of the National Standard LVS 445:2011 „Operation and technical servicing of natural gas distribution and Consumers' gas supply systems with a maximum operational pressure up to 1.6 MPa (16 bar)" and developing a new gas supply standard LV NS GS regarding the assessment of the technical condition of distribution gas pipelines.

8. In order to make calculations of the assessment of the technical condition of gas pipelines easier and to automate them, it is necessary to create a special purpose software on the basis of the algorithm for performance of diagnostics of steel underground gas pipelines as developed within the Thesis.

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