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Technical Condition Assessment of the System of Gas Distribution Pipelines

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Abstract. **The objective of technical condition assessment of the system of gas distribution pipelines is to obtain reliable information concerning the technical condition of the particular sites of the distribution system for successful planning of their maintenance and repair works, as well as for taking decisions on the extension of the operation time, reconstruction or elimination. The developed methodology provides for the development of the indices describing the sites of the system of gas distribution pipelines – the base factor (F_{ij}), the share of the score set for each factor (B_{ij}) in the group of the factor shares ($ß_i$), the shares of the group (a_i), based upon which, by means of applying the linear algorithm, the group calculation score (B_{ij}) and the integral score (F) are set and according to these scores the technical condition of the particular site is assessed and the conditions for its further operation are defined.**

Keywords: **the system of gas distribution pipelines, monitoring, classification, assessment.**

I. ASSESSMENT PRINCIPLES

At present, a particular methodology of technical condition assessment of gas distribution pipelines operating in Latvia is not applied [1,2,3]. Since the 1960s,when the first gas distribution pipelines were built, the assessment of their technical condition using a unified methodology has beena topical issue.

The methodology of technical condition assessment of the systems of gas distribution pipelines is based upon the systematic control (monitoring). The monitoring includes the following stages [5,9,10]:

- periodic supervision (survey, inspection);
- technical maintenance by applying special devices;
- technical diagnostics.

The information obtained asa result of the monitoring of technical condition of individual parameters of the system of gas pipelines, as well as the information contained in the project, construction and operational documentation is systematised and analysed in compliance with the methodology of technical condition assessment [14].

The information on the sites of the systems of distribution pipelines is collected during the whole period of their operation as entries in operational log-books, inspection protocols and acts on performed repairs, reports on technical diagnostics, etc. [11,13,15].

Technical condition assessment procedure of the systems of gas distribution pipelines can be dividedinto the following stages:

- collection of technical information;
- the conditional split of the gas pipeline in certain (characteristic) sections;
- assessment of acertain section by means of applying the score evaluation;
- setting the term of the technical diagnostics;
- setting the term of the further maintenance;
- the rating assessment of the technical condition of the site.

The graphic presentation of the stages of technical condition assessment of the systems of gas distribution pipelines is shown in Fig. 1.

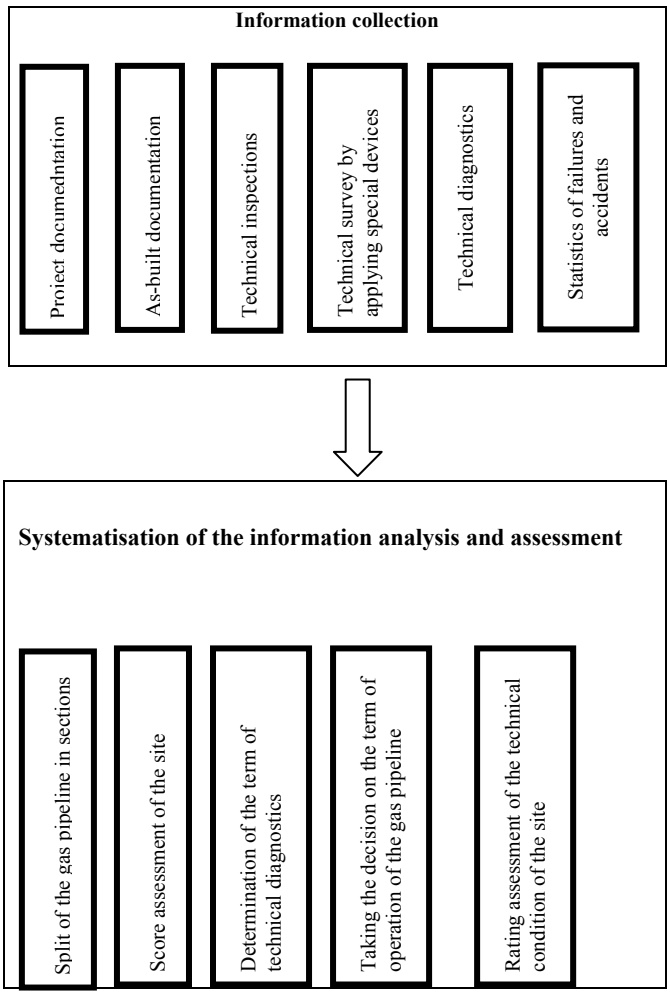

Fig. 1. The stages of technical condition assessment of the sites of the systems of gas distribution pipelines.

The result of the collection of information is the set of factors that describe the technical condition of the sites of the

gas pipeline. The list of the groups of factors obtained as a result of the information collection contains the information on the territorial gas division, readings of devices, diagnostic and laboratory measurements.

II. Classification of the Sections of the Gas Pipeline

It is recommended performing the technical condition assessment of gas pipelines within the borders of the sections of conditionally split gas pipelines [5,9,10].

For the purpose of setting the borders of such sections, it is necessary to carry out the classification of these sections. All the data describing the relevant gas pipeline can be found in the construction and operational documentation of the gas pipeline.

The splitting of the gas pipeline within the characteristic sections allows defining the borders of sections with similar characteristics for the purpose of establishing the technical condition of the gas pipeline.

The splitting of the gas pipeline in sections and the borders of these sections are determined taking into account the key factors describing the gas pipeline in compliance with Table 1.

TABLE I

FACTORS DESCRIBING THE GAS PIPELINE

Description of the gas pipeline	The material and the method of installation of the gas pipeline		
	Underground steel	Above ground steel	Underground PE
General	Construction project		
	The year of putting the gas pipeline into operation		
	Location (town, village, non-residential location)		
	Designed pressure		
Specific	Thickness of the wall of the pipeline	Thickness of the wall of the pipeline	SDR
	Type of insulation	-	Pipeline material
	Aggressiveness of the soil		Durability reserve coefficient
	Method of anti-corrosion protection		Welding technology
	The year of commissioning of the electrical chemical protection device		-

Within the borders of a defined (characteristic) section, all the characteristic parameters (for the steel gas pipeline: uniform project, the same year of commissioning, the location of installation, pressure, thickness of the walls, the type of insulation, the aggressiveness of the soil, the method of electrical chemical protection and the year of commissioning of the device) have to be equal.

III. The Quality Assessment of the Technical Condition of the Sections of the Gas Pipeline Based upon the Score Points

In comparison with the methodology described in standards and regulations of Russia [9,10] and Germany [5,6,7], the methods presented in the article for the purpose to define the intervals of the quantitative assessment of the technical condition of the sections of the gas pipeline include the score assessment that isapplied and based upon the system of factors (F_{ij}) and groups (G_i):

- the regional group (G_1) contains factors from F_{11} to F_{13};
- the information/ technical group (G_2) contains factors from F_{21} to F_{29} and $F_{2\text{-}17}$ (the year of commissioning, the operational pressure, diameter, the wall thickness, etc.);
- the device group (G_3) contains factors from F_{31} to F_{38} (leakages, insulation, leakage proof, etc.);
- the diagnostics group (G_4) contains factors from F_{41} to F_{49} and $F_{4\text{-}13}$ (the data obtained as a result of technical diagnostics);
- the laboratory group(G_5) contains factors from F_{51} to F_{54} (compliance of the pipe material and welded joints with the standard, etc.).

It is recommended performing the quantitative score assessment of the technical condition of the sections of the gas pipeline at least once every five years.

A certain meaning of the number, score B_{ij} within the range from 0 to 10 is allocated to each factor depending on the impact of the factor subject to assessment at a particular site. The value of the score B_{ij} is selected based upon a table, which is developed in compliance with the following form:

TABLE II

GRADE BIJ VALUE

Factor denomination (F_{nm})	Factor title	Steel, PE gas pipelines or GRI_{ie}	
		The actual condition of the factor	Score ***(B_{ij})***

Sample of the Fragment of Table2:

F_{25}	Diameter of the gas pipeline	above 350 mm	10
		from 250 to 350mm	8
		from 150 to 250 mm	4
		up to 150 mm	0
F_{26}	Thickness of the pipe wall	up to 5 mm	10
		from 5 to 10 mm	5
		above 10 mm	0

Step-by-step multiplication of each factor and the aggregate of the factors of each multiplication within each group produce the assessment score of each group B_i

$$B_i = \sum_{j=1}^{j} \beta_{ij} \cdot B_{ij} , \qquad (1)$$

Each group, in turn, is described by the share α_i based upon a table, which is developed in compliance with the following form:

TABLE III

GROUP PART CHARACTERIZATION

Group denomination (G_i)	Title of the group of factors	Factor denomination (F_{ij})	Factor title	Underground steel gas pipelines		
				Groupshare, a_i	The share of the factor within the group, $ß_j$	Mandatory character (Table 3)
1.	2.	3.	4.	5.	6.	7.

Sample of the Fragment of Table3:

1.	2.	3.	4.	5.	6.	7.
G_1	Gas units	F_{11}	Climate zone	0.05	0.3	1
		F_{12}	Seismicity		0.4	1
G_2	Information/technical	F_{21}	Operational time	0.20	0.12	1
		F_{22}	Operational pressure		0.08	1
G_3	Devices	F_{31}	Leakages via the basic material of the pipeline	0.3	0.4	1
		F_{32}	Leakages via the welding joint		0.2	1
G_4	Diagnostics	F_{41}	Defects of welded joints	0.45	0.14	2_1
		F_{42}	Mechanical damages of pipelines and fittings		0.05	2_1
		F_{43}	Pipeline corrosion		0.28	2_1
		....	……			
G_5	Laboratory	F_{51}	Calculation of test results			

By means of the step-by-step multiplication of each score of the group with its share and by summing up the obtained results we obtain the integral score assessment of the relevant section of the gas pipeline (site) – *F*

$$F = \sum_{i=1}^{i} \alpha_i \cdot B_i = \sum_{i=1}^{i} \alpha_i \cdot \sum_{j=1}^{j} \beta_{ij} \cdot B_{ij}, \qquad (2)$$

If complete information has not been obtained concerning individual factors the score – *F* has to be adjusted based upon the following formula:

$$F = \frac{F}{(1 - \sum_{i=1}^{m} \gamma_i)}, \qquad (3)$$

where γ_i – the complete i-th share of the non-estimable factor that is obtained by multiplying the share of the factor within the group with the share of the group containing the relevant factor.

The registration of the mandatory character of each factor is determined based upon the detailed division of the mandatory character in compliance with Table 4.

The obtained value of the score F has to be rounded down to one decimal.

TABLE IV

THE MANDATORY CHARACTER OF THE ASSESSMENT OF FACTORS

Denomination	The title of the group of factors
1	A factor whose control is mandatory. It has to be taken into account ineach assessment.
2_1	The corrosion condition and the insulation damages have to be determined inall dug-up manholes made during the operation. The importance of other factors is determined by performing the technical diagnostics.
2_2	A parameter that has to be surveyed as an additional parameter. The control has to be performed in case of leakages or ruptures caused asaresults of defects as well as upon reaching 50 years of operation.
2_3	A parameter that has to be surveyed as an additional parameter. The control has to be performed indug-up manholes after 50 years of operation (at least 1 dug manhole) or in case of leakages.
2_4	A parameter that has to be surveyed as an additional parameter. The control has to be performed in case of leakages or ruptures caused as a results of defects or once upon reaching 50 years of operation.
3	A parameter that has to be surveyed as an additional parameter. The control has to be performed according to certain methodology.

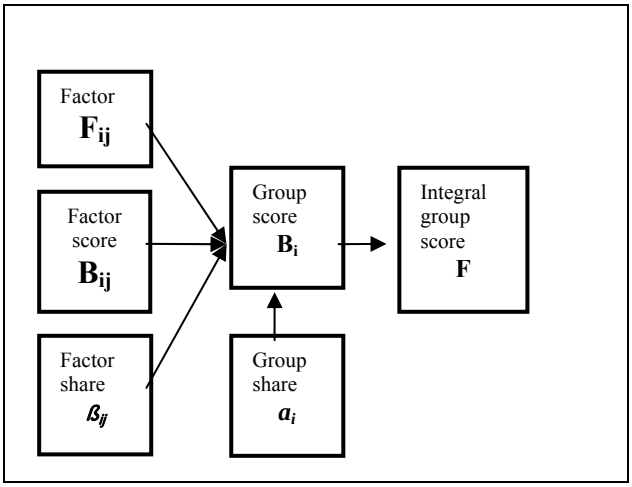

Fig. 2. The algorithm of determining the score of the section of the gas pipeline.

IV. Determining the Term of Technical Diagnostics and the Operation Time

The term of performing the technical diagnostics is set based upon the score assessment in compliance with Table 5.

For the sites where the score assessment exceeds 8 it is necessary to perform the assessment by an independent inspection institution concerning the conditions of further operation within a year.

TABLE V

THE TERM OF PERFORMING TECHNICAL DIAGNOSTICS

The quantitative assessment of the technical condition of the site of the gas distribution pipeline, *score points*	The term of performing technical diagnostics, *years*
From 0 to 4.0	5
From 4.1 to 5.0	4
From 5.1 to 6.0	3
From 6.1 to 7.0	2
From 7.1 to 8.0	1
From 8.1 to 10.0	The assessment of further operation has to be performed within a year

A sample table of the assessment of the technical condition of the systems of gas distribution pipelines:

TABLE VI

GAS DISTRIBUTION SYSTEM TECHNICAL CONDITION ASSESSMENT

Date of assessment	Site title	Section No.	Score (*F*)	Term of technical diagnostics	Further operation
05.06.2013	Bauska	I	1,7	2018	2023

The pilot project of the application of this methodology forthe assessment of the system of gas distribution pipelines was applied to evaluate nine sections of the gas distribution pipeline of Bauska Division of JSC "Latvijas Gāze" that were randomly selected (Table 7 and Fig. 3); these pipelines were constructed during the time period from 1970 to 1981.

Section	The year of construction	Pressure category	Diameter, mm	Length, m
I	1970	Medium	273	557
II	1970	Medium	219	635
III	1970	Medium	159	880
IV	1970	High	273	22
V	1971	Medium	159	625
VI	1974	Medium	159	389
VII	1976	High	273	174
VIII	1986	Medium	273	30
IX	1986	Medium	325	72
			Total:	3383

TABLE VII

JSC "LATVIJAS GĀZE" BAUSKA UNIT PIPELINE SECTIONS

The calculation results of the assessment of a single section are summarised in Protocol No.1.

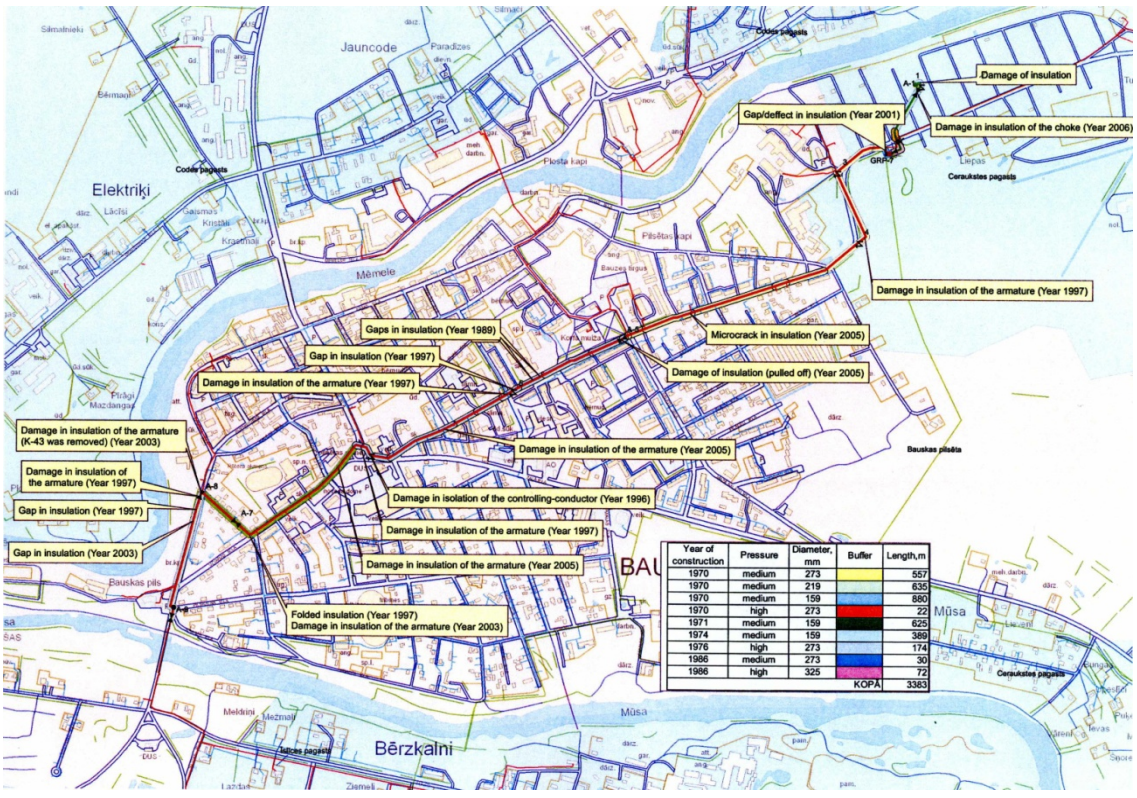

Fig. 3. Experiment.

PROTOCOL NO.1

SCORE ASSESSMENT OF A SECTION OF THE STEEL UNDERGROUND GAS PIPELINE

OPERATIONAL DIVISION: BAUSKA DIVISION

TITLE OF THE GAS PIPELINE (ADDRESS): THE SECTION OF THE GAS PIPELINE FROM BAUSKA GRS TO GRP NO.7

GAS PIPELINE SECTION NO.: NO.1

THE LENGTH OF THE GAS PIPELINE SECTION (KM): 0.174

THE LOCATION OF THE GAS PIPELINE DEPENDING ON THE LOCATION OF THE PIPES IN THE PLAN: CITY AND THE RESIDENTIAL PART OF THE INHABITED AREA

IMPORTANCE OF THE GAS PIPELINE: DISTRIBUTION GAS PIPELINE

THE ASSESSMENT SCORE OF THE SECTION: **1.7**

THE SHARE OF NOT ASSESSED FACTORS: 0.183

Factor denomination	Factor title	Factor condition	Score
F_{13}	Territories with special conditions	None	0
F_{21}	Operation time	From 20 to 40 years	4
F_{22}	Operating pressure, MPa	High, from 0.3 to 0.6 MPa	6
F_{23}	Primary control of welded joints, percentage	14	9
F_{24}	Location of the gas pipeline depending on the placement of the pipelines in the plan	Outside the city	5
F_{25}	Diameter of the gas pipeline, mm	From 250 to 350	8
F_{26}	Thickness of the pipe wall, mm	From 5 to 10	5
F_{27}	Insulation type	Particularly improved	0
F_{28}	Presence of EKA [electrical chemical protection]	Yes	0
F_{29}	Time without protection	0.139	14
$F_{2\text{-}10}$	Ground water level	Low	0
$F_{2\text{-}11}$	Crossings with water obstacles	None	0
$F_{2\text{-}12}$	Crossing with railway and tram rails	None	0
$F_{2\text{-}13}$	Crossing with the road	None	0
F_{31}	Leakages via the basic material of the pipeline, pcs/km	None	0
F_{32}	Leakages via the welding joint	None	0
F_{33}	Leakages via the flange joints and shut-off devices, pcs /km	It is not taken into account	0.021
F_{34}	Stray electric current	None	0
F_{35}	Protection of the gas pipeline, %	100	0
F_{36}	Insulation damages during the complex inspection	Up to 10 damages per 1 km	2
F_{41}	Defects of welded joints	None	0
F_{42}	Mechanical damages of pipelines and fittings	None	0
F_{43}	Pipeline corrosion	Negligible corrosion	4
F_{44}	Impact strength	It is not taken into account	0.05
F_{45}	Plasticity	It is not taken into account	0.05
F_{46}	Insulation defects indug-up manholes	It is not taken into account	0.041
F_{47}	Soil aggressiveness	Low	0
F_{48}	Bio-corrosion	It is not taken into account	0.023

The score assessment of all the sections is summarised in Table 8.

TABLE VIII
ALL PIPELINE SECTION ASSESSMENT IN GRADES

Section	I	II	III	IV	V	VI	VII	VIII	IX
F	1.41	1.32	1.23	1.32	1.59	1.58	1.55	1.58	1.52
$F_{correction}$	1.7	1.6	1.5	1.6	1.9	1.9	1.9	1.9	1.9

V. CONCLUSIONS

All the score points obtained during quantitative assessment of the whole gas distribution pipeline system have to be used to define time for the repeated technical diagnostics for the purpose of evaluating and stating the necessary repairs or other measures in order to improve safety of the system as well defining the priority of their performance. Firstly, the measures have to be taken for the group of unified type of objects having the maximum score points.

REFERENCES

[1] *LBN 242-02.Gāzessadales un lietotāju ārējie tīkli*, LBN, 2002
[2] *LVS 445:2011. Dabasgāzes sadales sistēmas unlietotāja dabasgāzes apgādes sistēmas ar maksimālo darbaspiedienu līdz 1,6 MPa (16 bar) ekspluatācija un tehniskā apkope*, Latvijas valsts standarts, 2011..
[3] *LVS 423:2002/A1:2009. Vispārīgās prasības tērauda pazemes gāzes vadu korozijaizsardzība*, Latvijas valsts standarts, 2009.
[4] I. Platais, P. Graudiņš, *Gāzapgāde. 2.daļa. Dabasgāzes gāzapgādes sistēmu izveide, ierīkošana un apkalpe*. Rīga: RTU izdevniecība, 2008.
[5] *DVGW Technische Regel G 401:1999. Entscheidungshilfenfür die Rehabilitation von Gasverteilungsnetzen*, Germany, 1999.
[6] H. Holtschulte, "Erfassung und Bewertung von technischenDaten und LeistungenalsEntscheidungs-hilfenfürUnterhaltungsmaßnahmen in Rohrnetzen", WAT'80, Aachen, DVGW-SchriftenreiheWasser Nr.23.
[7] P. Hofer, *Bestimmung der Erneuerungsraten für Gasrohrnetzeim Rahmen der strategischen Langzeitplanung*. Gwf Gas/Erdgas 1995, p. 136.
[8] DVGW Technische Regel G 412 (A):2010. Kathodischer Korrosionsschutz (KKS) von erdverlegten Gasverteilungsnetzen und Gasverteilungsleitungen.
[9] *GAZPROM HH-2005* Instrukcija po diagnostirovaniju tehnicheskogo sostojanija stal'nyh podzemnyh gazoprovodov, Moskva, 2005.
[10] *RD 12-411-01* Instrukcija po diagnostirovaniju tehnicheskogo sostojanija stal'nyh podzemnyh gazoprovodov, Moskva, 2010.
[11] J.Marean, M.Adamo, *Natural gas pipeline assessment.* Gas technology institute, Illinois, 2012.
[12] John A.Beavers, Neil G.Thompson *Externsl Corrosion of Oil and Natural Gas Pipeline,* .USA, 2006
[13] P.Burgherr, S.Hirchberg, *Comperative Assessment of Natural Gas Accident Risks.* Paul Scherrer Institut, 2005
[14] V.V.Kljuev, Nerazrushajushhij kontrol' i diagnostika. Asociacja OKO: Moskva, 2000.
[15] Hamid Reza Jafari *Applying Indexing Method to Gas Pipeline Risk Assessment by Using GIS: ACase Study in Savadkooh, North of Iran*. University of Teheran, 2011

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