EXTENSION OF SERVICE LIFE OF GAS MAINS: CONCEPTION, INVESTIGATIONS AND PRACTICAL RESULTS

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ABSTRACT

A new problem related to the extension of service life and analysis of safe operation of long-distance gas pipelines is highlighted. A complex of analytical, calculation and instrumental investigations have been carried out. These investigations have allowed to develop appropriate scientific-methodical documentation.

An express method for predicting service life that enables, depending on executive documentation, to obtain an approximate assessment of technical status have been developed. This assessment allows to schedule dates and content of inspection and repair works.

A system of setting periods of safe operation including amortization and base periods and period of operation by technical status and final period is suggested on the basis of the above developments.
TABLE OF CONTENTS

1. Background
2. Concept of service life extension
3. Research work on extending service life
4. Substantiation of safe operating period

Results and conclusion
1 BACKGROUND

The increase in gas pipelines age in the world gas industry resulted in a new problem of investigating their integrity, extension of service life and forecast of technical condition. According to western terminology, this concerns pipeline integrity management system that urges to provide functioning and control of gas-transmission systems with regard to economic expediency or in compliance with purpose. The main element of this system is service life analysis of gas mains.

Under the present conditions and based on a complex of factors, including technical status, supply volumes, development prospects and gas transmission efficiency, the gas industry puts forward a new target of the period of safety operation of gas transmission system and its main long-distance gas pipelines. If only depreciable life of gas pipeline have been considered in previous years, then under the market conditions it is necessary to consider all aspects remembering that the main task that includes the provision of safety operation and reliable gas supply to end users remains.

From the above it is necessary to develop methodical documents embracing the assessment of operational service life, concept and method of extending this service life and the prediction of gas pipeline technical status with allowance made for capital repair and reconstruction. This statement has become possible after extensive and long study and a complex of practical works on diagnostic service and extension of service life gas pipelines worked out their depreciable life.

Paper objective is to formulate a conception of service life extension and to state methodology and engineering developments on complex estimation of service life on the basis of which one can make a forecast of technical condition of gas mains.

2 CONCEPT OF SERVICE LIFE EXTENSION

When developing this conception, it is necessary to consider that the problem of service life estimation includes several aspects: formal aspect on the basis of which gas pipelines that worked out their depreciable life must extent service life; scientific aspect in which one must consider gas pipelines as extended repairable systems (rehabilitation of separate sections) being operated under varying loads in different climatic zones and, generally, under a single system combined by operating practices; engineering aspect which includes a complex of design works on analysis of technical condition of gas pipeline having different defects.

Conception of estimation and extension of gas pipeline service life includes steps as follows:

1. Analysis of initial information, its processing, accumulation and selection of potentially dangerous sections.
2. Instrumental step – NDT inspection of potentially dangerous sections and, if required, monitoring of these sections depending on defect type (thinning, caverns, dents, cracks, etc.).
3. Estimation step – estimation of defect risk and operability of potentially dangerous section. Special attention should be paid at ranking of defects by a risk level and estimation of probability of defect location on a pipeline section under inspection.
4. Express-analysis of pipeline service life to the next inspection.
5. Preparation of expert appraisal for gas pipeline operator with indication of service life extension period (for gas pipeline no less than 5 years).

Besides, the conception includes methodology for extending service life of both piggable and unpiggable gas pipelines (Fig. 2).

The Figure 2 illustrates that in case when there is no possibility to apply pigging inspection, the main attention should be paid the analysis of technical status of danger sections. Their selection is to be accomplished according to a specially developed “Instruction on extending safety operational life of gas mains (GM)".
Fig. 1. Concept of securing operational capability and service life of Gazprom's gas pipelines

GAS MAIN IS PREPARED FOR PIGGING
- Analysis of risk of actually detected defects
- Evaluation of sources of mechanochemical wear and out-of-design mechanical impacts
- Evaluation of residual life
- Prediction of serviceability and operational risks
- Ranking of defected sections and planning of a system of GM maintenance (repair and rehabilitation)
- Planning of a system of diagnostic inspection (pigging)

GAS MAIN IS NOT PREPARED FOR PIGGING
- Analysis of operation history, location of danger sections (DS)
- Diagnostic of DS technical conditions
- Calculation-experimental assessment of actual technical conditions
- Evaluation of DS MG life residue
- Prediction of serviceability and operational risks on the basis of sampling study
- Prediction of parameters of a system of GM maintenance (repair and rehabilitation)
- Prediction of diagnostic inspection

EVALUATION OF THE EFFICIENCY OF MAINTENANCE STRATEGY
MAKING OF MANAGEMENT DECISION ON EXTENDING OPERATIONAL SAFETY SERVICE LIFE

Fig. 2. Difference between the methodologies of extending safety operational life of gas mains
By the analysis results the following candidate solutions are assumed:

- Continuation of operation without changing gas pressure schedule;
- Operation under decreased gas pressure;
- Termination of operation for rehabilitation and replacement of defected section.

3 RESEARCH WORK ON EXTENDING SERVICE LIFE

As one can see from the above conception, a sufficient place in solving the problem of gas pipeline service life extension is filled with, together with instrumental works, evaluation of risk of detected defects and prediction of their development. For their realization a complex of calculations has been performed. The calculations included analysis of each typical defect: thinning, elongation, pitting, dents, cracks, out-of-design positions, etc. The results of these investigations are given in normative documents, which permit to refine the evaluation of serviceability of pipeline sections having different defects. The algorithm of decision making for a gas pipeline section with dents can be cited as an example.

For the defects of corrugation (dent) type there are three possible variants of decision-making depending on a level of values of controllable parameters:

- “to leave” – operation of a gas pipeline section under the former operating conditions. A defect with existing parameters is not dangerous from the viewpoint of pipeline strength;
- “to band” – operation of gas pipeline section under consideration is possible only after force banding of the defect with willing the space between pipeline and band with special material;
- “to cut out” – a defected pipe section is to be cut out and replaced with a new pipe section.

Recommended solutions depending on permissible values of checked parameters of defects are given in Table below:

<table>
<thead>
<tr>
<th>Longitudinal direction</th>
<th>Hoop direction</th>
<th>Defect depth</th>
<th>Recommended solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual deformation</td>
<td>Increment deformation</td>
<td>Residual deformation</td>
<td>Increment deformation</td>
</tr>
<tr>
<td>0.030</td>
<td>0.0035</td>
<td>0.020</td>
<td>0.0035</td>
</tr>
<tr>
<td>0.0301-0.050</td>
<td>0.0035-0.005</td>
<td>0.0201-0.035</td>
<td>0.00361-0.005</td>
</tr>
<tr>
<td>&gt;0.050</td>
<td>&gt; 0.005</td>
<td>&gt; 0.035</td>
<td>&gt; 0.005</td>
</tr>
</tbody>
</table>

The investigations included also a solution of problem on reliability and representativeness of inspection carried out. In the process of inspecting technical status of gas pipeline sections engineers face a natural question, namely what is the probability of missing a dangerous defect.

To answer this question specialists from VNIIGAZ have developed a special method, the main aspects of which include:

- An approximate list of potentially dangerous sections (PDS) of a specific gas pipeline drawn up on the basis of initial information;
- Venn diagram, in which a general PDS family with dangerous defects, is build on the basis of finite sets theory;
- A minimum number of PDS, which it is necessary to analyze in order that the probability of defect missing does not exceed a permissible level (e.g. this probability should not be higher than a permissible capability of defect detection by instrumental methods, for example, during pig running) is set on the basis of methods of conventional probabilities.
From the above one can see that to extend service life a sufficient complex of instrumental and calculation works are required. At the same time operational service must have operative qualitative information about potentially dangerous sections, technical condition and lifetime of gas pipelines. In this connection the development of express-method is of practical importance.

Schematic diagram of express-method for predicting gas pipeline service life is given in Fig. 3. This method includes, on numerical score, two blocks that characterize reliability, from the one hand, and operational risk, from the other hand. This method includes, on numerical score, two blocks that characterize reliability, from the one hand, and operational risk, from the other hand. The reliability block includes condition of metal, weld and coating, a level of deformation, cathodic protection, etc. The operational risk block includes gas pipeline category, its technological parameters, the presence of other gas pipelines in technological corridor, a number of potentially dangerous sections, etc. These parameters and factors are assessed on a score basis. Comparison of these blocks makes it possible to obtain an integral estimation of technical status of this particular gas pipeline and to make decision on its further operation. For example, the above express methods envisages the evaluation of approximate maintenance schedules, urgent repair content and thus allows to extent service life.

The above methods have been applied for the last three years on different gas pipelines, over 8 thousand km in length, that allowed to extend service life of these gas pipelines by 7-15 years. The pipelines belong to the enterprises as follows: Mostransgaz, Lentransgaz, Severgazprom, Permtransfaz, Kubangazprom, etc.

4 SUBSTANTIATION OF SAFE OPERATING PERIOD

Substantiation of gas pipeline safe operating periods is of great importance for the current operation and prospects for further development of gas transmission system. Based on the experience of extensive research and engineering activity specific periods of operating have been determined, with each period including definite types and volumes of work. Figure 4 illustrates a schematic diagram of gas pipeline safe operating periods, the main of which are as follows:
• Depreciation: from commission to 33 years (25 years)
• Base: from commission to 40-45 years
• Extended: from 45 to 60 years
• Final (liquidation): over 60 years

Depreciation operating period is characterized by depreciation service life - a parameter that does not depend on actual technical status of a gas pipeline. The parameter is defined by the excepted norms and periods of amortized deduction to equipment and structures according to the current legislation on financial and economic activity. Depreciation service life specifies an operating period during which maintenance is accomplished partially or completely on the basis of tax-free amortized deductions. Depreciation service life is not related to technical status or physical pipe and structural component service life.
Prediction of optimal depreciation service life is to be carried out with the help of models. These models should include general economic factors, e.g. a factor of financial risk of gas main operation due to unstable gas supply in specified volumes together with technical parameters and economic structure of operating expenses. At present for active gas mains depreciation service life is revised from 33 to 25 years.

**Base operating period** is a technically substantiated service life, which is defined by actual or predicted technical status of a gas pipeline, as well as by technical (instrumental) parameters of maintenance system. The experience of long operation and evaluation of Gazprom's gas transmission system service life show that 40 – 45 years can be taken as a base period for Russian gas pipelines. This value is recommended to take as an assigned service life during designing new gas mains.

**Operating period on technical status** includes a period that is based on the procedure of extending safe operating period. This period includes a complex estimation of technical status. This period can be characterized as a period of operation by an actual technical status and can amount to 45 – 60 years.

After reaching a total calendar lifelength of 55 – 60 years gas pipelines enter a final operating period. This period is characterized by an increase in base metal and weld ageing resulted in increasing a number of defects and fatigue cracks. In this case the probability of coming of limiting state by mechanical criteria of failure or by economical criteria of Opex increase on maintaining serviceability rises essentially. To make a decision on the possibility of extending safe operation in a final phase a complete inspection of pipe metal, welds, fittings and valves, as well as the use of new calculation criteria on fatigue limit are required.

Figure 5 illustrates the zones of safe operation of gas pipeline with defects for different periods of its operation. For a period below 45 years the well-known curve that limits a zone of safe operation and based on large-scale tests of defected pipes both in Russia and USA (Battel Institute) is applied.

![Safe operation zone](image)

$$K_h = \frac{\sigma_{\text{nom}}}{R_s} \quad \text{load factor}; \quad K_n \quad \text{failure factor that considers a defect size}$$

**Fig. 5. Safe operation zone vs. defect size and service life**
For a period of 45-60 years this zone decreases due to some reduction in pipe metal strength.

For a final period (over 60 years) a zone of safe operation is defined by metal fatigue processes. In this case a determining factor is durability that decreases efficiently sizes of permissible defects on gas pipelines.

An important moment in making decision on safe operating period extension is economic expediency of gas pipeline rehabilitation strategy with regard to construction of new gas pipeline. Otherwise, the decision on gas pipeline liquidation and utilization is made. This situation is shown in Figure 6 where the dependence between expenses and gas pipeline service life is illustrated. It is clear that if during the period between 30 and 60 years maintenance costs are growing linearly, then in final stage of operation (60 and more years) maintenance costs are growing exponentially. This explained by the growth of repair volumes and the necessity in inspecting practically all pipeline sections. It is obvious that after 60-year operation of gas pipeline it is necessary to perform its economic analysis and to evaluate technical status before making decision on extending its operation or liquidating. This is the illustration of the concept of pipeline operation vs. its function.

**Fig. 6. Termination of gas pipeline operation (liquidation) due to technical status**
RESULTS AND CONCLUSION

1. Scientific-methodical support for extending service life and safe operating period of gas pipelines including the concept and algorithm of decision-making on extending service life, express method of service life prediction and method of defining safe operating period.

2. The use of development data has allowed to operational departments and engineering companies to accomplish practical works on gas pipelines and to extend their service life by 7-15 years.

3. Specialists have received the possibility to control repair work volumes and minimize maintenance costs thanks to performing priority works on service life extension the costs on which is lower by several times compared with the repair costs.

4. There is a system of complex analysis and prediction of technical status and evaluation of service life of gas mains that provides reliable and safe operation of gas-transmission systems.