Processing and Analysis of In-Line Inspection Results for Selective Repair of Main Gas Pipelines with Account of Technogenic Risks

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Abstract

To achieve the system reliability of the linear part (LP) of main gas pipelines (MG), effective methods of their inspection are needed, which, first of all, include in-line inspection (ILI). During planning maintenance and repair of LP MG with account of the technogenic risk of accidents, it is required to process a large amount of data both for the defects identified on the pipes during the ILI, and for the geoinformation data on the objects of the MG environment. In the report discusses the problems dealing with accounting the results of ILI in assessing the frequency of accidents for the LP MG and shows how the usage of modern information technologies allows to support the adoption of rational management decisions when identifying priority selective repair potentially dangerous sections LP MG.

1 Accident Rate on the main gas pipelines of Russia

Recently, much has been said about the global "reformatting" of the world market for gas supplies due to its transportation in liquefied state, but the pipeline method in Russia remains the most common.

MG are one of the most environmentally friendly types of hydrocarbon transportation, but the LP MG sites located between valves (MKU) are represent fire and explosion hazardous tanks, and their emergency destruction can lead not only to serious economic losses, but also to death of people, because of mechanical and thermal influences from explosion.

The accident rate on LP MG in Russia dealing with the fact that the majority number of MG were built in 70-80 years of the last century. So far average "age" of MG approaches 25 years, and 15% from them already developed the normative endurance which is 33 years [1].

However, after 30 or even 40 years of exploitation, some areas of MG may not be subject to corrosion and damage. Therefore the modern and efficient methods of inspection of MG, both the subsequent maintenance and selective repair on certain sites are capable to increase a serviceable life of 70% of MG up to 45-50 years. Application of such approach will allow to save many hundreds of billions of rubles [1], in comparison with the complete overhauling of MG.

According to annual reports Federal Environmental, Industrial and Nuclear Supervision Service (ROSTEKHNAZOR) [2] the total length of LP MG in Russia increased from 160 to nearly 190 thousand km from 2004 to 2016. The number of accidents at the same period of time reduced from 20-30 till 8-10 accidents in a year, and the relative frequency of accidents a year decreased by 1000 km almost by 4-5 times (from 0,18 till 0,04).

Such decrease in accident rate, first of all, dealing with thes introduction of ILI on MG of Russia. If to accept quite authentic assumption that in recent years increase in a share of sites of LP MG of the surveyed ILI happened in all gas transmission companies approximately identical rates and to impose the schedule of decrease by years of percent of sites of LP MG of uninspected ILI on one of gas transportation subsidiaries (GTO) of PJSC «Gazprom» on statistical points of values of relative frequency of accidents on 1000 km per year according to annual reports ROSTEKHNAZOR [2], then it is possible to see (see the figure 1) rather significant correlation.

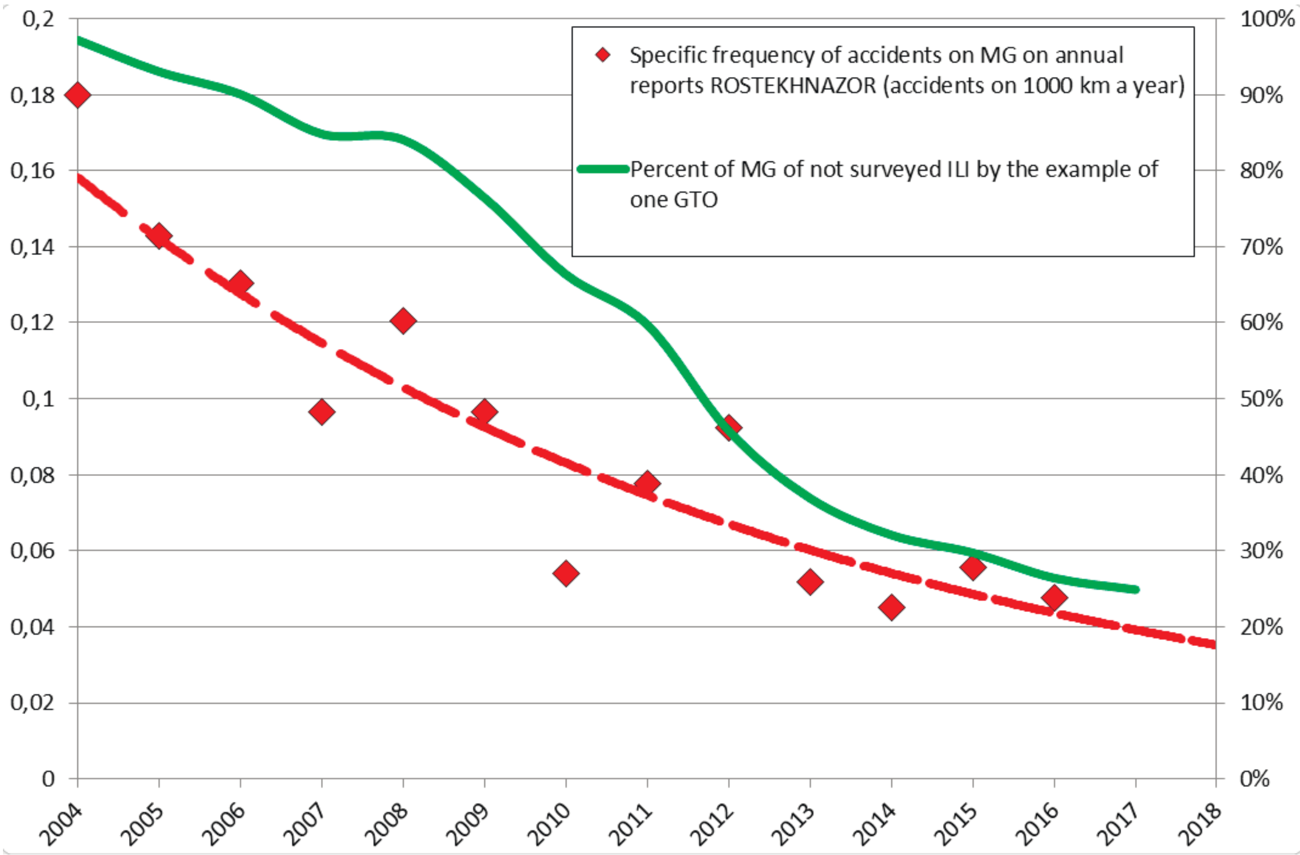

Figure 1: Specific frequency of accidents at MG Russia in comparison with the implementation of the ILI by the example of one GTO

The first ILI in this GTO were carried out in 2003 - 2005. From the total length of LP MG now ILI is captured by nearly 80%. On certain sites of LP MG, ILI it is carried out already 4 and even 5 times. And MG with pipes with a diameter over 500 mm are surveyed by ILI almost for 100%.

2 The methodology for assessing the technogenic risks of accidents on main gas pipelines

2.1 Normative documents of PJSC «Gazprom» on the quantitative assessment and the analysis of risk

The System of Management of Technical Condition and Integrity (SUTSC) of LP MG [3] is created and is improved in PJSC «Gazprom» due to ensure stable gas transportation. The methodological basis of the SUTSC is the normative documents (ND) for assessing the technical condition and risk analysis for hazardous production facilities of gas transportation companies [4-7].

According to ND [4] program of diagnostics, maintenance and repair of LP MG have to be based not only on indicators of integrity [5], but also on the results of the quantitative risk assessment of accidents which includes assessment of an expected frequency of accidents [6], and sizes of potentially possible damage from accident [7].

According to statistical data ROSTEKHNAZOR [2] for the last ten years at accidents on LP MG it was not recorded any death or the victim. In cases where an accident at MG cannot cause significant damage to human life and health, it is also necessary to take into account the damage to production and the costs of liquidation of the accident, damage to the property of third parties, as well as environmental damage when assessing the value of potential damage. At the same time, the value of man-made damage, and, consequently, man-made risk, is primarily determined by the presence of certain objects of the environment along the MG route

It is quite apparent that at identical probability (frequency) of accident, the priority of repair should be given to that site for which destruction or elimination of objects of an environment (buildings, processing equipment, roads, forests, agricultural grounds etc), in case of accident can result in the greatest damage.

According to ND [4] justification of repair and/or reconstruction of the site of LP MG the index of specific technogenic risk counted as the multiplication of an expected frequency of accidents (per a year) and damage sizes at accident (RUB).

According to statistical data ROSTEKHNAZOR [2] from 2009 to 2016 the common damage from accidents on LP MG of Russia did not exceed 400 million rubles per year, and relative damage - 2 thousand rubles on one km per year. And the damage from one accident grew to about 30 million rubles.

According to ND [4] in cases when the quantitative assessment of relative technogenic risk for the analyzed site of LP MG exceeds 15 000 rub / (km · year), the risk is considered inadmissible, and it obliges gas transmission companies to realize actions for decrease as probabilities of accidents (repair or replacement of the defect pipes), and possible damage (a conclusion of objects of an environment out of limits of a security zone). If the relative risk is less than 15 000 rub / (km · year), but it is more than 2 000 rub / (km · year), the technogenic risk is considered acceptable that assumes necessary of scheduling and realization of actions for technical diagnosing of the site of LP MG within planning period and also the actions directed to decrease in possible damage. The relative risk is less than 2 000 rub / (km · year) are considered slight (admissible).

In the presence of estimates of probability (expected frequency) of accidents for the considered site of LP MG which can be received on ND [6], the algorithm of assessment of technogenic risk of accident according to ND [7] includes the following main stages:

- definition of calculated scenarios of accidents (the fire in a ditch, struyevy it is ardent, a dispelling of a low-speed loop of gas and a dispelling of two streams gas);
- assessment of the conditional probabilities of implementation of calculated scenarios of accidents on a tree of events;
- calculation of intensity, totals and duration of emissions of natural gas;
- calculation of distribution of the striking factors of accidents (chips of the destroyed MG, an air wave of compression, gas contamination and thermal radiation from the fire);
- calculation of number of victims among the population and personnel from accidents;
- calculation of the number of destroyed and damaged property and the natural environment from accidents;
- calculation of damage from accidents;
- calculation of potential, individual, collective and social risks from accidents;
- calculation of the expected annual damage and technogenic risk taking into account frequencies of emergence of accidents.

To assess the above-described algorithm of technogenic risk asessment in the SUTSC of LP MG, it is necessary to process a colossally large amount of initial data, an approximate list of which is given in the ND [8, Annex A].

This list includes more than seventy tables reflecting the technological characteristics of the LP MG section, the actual layout of the pipes, the location of compressor stations, information on gas pipeline crossings through water barriers, railways, roads, information about parallel gas pipelines, roads and Railways, a list of gas pipeline sections passing near industrial facilities, settlements, information about the climatic region, data of operational documentation, etc. Moreover, each of the above tables contains several dozen columns and, in some cases, several hundred rows, and besides all the tables should be compiled for each pipeline section.

Besides it is necessary to have detailed topographical and cartographical information including a flow diagram of MG, plans of routes of the main gas pipelines and the description of objects of a social, economic and production and natural environment.

Collecting and formalization of all listed above input data is rather laborious task, but following ND [4] it is quite possible to solve. Procedures of the quantitative assessment and the analysis of technogenic risk of operation of hazardous production facilities of transport of gas in details are also unambiguously registered in ND [7].

However with results of ILI many questions arise with assessment of probability (expected frequency) of accidents for the considered site of LP MG.

2.2 The methodology for assessing the expected frequency of accidents, taking into account the results of the ILI

At assessment of probability (expected frequency) of accidents ND [7] recommends to use the techniques based on the principle of adjustment of average specific frequency of accidents on gas pipelines by means of the system of the coefficients and/or mark estimates considering influence, inadequate on different sections of routes MG, on the gas pipeline of heterogeneous factors and to preferred application the Technique of expert assessment of an expected frequency of accidents in the section of the pipeline (MEHOCHAGaz) developed in LLC «Gazprom VNIIGAZ» as a part of ND [6].

The Central postulate of MEHOCHAGaz is that for the considered n-th section of the gas pipeline the value of the total coefficient of influence of k_{vl} is determined, showing how many times the expected specific frequency of accidents in this section λ_n differs from the average specific frequency of accidents λ_{sr}.

According to MEHOCHAGaz, the expected relative frequency of accidents (per 1000 km per year) on the n-th section of the route is determined by the formula:

$$\lambda_n = \lambda_{sr} \cdot k_{vl} = \lambda_{sr} \cdot k_{reg} \cdot k_{vozr} \cdot k_{kat} \frac{\sum_i^I \sum_j^{J(i)} p_i \cdot q_{ij} \cdot B_{ij}}{B_{sr} = const}, \tag{1}$$

где k_{vl}, k_{reg}, k_{vozr}, и k_{kat} - the nondimensional coefficients of influence, respectively: common, regional, "age" and "category".

B_{sr} - mark assessment of the hypothetical average section of the pipeline in which accident rate corresponds λ_{sr};

$0 \le B_{ij} \le 10$ - mark assessment observed on the analyzed site of MG of "natural" value of a factor of influence of F_{ij} in a 10-mark scale, defined by the corresponding mark and factor function $B_{ij} = \varphi_{ij} (F_{ij})$;

p_i и q_{ij} - shares (weights) of the *i*-th group of factors and the *j*-th factor in the *i*-th group, respectively;

I и $J(i)$ - accordingly: the number of calculated groups of factors of influence and the number of factors of influence in the *i*-th group.

Results of ILI in MEHOCHAGaz are considered through such factors of influence as: a Stress Corrosion Cracking (SCC), external corrosion (without SCC), quality of production of pipes, installation and construction works and natural influences (results of ILI regarding defects of geometry, joint welds and mechanical damage). Possible mechanical influence of the third parties and level of technical operation is also considered.

Average relative frequency of accidents λ_{sr} for the onshore section of the gas pipeline with results of ILI according to ND [6] has to be accepted equal 0,2 (accidents on 1000 km per year) that badly corresponds to the relevant statistical data provided on the figure 1. Though such recommendations of ND [6] are quite explainable as MEHOCHAGaz was developed at the beginning of 2000, and apparently in 2004 the average relative frequency of accidents λ_{sr} for LP MG in Russia really was size of the figure 1 about 0,18. However today usage of value of λ_{cp}, that regulated in ND [6] is hardly expedient as at the same time estimates of technogenic risk of accidents on sites of LP MG, most likely, will be overestimated by 4-5 times that can inevitably lead to inaccurate administrative decisions when scheduling maintenance and repair of MG.

Though at the choice of a priority of repair of this or that site of LCh MG absolute values of estimates of risk have no basic value as at their comparison only the relative values are important (it is more, it is less and in how many times).

The undoubted advantage of MEHOCHAGaz is that due to the linear summation of score estimates of B_{ij} the dependence (1) can be presented in the form:

$$\lambda_n = \sum_{i}^{I} \sum_{j}^{J(i)} \lambda_{ij} \,, \tag{2}$$

where $\lambda_{ij} = \lambda_{sr} \cdot k_{reg} \cdot k_{vozr} \cdot k_{kat} \dfrac{p_i \cdot q_{ij} \cdot B_{ij}}{B_{sr} = const}$, (3)

expresses the relative specific frequency of accidents (per 1000 km per year) on the n-th section of the route associated with each individual factor of influence F_{ij}.

Representation of dependence (1) in the form of (2) gives the opportunity to simplify a problem of splitting the LP MG into certain calculated sites as allows to determine λ_n by each of factors of influence of F_{ij} separately, taking into account its significance and the changing along the MG.

Changes along the MG of numerical values of the factors of influence considering possible mechanical influence of the third parties and level of technical operation have the fixed discrete character or are the monotonic. Therefore, for calculation of the expected specific frequency of accidents for these factors of influence there is enough splitting LP MG into calculated sites within which their natural values remain constants, and at assessment of the expected specific frequency of accidents on them within MEHOCHAGaz there are no questions.

Provided that according to MEHOCHAGaz the sum of all weight coefficients $\sum_{i}^{I} p_i \sum_{j}^{J(i)} q_{ij} = 1{,}00$, the influence factors considering results of VTD are most significant as the sum of their weight coefficients is equal 0,81 ($p_3 = 0{,}37$ and $q_{31} = 1{,}00$ for SCC, $p_2 = 0{,}06$ и $q_{21} = 1{,}00$ for external corrosion, $p_{456} = 0{,}38$ и $q_{456} = 1{,}00$ for defects of geometry, joint welds and mechanical damage), i.e. results of ILI more than for 80% determine the size of the expected relative frequency of accidents.

And with the influence factors considering results of ILI within MEHOCHAGaz there is a number of problems which reason that circumstance that any defect identified during ILI has strictly particular coordinate but its length is only several millimeters, or it is not specified in the report on ILI at all (the value zero registers).

The fact, first of all, that any score according to the ND [6] should not exceed 10 points, and in the MEHOCHAGaz says literally the following: - " the detection of a dangerous defect on one kilometer of the analyzed potentially hazardous area (PHA) immediately displays the score at the worst value of 10 points». If this dangerous defect is SCC, then k_{reg} = 0,81 (the central region), k_{vozr} = *1,5* (a serviceable life more than 30 years), k_{kat} = 0,9 (category pipes III) and B_{sr} = 1,97 (for the onshore section of the gas pipeline with results of ILI) the expected relative frequency of accidents (on 1000 km per year) will be

$$\lambda_{31} = \lambda_{sr} \cdot k_{reg} \cdot k_{vozr} \cdot k_{kat} \cdot \frac{p_3 \cdot q_{31} \cdot 10}{1{,}97} = 0{,}2 \cdot 0{,}81 \cdot 1{,}5 \cdot 0{,}9 \cdot \frac{0{,}37 \cdot 1{,}0 \cdot 10}{1{,}97} = 0{,}41 \,,$$

that is the accident rate of the considered PHA is twice higher than average.

With a length of PHA of L expressed in km assessment of probability (expected frequency) of accidents the bound to each separate factor of influence of F_{ij}, is defined as

$$P_{ij} = \lambda_{ij} \cdot \frac{L}{1000} \,. \tag{4}$$

Then, for the considered situation we receive

$$P_{31} = \lambda_{31} \cdot \frac{L}{1000} = 0{,}41 \cdot \frac{1}{1000} = 4{,}1 \cdot 10^{-04} \,.$$

At damage from one accident in 30 million rubles assessment of specific technogenic risk for such site of LP MG will make 12,3 thousand rubles on one km per year that according to ND [4] demands at least the subsequent technical diagnosing. So far all estimates made by us have quite adequate values.

Now we decompose the above-considered kilometer segment into ten 100-meter PHA and try to calculate the specific frequency of the accident on each of them. Since only one defect has been identified in the entire 1 km section during the inline inspection, it is obvious that it will only occur in one 100 m PHA and there will be no defects in the other nine PHA. Thus, for nine PHA score B31 = 0 (there is not a single defect KRN), and one of the ten 100 meter PHA get B31 = 10. The expected specific frequency of accidents (per 1000 km per year) at this site will still be 0.41, but the probability (expected frequency) of accidents according to the ratio (4) will decrease tenfold (proportional to the reduction in the length of the analyzed area L from 1 km to 100 m).

Since there are no defects on nine 100-meter PHA, the probability of an accident on the KRN factor is zero. Since POU is a defect with the assessment of the probability (expected frequency) of accidents according to Madagas decreased ten times, and for the initial analyzed kilometre stretch, it will drop exactly the same amount. Then at damage from one accident in 30 million rubles assessment of relative technogenic risk will make about one thousand rubles on km per year, and such risk according to ND [4] has to be considered as slight (acceptable). It is quite apparent that if a piece with defect 100 m long, we still divide into ten intervals on 10 m (approximate length of one pipe), then for all initial analyzed site assessment of probability (expected frequency) of accidents, as well as specific risk, will decrease still ten times.

Finally, if we consider that length of the defect identified during VTD is only several millimeters, and there are no defects on the site of one km, then we will receive that though on several millimeters the expected specific frequency of accidents (on 1000 km a year) is rather high, and still makes 0,41, but the probability (expected frequency) of accidents both on a piece with defect, and for all initial analyzed site will be almost equal to zero.

It would seem, from the created problem situation it is possible to offer rather simple exit. If on MEHOCHAGaz on the PHA ball assessment already exceeds the maximal value in 10 points, then it is not necessary to divide it into more shallow calculated pieces, and on all length of the site to accept identical assessment of probability (expected frequency) of accidents. However such approach at the subsequent assessment of technogenic risk is hardly rational as it is necessary to consider an arrangement of objects of an environment of MG. So, if the defect of SCC is located in immediate a bliza to an object of an environment which destruction at accident, can be bound to extensive damage, then the averagings received in the way apart to 1 km of assessment of probability (expected frequency) of accidents will give significantly the underestimated estimates of technogenic risk and vice versa when the defect of SCC is on removal almost in 1 km, estimates of technogenic risk will be unreasonably overestimated.

Thus, it is desirable to consider the actual coordinate of the defect identified during ILI, at least to within one pipe what there would be an opportunity to range all defect tubes on a priority of selective repair taking into account technogenic risk.

Within MEHOCHAGaz for this purpose it is possible to suggest to refuse a tight restriction on the maximal values of score estimates (10 points) concerning the factors of influence considering results of ILI.

If on the considered site of LP MG with L km long, by results of VTD only one defect of SCC is identified, then according to MEHOCHAGaz ball and factor function has to be written down in a look $B_{31} = 5,33 \cdot I_{sc}$, where I_{sc} - expressly injected complex called an indicator of intensity of a stress corrosion which is calculated through average density found a stress - corrosion defects and with only one defect with the relative depth of $d_{sc\text{-}i}$ (% of wall thickness of a pipe) equal $I_{sc} = d_{sc-i} / L$.

And, if $I_{sc} >$ 1,875, then ball assessment of B_{13} has to be limited to the maximal value – 10 points. Then from a ratio $B_{31} = 5,33 \cdot I_{sc} = 5,33 \cdot d_{sc-i} / L = 10$ it is possible to define that if one defect of SCC on the site 1 km long gives B_{31} = 10, then its relative depth is only 2% of wall thickness of a pipe. But if to consider that length of this defect not of 1 km, and only several millimeters (or zero), then for an index of intensity of a stress corrosion at $d_{sc\text{-}i} \rightarrow 0$ we will receive indeterminacy in a look $I_{sc} = 2\% / d_{sc-i} \rightarrow \infty$, unambiguously larger, than 1,875.

If in MEHOCHAGaz for the factors of influence considering results of ILI to refuse a tight restriction on the maximal values of ball estimates (10 points), and to substitute the ball and factor function B_{31} for defect of SCC with the relative depth of d_{sc-i} in a ratio (4) for assessment of probability (expected frequency) of accidents, we will receive

$$P_{31} = \lambda_{31} \cdot \frac{L}{1000} = \lambda_{sr} \cdot k_{reg} \cdot k_{vozr} \cdot k_{kat} \cdot \frac{p_1 \cdot q_{31} \cdot 5{,}33 \cdot d_{sc-i}}{1{,}97 \cdot 1000} \tag{5}$$

Using the ratio of (5) probability (expected frequency) of accident is defined for any defect of SCC regardless of length of the analyzed site of LP MG. Having assessment of an accident risk and having information on environment objects in a defect coordinate point on ND [7] it is possible to estimate technogenic risk. With two and more defects, the technogenic risk on each of them can be summarized on the site of LP MG of any extent though on each pipe or on all MKU. Knowing length of the analyzed site and having found values of estimates of specific technogenic risk all pipes or MKU it is possible to range easily from the point of view of a priority of maintenance and repair.

According to MEHOCHAGaz score and factor functions for external corrosion (without SCC) defects and defects of geometry, joint welds and mechanical damage, have an appearance similar to defects of SCC, respectively $B_{21} = 0{,}00565 \cdot I_{\text{c}} = 0{,}00565 \cdot d_{c-i} / L$ и $B_{456} = 0{,}11 \cdot I_{mech} = 0{,}11 \cdot d_{mech-i} / L$, and therefore for all of the factors considering results of ILI it is possible to use ratios of type (5).

Thus, degree of danger of the defects identified during ILI is considered in MEHOCHAGaz only through one equivalent indicator – the relative depth of defect (or the relative length for sites of joint welds). Therefore, for example, for external corrosion defects (except SCC), than more their relative depth, that high probability (expected frequency) of accident. However, if to analyze ILI reports at whom degree of danger of anomalies according to ND [8] is estimated on three categories: (A) – defects subject to external inspection as soon as possible, (B) – the defects which are subject to external inspection in a planned order and (C) – anomalies admissible at pipeline maintenance, sometimes it is possible to find apparent contradictions with provisions of MEHOCHAGaz.

So specialists of the same specialized organization which was carrying out ILI in 2016 on one of MKU with category pipes I for defect like CORR (corrosion) at wall thickness of a pipe of 9 mm and absolute depth of defect of 1,35 mm (the relative depth of 15%) appropriated category (A), and on other MKU with pipes all the III to category, appropriated to the same type of defect of CORR at wall thickness of a pipe of 8 mm and absolute depth of defect of 6,4 mm (the relative depth of 80%) only category (C). It would seem, according to MEHOCHAGaz, everything has to be exactly the opposite, but the matter is that in case of the former absolute lengths of defect made nearly a meter (851 mm), and in the second it was only 29 mm, but the most important, the defect with the relative depth of 15% was identified on a pipe with external diameter of 1020 mm, and defect with the relative depth of 80% - on a tuba with a diameter only 530 mm.

For elimination of that contradictory situations at assessment of probability (expected frequency) of accidents in MEHOCHAGaz it is possible to suggest to consider not only the relative depth of defect, but also other its parameters (defect length, external diameter and wall thickness of a pipe etc), or at least to limit calculated values of the relative depth of defects, for example, for category of danger (A) to values more than 30%, for category (B) – from 15% to 29%, and for category (C) – less than 14%.

From the analysis of the coefficients standing in expressions for score and factor functions (5,33 for SCC, 0,00565 for external corrosion and 0,11 for defects of geometry, joint welds and mechanical damage) and corresponding to them to weight coefficients ($p_3 = 0{,}37$, $p_2 = 0{,}06$ and $p_{456} = 0{,}38$), it is possible to estimate that according to MEHOCHAGaz with the same relative depth degree of danger of defects of SCC in 6 thousand times more, than defects of external corrosion as (5,33·0,37)/(0,00565·0,06) = 5 817, and defects of geometry, joint welds and bruises it is more dangerous than external corrosion more than by 100 times - (0,11·0,38)/(0,00565·0,06) = 123. The given ratios demand separate detailed discussion as it agrees, for example, ND [5] a rank of danger of defects of loss of metal and crack-similar defects depends not only on defect depth, but on a number of other factors, such as, the defect length and also diameter and wall thickness of a pipe, an ultimate strength of metal, impact elasticity etc.

And on ND [5] other things being equal parameters a rank of danger of crack-similar defects (which SCC treats), of course, higher than, defects of loss of metal (to which external corrosion belongs). However, as show calculations, with an identical relative depth of defect and any values of other parameters, the rank of danger of crack-similar defects cannot be more rank of danger of defects of loss of metal more than several times (i.e. no more than on one order, but not on three orders as it turns out on MEHOCHAGaz).

Besides, according to ND [5] if when determining damage of the MG line section on a pipe there are several defects of one type or various types, then at calculation of an index of technical condition of pipes consider only one defect giving the maximal damage. In ND [6] this moment does not make a reservation in any way, but proceeding from the common methodology of MEHOCHAGaz, at assessment of specific frequency of accidents, most likely, all defects identified during ILI have to be considered. Perhaps, most rationally when ranging a priority of repair for MKU to consider on each pipe only one most dangerous defect, and when ranging pipes – all defects identified on it.

In reports on ILI the revealed defects - anomalies (ANOM), fall into to particular type which total makes nearly three tens. Most often (more than 80% of defects) are identified as anomalies like CORR (corrosion), further there are GWAN (girth weld anomaly), MIAN (pipe mill anomaly), DENT (dent), TECH (technological defect), TMTM (metal outside), ARTD (artificial defect) etc.

But MEHOCHAGaz does not contain the answer to a question, what types of anomalies according to reports of ILI it is necessary to fall into to the least dangerous defects – external corrosion (without SCC) and what to the most dangerous – SCC. It is clear, that all other types of anomalies have to define the influence factor considering quality of production of pipes, installation and construction works and natural influences.

At the same time it is quite apparent that to external corrosion (without SCC), it is necessary to refer, first of all, anomalies like CORR (corrosion) and COCL (corrosion cluster). It is possible to include in the same group GRIN (grinding).

The anomaly like SCC (stress corrosion cracking) belongs to the most dangerous defects of SCC, but considering ND [5], it is expedient to include in this group all crack-similar defects, such as CRAC (crack-similar defect), CSCC (zone of cross cracks), LWCR (longitudinal seam weld crack) and LACR (stratification).

3 Approbation the methodology for assessing the technogenic risks

The Risk calculated and analytical module (RAM) was developed for approbation of the methodology for assessing the technogenic risks of accidents and definition of a priority of maintenance and selective repair of LP MG [9], which undergoes the procedure of filing in Uniform the register of the Russian computer programs now. For processing of large volume of input datas on the objects of an environment of MG identified according to ND [8, Appendix A], and information about are more white than 700 thousand defects revealed in recent years at ILI, RAM "Risk" was realized in the environment of a geographic information system ArcGis Desktop.

After digitization (vectorization) of topographical and cartographical information, input data about objects of an environment and objects of LP MG are published on the ArcGis Desktop geographical portal, due to formation of their list and the main characteristics with the indication of geographical coordinates of objects and arrangements concerning a gas pipeline axis. Then the cost of objects of an environment of MG is determined. Further information about technical condition of sites of LP MG is added and calculation of estimates of technogenic risk, both for all GTO and for each its linear production division (LPU), MKU and on each separate defect pipe is made.

For support of adoption of rational administrative decisions when determining precedence of selective repair of potentially dangerous sites LP MG, results of calculations of RAM "Risk" are presented in the form of the schedules and histograms reflecting dynamics of change of estimates of specific technogenic risk on the analyzed sites and priority of their repair.

So figure 2 shows the dynamics of changes in estimates of specific anthropogenic risk for the entire (surveyed ILI) length of LP MG for one of GTO from which it is visible that these estimates do not exceed the established ND [4] of acceptable values (15 thousand rubles on km a year) though at estimates of probability of accidents in the current release of RAM "Risk" the value λ_{cp} = 0,2 the regulated ND [4] is used.

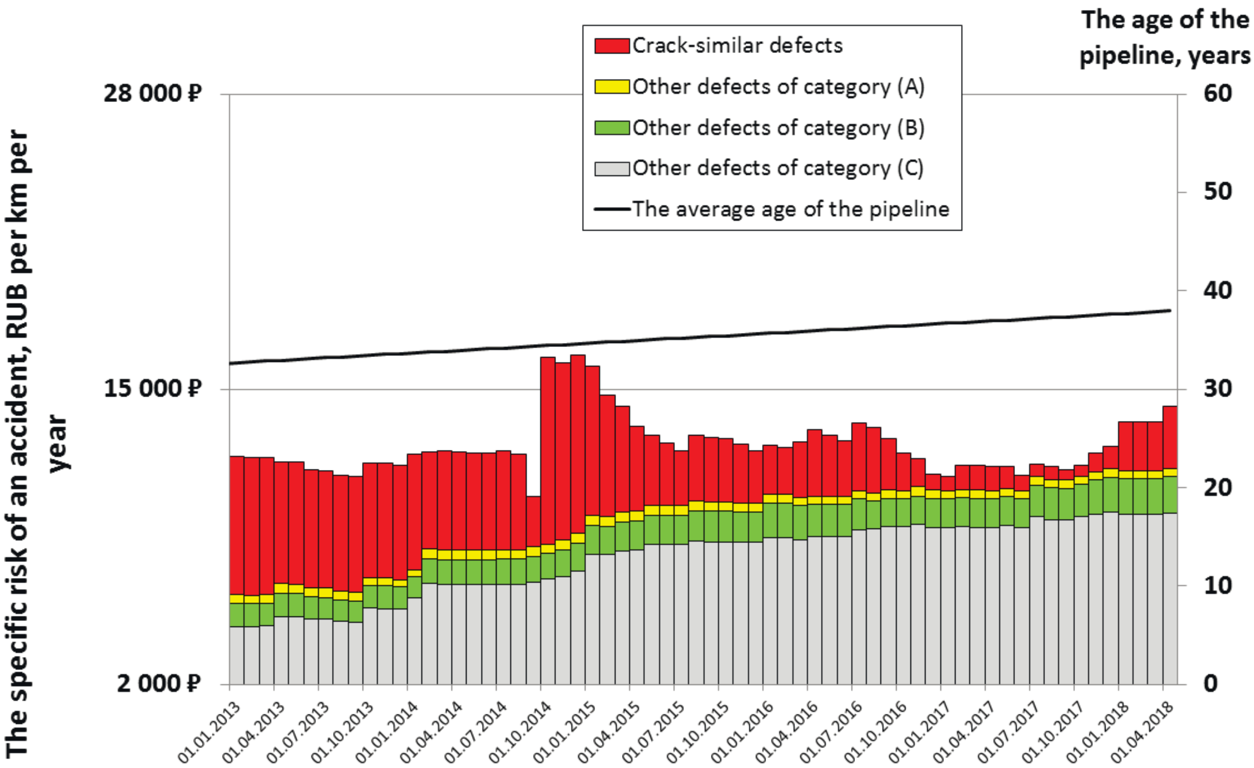

Figure 2: Dynamics of change of estimates of specific technogenic risk for LP MG by the example of one GTO

Due to selective repairs, the risks associated with crack-similar defect can be effectively reduced. However, the risks associated with other defects with a low hazard assessment (C) are steadily increasing from year to year, in direct proportion to the average age of MG (approaching 40 years).

Realization of methodology of ND [4-7] by the example of one GTO showed that the common integral index the "Risk" calculated taking into account results of VTD allows to solve efficiently problems not only a priority of carrying out, but also economic feasibility of repair of LCh MG, as at the level of GTO - system in general, and at the level of its separate elements - LPU, MKU, and even each separate pipe.

During the testing and practical application of ND [6] the problematic issues and limitations described in section 2.2 of this article are identified. Currently, together with the specialists of Gazprom VNIIGAS, the elimination of the identified problems is carried out, as well as the refinement and formalization of the algorithm for calculating the probability of an accident in the areas of MG with the presence of inline inspection. A modified and unambiguously formalized algorithm for calculating estimates of the probability (expected frequency) of accidents in such areas of MG, it is advisable to agree with Gazprom VNIIGAZ, to bring to the discussion of TRP specialists and ultimately approve at the level of PJSC Gazprom.

All regulated changes in MEHOCHAGaz should be considered in the subsequent releases of RAM "Risk" then on its basis it will be possible to create the informational and analytical system of the class BI (Business intelligence) the realizing OLAP technology (Online analytical processing) for support of adoption of rational and reasonable administrative decisions when scheduling technical tinning and selective repair of LP MG. The estimates of technogenic risk calculated in RAM "Risk" will accumulate in tables of the relational database (OLAP cubes) with a binding to LPU, MKU, the defect pipe and each separate defect taking into account type of its anomaly identified at ILI. All these data will be defined on a timeline taking into account terms of carrying out ILI and repair of pipes, when fixing once a month, taking into account an interval of scheduling and adoption of administrative decisions. The users who got the authorized access to this information system will be able to carry out via the web interface the analysis of estimates of technogenic risk on LP MG in any cuts interesting them and in any point of Internet access or to internal network of gas transmission company.

Except display of information in the form of tables, schedules or charts (as it, for example, is shown in the figure 1), in this analytical system it is expedient to realize service like "Yandex traffic". Against the background of topographical information to estimate the most dangerous sites of LP MG with unacceptable technogenic risk at 10 points and to display in red color, sites with acceptable risk from 1 to 9 points – yellow, and sites with slight (admissible) risk of 0 points – green.

Such figurative submission of information will give the chance to users at the viewing scale most shallowly quickly to assess the common situation for all gas transmission company, and at increase in scale to detail information on LPU or MKU. It will allow to define, quickly enough, the most problem sites also will be reduced by time for adoption of rational administrative decisions when scheduling diagnostics and selective repair of LP MG taking into account technogenic risk.

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