Aspects of research of indicators of emergency risk of long-term operating pipelines

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Abstact
Failures of the main gas pipelines followed by thermal influence, atmosphere gas contamination, distribution of shock airwave etc cause significant damage to environment. Negative influence of pollutants of the atmosphere is caused by their toxicity and discontenting properties. Therefore in gas transmittal pipelines administration and their structural divisions it is expedient to organize the relevant coordination groups of the experts responsible for qualitative, equal and full preparation of information materials, realization of correcting impacts on high threat location by results of the analysis of emergency risk, interaction with expert organizations, etc.
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The impossibility of analysis of emergency risk without some information material concerning both high threat location (HTL), and its environment is obvious. Careful, correct and qualified selection of these materials is the defining condition of all further work within such analysis.

It should be noted that to create base of information materials is problematic without close interaction between organization of the Customer and the organization analyzing the emergency risk. Therefore in gas transmittal pipelines administration (GTPA) and its structural divisions it is expedient to organize the relevant coordination groups of the experts responsible for qualitative, simlar and full preparation of information materials, realization of the correcting impacts on HTL according to the results of the analysis of emergency risk, interaction with the expert organizations, etc. Samples of information materials, are given below, from typical gas transmission HTL (with code names of objects) are designed for specialists of such groups [1-6].

Calculations of indicators of emergency risk begins with construction on a real cartographical basis of fields of potential territorial risk.

That striking factor makes different danger to various recipients. For example, having entered the thermal radiation of the fire, the person has a chance to leave a dangerous zone. There is no such chances for motionless objects (buildings, constructions, property, etc.), and possible damage to them from the fire depends absolutely on their properties only. That is why the potential risk of harming to various recipients has, as a rule, various territorial borders. So, the amount of types of recipients defined (people, buildings and constructions of different function and executions, vehicles, objects of live and inorganic nature, etc.), is equal to the amount of potential for them fields of risk.These schemes have certain distinctions for linear part of main gas pipeline (MGP) and vulgar constructions, however, basic data for them remains the same. On all allocated danger sources within HTL this output data includes:

- Scenarios of accidents and probability of consequences of accidents;
- Frequencies of emergency failures;
- Probabilistic areas of coverage of affecting factors.

For territorial referencing of the sources of danger and probabilistic damage areas of recipients the cartographical basis falls into their elements (cells). Gas pipelines reffred to this or that center are considered as linear objects, and vessels of high pressure, gas-compressor units (GCU), block valve stations, etc. - as point objects. The sizes of cells are chosen on the basis of required accuracy of calculations. For vulgar constructions surrounded by built-up territories and areas of MGP where violations of security zones take place, crossing of the route means of communication, congestions of people, characteristic (in the directions I and J) size of cells should be no more than 5-10 m; in other cases it can be increased up to 20-50 m.

The following should be defined for each cell:

- coordinates i, j;
- danger source index (dangerous element) n_e;
- length of a linear element.

For linear elements in the certain center the frequency of dangerous events depends on the pipeline length within the organization:

$$f_{i,j}^{(n_e)} = \lambda^{(n_e)} \cdot L_{i,j}^{(n_e)}, \qquad (1)$$

where $\lambda^{(n_e)}$ - is the frequency of dangerous events determined in the course of frequency analysis.

For point sources of danger, which got to a certain cell, the frequency of dangerous events determined by the frequency analysis, is not subjected to specification.

Further it is necessary to combine probabilistic zones of affection of recipients according to all possible scenarios of accidents for concrete sources of danger within concrete principal point. Shares of various scenarios are considered at such combination. For example, for underground gas pipeline both the fires in the form of a columned plume (fire in foundation pit), and in the form of the flooring burning gas streams are possible. In this case the integrated probability of affection of the recipient of P (S) in arbitrary point S of the territory is expressed by:

$$P(S)=k\cdot P_{ffp}(S) + (1- k) P_{jet}(S), \qquad (2)$$

where: k – rate of fires of “cut and cover” type;

P_{ffp} – probability of affection during the fire in foundation pit;

P_{jet}– probability of affection during the fire of jet type;

It should be noted that at accidents on underground gas pipelines probabilistic zones have more or less continuous orientation concerning the MGP axis. According to the researches of JSCo “Giproniigas”, possible deviations of deck streams of gas from axis of underground MGP make several degrees and they can be neglected. Thus, probabilistic zones of affection of recipients calculated for concrete accident on underground MGP using Gauss integral and corresponding probit-function, it is possible without additional adjustments to extrapolate on any similar accident during the chosen period. During rupture of the overhead gas pipeline orientation of the burning streams of gas can be various. In the first approximation it is usually accepted that such streams are focused horizontally and equally towards the sides of horizon. From this assumption follows that the further recipient from the place of gas seepage is, the less the probability that it will appear in zone of action of flat torch is. For circular probabilistic zone mathematical expectation of probability of thermal affection of the recipient at distance ρ looks as follows:

$$\overline{P}(\rho) = \frac{1}{2\pi} \int_{-\varphi(\rho)}^{+\varphi(\rho)} P(\rho, \alpha)\ d\alpha, \qquad (3)$$

where the probability P (ρ, α) in points ρ, α (polar coordinates) is defined by Gauss integral.

Thus, the obtained values of probabilities are summarized on each cell taking into account the frequency of emergence of accidents. Its summation defines the field of potential risk in all allocated territory:

$$R_{T\Sigma}(x, y) = \sum_{N} f_{i,j}^{(n_э)} \cdot P_{i,j}^{(n_э)}(x, y), \qquad (4)$$

where i=1...I, j=1...J, N – total number of dangerous elements

Field of potential risk is often expressed as isolines with a step 1/year. In this case the value of risk in the concrete center is referred to the principal point or any other characteristic point of a cell, and isolines are carried out with the method of linear interpolation determined by a step. Other way is color association of cells with values of potential risk in the set interval.

In relation to linear part of MGP, task of creation of the field of potential risk is possible to be simplified. If within the allocated area of MGP fault rate is invariable, it is enough to determine value of risk by a normal to MGP in any point of MGP, and then to build isolines of risk, which repeat MGP route configuration.

For the recipient located in any point of *S(0, h)*, which is on a normal at distance *h* from the gas pipeline, affection is probable at incident initiation with the maximum radius of zone of negative impact of R_{max} in any point of gas pipeline with coordinates $\tilde{x}_1(h)$ and $\tilde{x}_2(h)$ and length $L(h) = 2\sqrt{R_{max}^2 - h^2}$.

With increase of *h*, that is with removal of point *S (0, h)* from the gas pipeline, the length of dangerous area of gas pipeline decreases and at $h = R_{max}$, it is equal to zero (i.e. dangerous site turns into a point). Thus, random variable (coordinate of point of rupture with ignition of gas on linear source) that defines a possibility of thermal affection in point *S(0, h)*, should be within the range:

$$\tilde{x}_1(h) = -\sqrt{R_{max}^2 - h^2} \le \tilde{x} \le \tilde{x}_2(h) = +\sqrt{R_{max}^2 - h^2} \qquad (5)$$

Such reasoning can be applied also for noncircular probabilistic zone of thermal affection. As function *L(h)* is the width of this zone at distance *h* from gas pipeline axis, than approximation of border of probabilistic zone of affection (borders of 1% affection) by function F (x, h) = 0 will allow to determine approximately coordinates of $x_1(h)$, $x_2(h)$ of a dangerous area of the gas pipeline, and length of this area $L(h) = x_1(h) - x_2(h)$.

The probability of initial negative event is the function of random variable with a density of distribution of λ

$$R_T(h) = \int_{\tilde{x}_1(h)}^{\tilde{x}_2(h)} \lambda_T(\tilde{x}) \cdot P_T\left[\rho(\tilde{x}, h)\right]\ d\tilde{x} \qquad (6)$$

In the conditions of technological objects (flowing plant, gas-distribution station, NGV-refuelling compressor station) spatial organization of dangerous elements differs with great complexity. Besides, these elements differ from each other with technical characteristics (pipelines of various diameter and a type of laying, vessels of high pressure of various execution and with different binding, etc.), which influences the sizes and forms of probabilistic zones of affection. For creation of fields of potential risk on such objects special program complexes are usually used.

In the methodical plan at creation of fields of potential risk for technological objects it is necessary to consider the following.

1. Indicators of risk of flowing plant and gas-distribution station are usually defined by «long-range» sources of danger, connected with «high-pressure end» (this means with main gas pipeline or offshoot pipeline). Inside one may exclude from calculations area gas pipelines of small diameters and of rather low pressure (for example, in boiler rooms, reserve gas-turbine power plants, etc.). The same concerns the warehouses of fuels and lubricants, methanol and odorant. Besides, it is allowed not to consider basic possibility of accidents in compressor shops or individual shelters for gas-distribution station due to leak of turbine oil or fuels and lubricants. At such accidents the personnel have usually enough time (up to 3 minutes) to leave a dangerous zone. Blasting burning of power gas in compressor shop at the presence in it of waste openings most probably will not lead to death of personnel. Real threat of death of some personnel arises only at destruction of the building of flowing plant.

2. In the conditions of dense development, buildings and constructions can be an obstacle for the burning gas streams, that is for a concrete point within the object area, there can arise an effect of thermal «shadow».

3. Frequency of refusals of separate types of the equipment (GCU, separators, dust collectors, gas air-cooling units, etc.) includes also the frequency of

accidents on pipeline binding of these objects. At the same time exhaust velocity for their emergency destruction is defined by diameter of submersible adapter.

4. At ruptures of pipelines and devices on «high-pressure end» of flowing plant emergency overlapping of valvase can be carried out in 2.0-2.5 minutes that is more than critical time of thermal influence of the flame for the person who is in the open area (1-2 minutes). As the most conservative assumption one should accept that in case of direct influence of the burning gas streams on light skeleton constructions (Service/Operation block, production generating unit, etc.), personnel, which are in them can die.

5. If determination of not only social but also property damage is required, it is necessary to consider scenarios on long (up to 30 min. and more) thermal impact of the fire, and also the opportunity of baric structural damages and process equipment by air-blast.

6. If two and more compressor shops are present in the content of flowing plant, integrated field of potential risk has to be constructed by means of overlapping of local fields of certain shops if assumed that accidents cannot occur simultaneously on objects of two and more shops.

7. If HTL contains identical flowing plants (gas-distribution station, NGV-refuelling compressor station) it is allowed to build the field of potential risk only for one flowing plant (gas-distribution station, NGV-refuelling compressor station) with further calculation on its basis of other indicators of risk for each flowing plant (gas-distribution station, NGV-refuelling compressor station)

8. If the task of analysis of emergency risk is limited only by the third parties, the continuous field of potential risk is possible not to built, and to be limited only by the territories where are (possibly) the third parties.

Before creation of the field of potential risk it is recommended to make the table containing results of calculations of dynamics of the emergency leakage and parameters of thermal affection (the sizes of stream and zones of thermal defeat) for intensity of leak for the end of 1 minute. Probabilities of initiation of blowout (fire) are given integrally on entire allocated element, that is, for example, on all «uniform» pipeline area, on all air-cooling units installation of gas, on all dust collectors, etc. It is convenient to determine by the same table the role of separate technological elements in the general picture of emergency risk.

After creation of the field of potential risk it is possible to proceed to definition of indicators of collective, individual and social risk, and also harm-doing of different types. In this part of analysis the information materials are used:

- Number and areal-time distribution of personnel of both HTL, and neighbor enterprises, population or occasional persons, which appeared (can appear) «registered» within the field of potential risk;

- Intensity of the movement along the thoroughfares, crossing MGP or laid in parallel in close proximity to MGP;

- Operating mode of personnel of HTL, neighbor enterprises, style of life of population, features of carrying out concrete types of agricultural and other works;

- Costs of business, revolving and other HTL assets, property of the third parties.

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