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PROBABILITY OF EMERGENCY RELEASE DURING DEPRESSURIZATION

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Abstract

"The idea of the proposed work is that the volume of an emergency discharge should be calculated based on the characteristics of the discharge event itself." There are some tools for this that are not used by developers of analysis methods. This refers to an automatic method of monitoring emissions using sensors up to an explosive gas concentration (EGC), automatic control of flow rates, pressure, visual control methods, by the sound of gas emissions, by the smell of a hazardous substance, etc. These methods, which can be calculated, are especially effective for partial depressurization of the block.

Keywords: emergency release, reliability, probability of depressurization, frequency, risk, technological equipment

I. Introduction

The level of reliability of oil field process equipment can also be seen in the forecast of the probability of complete depressurization of dangerous blocks, estimated by document [1] as the frequency of complete depressurization equal to 10^{-5} units/year. Let's consider the physics of the designated phenomenon and how it affects the reliability of equipment over time. Fig. 1 shows a graph characterizing the probability of failure of a technological unit due to its physical aging or wear. This graph is presented in LogP - LogT coordinates, where T is the operating time of the equipment, years, P is the probability of equipment failure.

II. Methods

To understand the essence of the analysis being performed, we note that the probability of failure (degree of wear) and the equipment reliability indicator add up to one. The higher the wear, the lower the reliability of the equipment. If we take as a boundary condition corresponding to the moment of block destruction the frequency of complete depressurization equal to 10^{-5} units/year. This means that complete depressurization of the block will occur once every 100,000 years. When analyzing the graph, you can find a variable value for the reliability indicator. If we take the probability of equipment failure at the level of 10^{-6} as an acceptable value, then it is found that at the initial stage and after 100 years of operation, the probability of failure is higher than the acceptable value. At the initial stage, the low reliability of equipment is explained by the presence of defects during its production at the manufacturing plant, the appearance of additional defects during its transportation to the construction site and during installation as part of the construction project. During operation, equipment wears out, accompanied by a decrease in residual life. Wear is expressed by a change in the thickness of power elements due to corrosion, the appearance of microcracks in critical equipment components caused by cyclic loads, changes in the structure of the metal as a result of aging, etc. The ability of equipment to completely depressurize is determined by the degree of its wear. The standard operating life of machines and devices does not exceed 10–15 years. As follows from the analysis of the reliability graph, the probability of complete depressurization of equipment within the established resource is negligible, therefore we consider it unacceptable to use complete depressurization as the main scenario for the development of an accident.

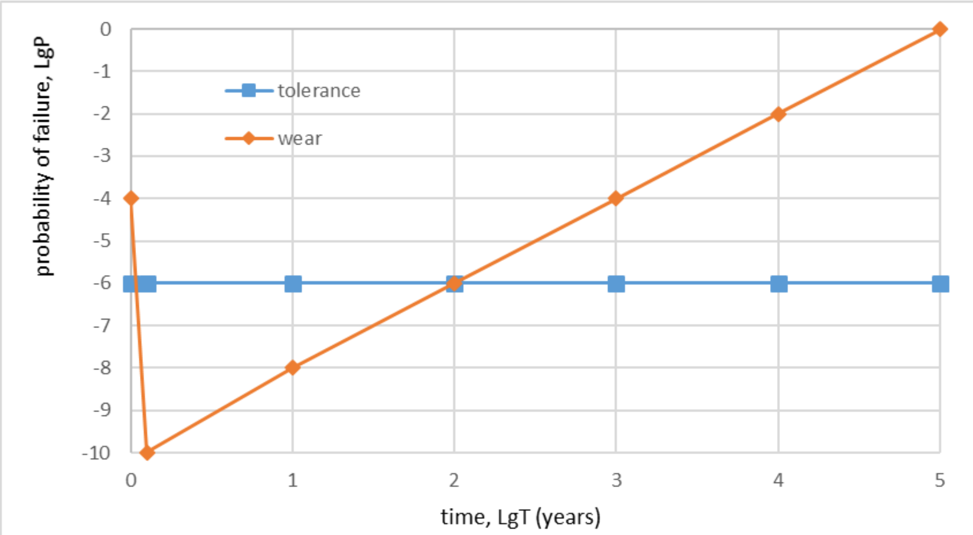

Fig.1: *Depenedence of equipment wear on time*

Accident statistics were most fully presented in RD 03-357-00 [1], where the following indicators can be found in Table 1: probability of depressurization of a process pipeline with a length of no more than 30 m $5x10^{-3}$ per 1 km of pipeline per year; probability of depressurization of the main pipeline (1-3) x 10^{-4} per 1 km of pipeline per year; probability of failure of machinery (pump or compressor) 3 x 10^{-3} per 1 km per year; the probability of complete destruction of the reservoir is 10^{-5} per year; the probability of partial depressurization of the tank is 10^{-4} per year.

Table 1: *Probability of depressurization of process equipment*

The probability of depressurization of a process pipeline with a length of no more than 30 m.	$5x10^{-3}$ per 1 km of pipeline per year
Probability of depressurization of the main pipeline	(1-3) x 10^{-4} per 1 km of pipelines per year
Possibility of failure of machinery (pump or compressor)	$3x10^{-3}$ per 1 km per year
Probability of complete tank destruction	10^{-5} per year
Probability of partial depressurization of the tank	10^{-4} per year
Possibility of rupture of connecting hoses during draining/filling of railway and road tanks	10^{-3} per refill or 10^{-2} per hose

As a base, we have to use the data presented in the table, which in the original source is called "Generalized statistical data for assessing the frequency of equipment failures." In particular, the value of partial block failure is presented here as the "probability of failure (incident)" with the dimension "per year". From the theory of probability, from the instructions of GOST R 50779.10-

2000 [2], it follows that the probability of a random event is a dimensionless quantity. The "frequency" or "probability" of partial block failure is 10^{-4}. With the release of the Methodology [3], a database on depressurization of process equipment, tanks and pipelines appeared. In appendix 1 to the specified Methodology, tables appeared indicating the frequency of complete and partial depressurization for certain types of equipment and process pipelines. The frequency of partial depressurization is presented in tables for different sizes of emergency opening in the range from 5 to 100 mm for equipment and from 12.5 to 100 mm for pipelines. In this case, each size of the emergency hole is assigned a certain frequency of system depressurization. According to the idea of this document, the volume of release should be determined depending on the size of the emergency opening. What to do next with the resulting emission volumes? The volume of release is determined not by the size of the emergency opening during partial depressurization of the system, but by the method of monitoring the tightness of the system. Partial depressurization is a dynamic process. It starts with a small omission of product and only in the absence of control will it progress over time. For partial depressurization of devices operating under pressure, 5 depressurization stages have been installed with emergency opening sizes of 5, 12.5, 25, 50 and 100 mm. As a result of lengthy calculations, it is possible to determine the volume of oil or gas release for each hole size[4]. Then, for all emission volumes, perform calculations of affected areas. What to do next with this data array? Our approach to solving this problem is as follows: The volume of emergency release in the event of partial depressurization of an apparatus or pipeline is determined not by the size of the emergency hole, but by the method of monitoring the tightness of the system. The volume of emergency release at on-site facilities equipped with an automatic gas control system is determined by the sensitivity of the control system. At linear structures and well pads, where there are no maintenance personnel, control of the system tightness is carried out by personnel on duty (inspectors of linear structures, mobile crew at well pads) at established intervals. The size of the oil slick formed on the surface of the earth is taken as an indicator of depressurization. In this regard, as a database on the frequency of partial depressurization (FPD), we take the total frequency presented in the tables of the Methodology [3,5,6]. As a result of summing the frequencies of partial depressurization, accident statistics are presented in Tables 2 and 3.

Table 2: *Frequency of depressurization of equipment and tanks*

Name of technical device	Dimension	Depressurization frequency	
		Partial	Complete
Devices under excess pressure > 0.07 MPa	pcs/year	$6{,}2x10^{-5}$	$3x10^{-7}$
Pumps	pcs/year	$5{,}62x10^{-3}$	$1x10^{-4}$
Compressors	pcs/year	$1{,}28x10^{-2}$	$1x10^{-4}$
Tanks and reservoirs under pressure < 0.07 MPa	pcs/year	$1x10^{-4}$	$5x10^{-6}$

Table 3: *Frequency of depressurization of process pipelines*

Pipeline diameter, mm	Specific failure rate, pcs/km/year	
	Partial depressurization (PD)	Complete depressurization (CD)
50	$8x10^{-3}$	$1{,}6x10^{-3}$
80	$6x10^{-3}$	$4x10^{-4}$
100	$4{,}5x10^{-3}$	$1{,}6x10^{-4}$
150	$3x10^{-3}$	$2{,}6x10^{-5}$
200	$2{,}4x10^{-3}$	$1{,}8x10^{-5}$
250	$1{,}9x10^{-3}$	$1{,}6x10^{-5}$
300	$1{,}7x10^{-3}$	$1{,}4x10^{-5}$
400	$1{,}4x10^{-3}$	$1x10^{-5}$

500	$1x10^{-3}$	$8x10^{-6}$
600	$8x10^{-4}$	$6{,}5x10^{-6}$
700	$7x10^{-4}$	$5{,}5x10^{-6}$
800	$6x10^{-4}$	$4{,}8x10^{-6}$
900	$5x10^{-4}$	$4{,}1x10^{-6}$
1000	$4{,}7x10^{-4}$	$3{,}8x10^{-6}$
1200	$4x10^{-4}$	$3{,}2x10^{-6}$

Calculation of the probability of leakage of flammable substances P1

Assuming that the start of a typical most probable accident is the partial destruction of a dangerous unit, the probability of a leak is determined by the product of the frequency of leaks of this element and the duration of the leak. P_i = Nt, where P_i is the probability of leakage of a hazardous substance; N – leakage frequency of the i-th element; t is the duration of the leak.

Calculation of emergency depressurization frequency N

The frequency of emergency depressurization is determined based on statistical data on the frequency of depressurization of individual units of the installation. The frequency of emergency depressurization can be determined for one unit (as a statistical indicator of the failure rate), for a group of units included in 1 technological installation (as the sum of the depressurization frequencies of the units included in the installation), for a complex of installations (as the sum of the depressurization frequencies of technological installations) and etc.

Determining the amount of hazardous substance involved in the accident

Data on the amount of hazardous substances released into the environment are necessary to solve the following problems:

- To determine the damage associated with the loss of valuable hydrocarbon raw materials;
- To determine the amount of compensation for damage to the environment;
- To determine the areas affected by personnel and the population during fires of flammable liquid spills;
- To determine the cost of restoring an object after an accident;
- To generate risk indicators, the frequency and probability of explosions and fires, the probability of injury to personnel and the population, and determine the locations of possible injury;
- To develop recommendations to reduce risk

III. Results

1. The use of the term "probability" with the dimension of frequency is unacceptable, since this follows from the theory of probability, which has no dimension.
2. The volume of emergency release in the event of partial depressurization of the system is determined not by the size of the emergency hole, but by the method of monitoring its tightness.

IV. Discussion

Emission potential

The consequences of accidents associated with the release of a hazardous substance into the environment determined by the energy potential, which can be realized in an unfavorable scenario. For fire and explosion hazardous industries that use flammable substances (liquids and gases), the main scenario of the emergency process is the oxidation of these substances with atmospheric oxygen, which leads to a fire or explosion. The consequences of such an accident determined by the magnitude of the energy potential of the flammable substance that can take part in the oxidation reaction. Let's consider an algorithm for calculating the amount of substances released for oil field facilities. Based on the nature of production, fisheries can be divided into the following groups:

- On-site facilities with the constant presence of maintenance personnel;
- On-site facilities with staff visits once a day;
- Linear structures controlled by a lineman once a day.

At the location of the release, hazardous objects can be above-ground or underground. This indicator has a significant impact on the volume of flammable substances involved in creating hazards. Based on the volume of release, accidents are divided into 2 groups: with partial depressurization of the unit and with complete destruction of the unit. Combustible substances can be in liquid or gaseous state. Liquid substances can accumulate for a long time on the surface of the earth. Gaseous substances create a cloud of gas-air mixture of certain sizes. Taking into account dispersion in the atmosphere, the size of the cloud depends on the consumption of flammable substances in the emission. With a long-term release, the potential stabilizes at a certain level, after which all additionally released gas is dissipated in the atmosphere. Methods for monitoring the tightness of a technological system can be divided into automatic and visual. Automatic methods include methods for monitoring technological parameters (pressure, level, flow), by changing which one can indirectly determine the degree of depressurization of the technological unit. The specified parameters make it possible to determine the possibility and degree of depressurization of a dangerous unit. In addition, automatic methods include direct methods for monitoring the presence of flammable substances in the environment, carried out using flammable gas detection systems using sensors up to explosive concentration (EVC), a sensor cable that reacts to the presence of oil and its products. The volume of methane emission that initiates the sensors, with their average distance from the emission site of 11.2 m, is 22 m^3.

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