Assesment Of Hazards Under Operation Of Ship's Ammoniac Refrigerating Machineries In The Caspian Basin

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The ten years' period of a development of Pre-Caspian states, earlier having entered the former USSR, is characterized as a transition to new patterns of ownership and economic mechanisms through intensification of all processes, increase of power-to-weight ratio of production, application of new techniques and materials, essentially new approaches to organization of work and actions of ships' owners. As the practice shows, usually such transition is accompanied by numerous technogenic catastrophes with human victims and severe moral and material losses both for community and environment. Dangerous situation formed up to now and connected with accidents, industrial injuries and ecological safety is explained both by constructional imperfection of obsolete equipment and equally low culture of safety, technological indiscipline and psychological mood of the people. These factors are not given due attention in the most scientific researches.

Since 1991 in USSR, and then in Russia, the State technological program " Safety of the Population and Economic Objects with Reference to Hazards of Natural and Technogenic Catastrophes" is being executed by the pooled efforts of leading research, design and educational institutions of the country. Within the framework of this program interesting data on methodology of examination and improvement of job and environmental safety based on general principles and new special scientific methods is accumulated. Nevertheless, a problem of prevention of emergency incidents remains to be unsolved up to now [1].

Risk of emergency incidents with negative ecological consequences is an inevitable concomitant factor of industrial activity, and in particular of using freon and ammoniac refrigerating machineries.

According to generally used terminology, the hazard is a degree of danger, defined by a combination of frequency (or probability) of undesirable events and significance of their impact [1; 2; 3 etc.]. In our opinion, the above definition of hazard should not be taken as final and it requires to be added with, at least,by two points .

1. Risk of operating dangerous industrial objects is permissible, if its value is so inappreciable, that for the sake of benefit (profit) obtained the community is ready to run the hazard. According to this definition, in order to assess hazard, the latter should be compared to profit, which is supposed to be received from a dangerous production activity. This will allow to define the well-grounded threshold between permissible and intolerable hazards. Meanwhile, not only a bound between permissible and intolerable hazard is of interest (which, by the way, can be given by directions in the normative documents), but, and in the greater degree, it is interesting to know how close subjects are to this threshold .

2. Identification of the dangers carried out with using statistical data on emergencies as connected with ship refrigerating machineries [4], shows that risk of operating refrigerators exists in the form of potentially possible emergencies. Therefore, hazards of such installations and most dangerous industrial enterprises should be estimated not by frequency but probability of occurrence of undesirable events (emergencies) and significance of their consequences.

Thus, the hazard should be determined by a comparison of stimating the following three parameters:

A. probability of emergencies, or degree of industrial hazards;

B. consequences of emergencies, or damage;

C. benefit, or profit from production activity.

To choose adequate measures of prevention of accidents the database of quantitative assessment of risk level (or degree of hazard) is developed based on theory of probability. Actually, the numerical scale for measurement of risk levels and a procedure of localization of the subject at risk on this scale is proposed.

When we elucidated the problem of providing safety we proceeded from the assumption that all events occurring in nature and community are the result of action of objectively existing laws, contradictions and various factors. It allows to consider most of emergency cases, as natural, causal phenomena, and removal or lessening of the emergency consequences implies, first of all, identification of the causes responsible and their elimination. The consequences of an emergency case are expressed in human, material or environmental damages.

According to theory of probability the emergency case, which is bound to occur as a result of any dangerous situation, is named as an undoubted event (U). The emergency case, which is not bound to take place as a result of a dangerous situation, is named as a variant event (V). The emergency cases, considered by us, can be included into neither U-, nor V-category. They should be considered as probable, or accidental events (À), entering between U and V.

From the classical definition of event probability three postulates follow:

A. probability of an undoubted event equals unity;

B. probability of a variant event equals zero;

C. probability of an accidental event is a positive number between zero and unity.

Here risk is considered as an ability of the system "human being -mechanism-environment"- to keep at operation under given conditions such a state, when the occurrence of accidents is excluded with some probability

The gained experience of personal observations on operation of such hazardous mechanisms as refrigerating machineries [4], has formed the basis for classification of causes leading to dangerous situations and their consequences, and, later on, causes and sequences of emergency cases. The above classification was used for construction of qualimetric simulation model of risk (danger) assessment [5].

Objective difficulties of a mathematical quantitative assessment of danger of industrial enterprises stimulate seeking approaches of using some elements of theory. of probabilities

A qualimetric method of estimation [5] falls into formal - logical methods and allows building-up " tree of attributes" (fig. 1). The degree of hazard of any object in qualimetric model is evaluated by parameter "A", and sequences of accidents – by parameter "B". These parameters are parameters of the highest (zero) rank of the tree. Hereinafter the term "parameter" corresponds to the term "event" in the theory of probabilities.

Parameter A can theoretically accept numerical values from zero up to unity:

$$0 < A < 1.$$

By this, it is supposed that a refrigerating equipment with parameter $A = 0$ is theoretically safe, and some installation with parameter $A=1$ has a marginal degree of danger, i.e. the running of such equipment is bound to cause damage.

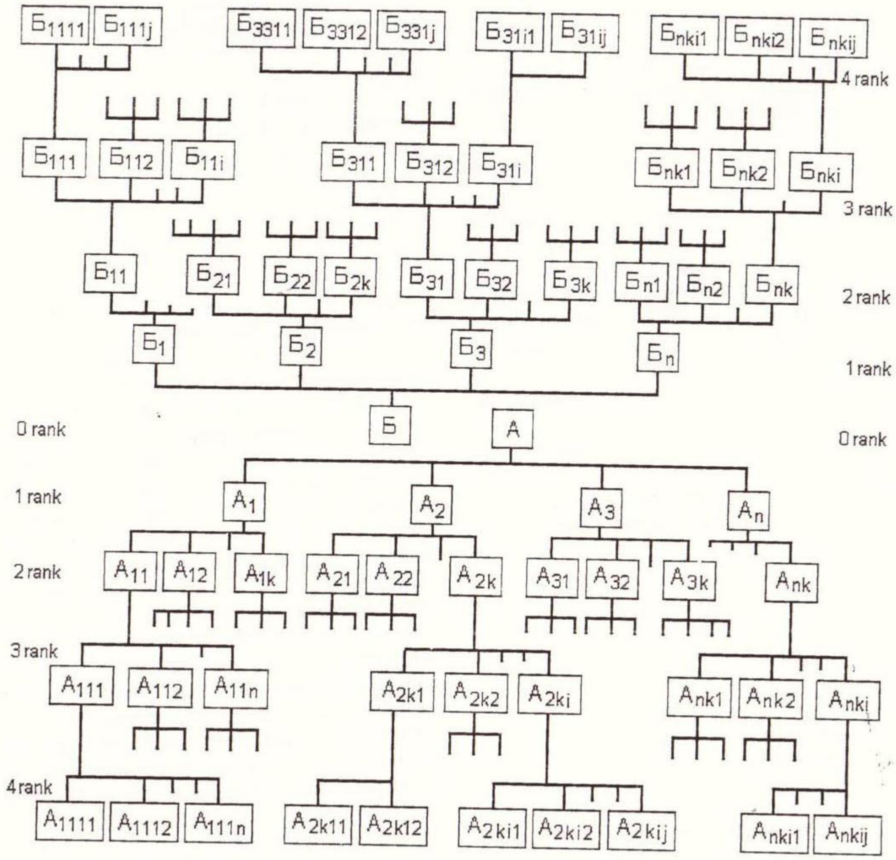

Fig. 1: Qualimetric model of estimation of degree of dangers of refrigerating machineries (A) and consequences of accidents (B)

Specific parameters $A_1 \div A_n$ in the dimensionless numerical form characterize hazards, inherent to industrial enterprises. They form the basis of "branches of a tree" and fall into the first rank of "the tree". These indexes are the factors organizing parameter A, and have the following sense: The probability of event A can take place if either event A_1, or event A_2, or event A_3, or event A_n, or the first, the second, and the third occur simultaneously. The theory of probabilities when operating such events offers a theorem of addition of probabilities.

Coefficients $\alpha_1 \div \alpha_2$ are coefficients of significance of the relevant specific (individual) parameters. The requirement of qualimetry is $\Sigma\alpha_n = 1$. The meaning of coefficients A represents a conditional probability of events $A_1 \div A_n$, i.e. the probability of event A can take place provided that event A_1, event A_2, event A_3, and event A_n occur. The theory of probabilities at operations with such events offers the theorem of multiplication of probabilities.

Specific (individual) parameters of the second rank (A_{11}, A_{12}, A_{13}, ... A_{nk}) are the factors forming parameters of the first rank. Coefficients α_{11}, α_{12}, α_{13}, ... α_{nk} are coefficients of significance of the relevant specific (individual) parameters. The requirement of qualimetry is: $\alpha_{nk} = 1$. It means that they characterize conditional probability of events A_{11}, A_{12}, A_{13}, ... A_{nk}.

Specific (individual) parameters of the third rank (A_{111}, A_{112}, A_{121}, A_{122} ..... A_{nki}) are the factors forming parameters of the second rank. Coefficients α_{111}, α_{112}, α_{121}, α_{122}, ... α_{nki} are coefficients of significance of the relevant individual parameters ($\Sigma\alpha_{nki} = 1$). Their meaning characterizes conditional probability of events A_{11}, A_{12}, A_{13}, ... A_{nk}.

Specific (individual) parameters of the fourth rank (A_{1211}, A_{1212}, A_{1213}, ... A_{nkij}) are the factors organizing parameters of the third rank, and coefficients α_{1211}, α_{1212}, α_{1213}, ... α_{nkij} are coefficients of significance of the relevant individual parameters of the fourth rank.

In principal, it is possible to formulate parameters of the fifth, sixth etc. rank, which will give concrete expression to the relevant parameters of higher ranks. The more ranks a model contains, the more valid results of using it. The main rule of qualimetry is: parameters of one rank should be independent of each other by meaning (at least - - conditionally independent).

The estimation of a degree of danger, i.e. probability of occurrence of accidents (A), constructed on the theorems of addition and multiplication, is yielded by the solution of a set of equations:

$$A = \sum_{n=1}^{n} \alpha_n \cdot A_n$$

$$An = \sum_{nk=11}^{nk} \alpha nk \cdot Ank;$$

$$Ank = \sum_{nki=111}^{nki} \alpha nki \cdot Anki;$$

$$Anki = \sum_{nkij=1111}^{nkij} \alpha nkij \cdot Ankij,$$

etc.

The individual parameters of the lowest rank are given subjectively by experts; other parameters are calculated according to the above formulas.

The procedure of forming parameters of tree "B" is similar to the above procedure of forming parameters of tree "A", and $\Sigma\beta_i = 1$ as well. It goes without saying, that probable consequences (as well as dangers) can not be equal to zero. Under B = 1 we could mean consequences with the most possible damage, i.e. 0 <B< 1.

However, the most of given specific (individual) parameters of tree "B" are such, the estimates by which we can not formalize conditionally. It is more reliable to execute estimations by such parameters through interviews with experts in the given field, that is physicians, economists, psychologists and others. Self-estimations are not excluded as well [5].

The estimation of consequences of probable accidents (Б) is yielded by the solution of a set of equations:

$$B = \Sigma B_n\, B_n;$$
$$Bn = У B_{nk}\, B_{nk};$$
$$Bnk = У B_{nki}\, B_{nki}, \ldots \ldots \ldots \text{etc.},$$

where B_{nki} - parameters, defining probable consequences of accidents;

β_{nki} - coefficients of a significance of parameters with the relevant indexes.

Estimation of hazard according to the models proposed above consists of the calculation of specific (individual) parameters of intermediate ranks, and integrated parameters A and B with consequent comparison of them. Since these two parameters have an identical range of changes (from 0 up to 1) and identical (dimensionless) measurement unit, it is possible with these parameters to make arithmetical actions, in particular , addition and subtraction. If one assumes that probability of accident is minimal ($A \to 0$); then hazard is permissible even at maximum values of consequences of accidents (B= 1). If the probability of an emergency case has maximum value (A = 1), the hazard can be permissible only at minimum value of consequences ($Б \to 0$). In the end it can be assumed that the sum of A+B would represent hazard at exploitation of industrial enterprise, risk being permissible, if A+B < 1.

For estimation of hazard it should be compared to profit, which is supposed to be received from a dangerous production activity. This profit is shown by a larger circle on Fig. 2 and conditionally taken as unity. If the circles indicating probability of an emergency case A and probable consequences of accident B are inscribed in a larger circle with overlapping *(a)* or fall outside the limits of the large circle *(б; в)*,then the hazard is considered intolerable. The value of exceeding the permissible limits of risk is marked by black color.

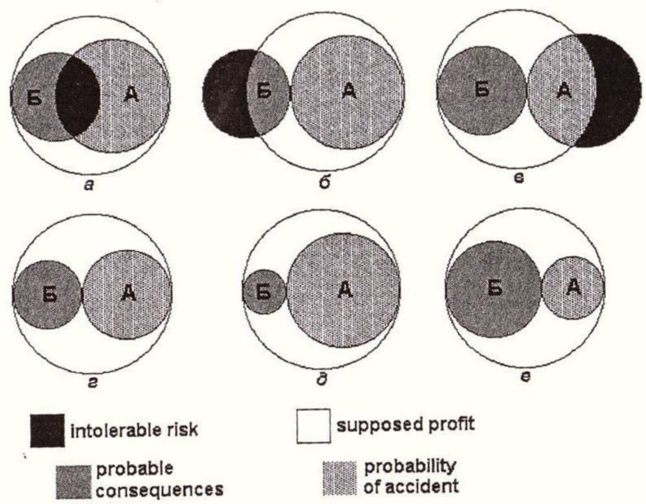

Fig. 2: Actions controlling degree of hazard

To lower a degree of hazard one should reduce either A (fig. 2 *e*), or B (fig. 2 *д*), or both (fig. 2 *г*).

One of the problems arising with projection, construction and run of ship's ammoniac refrigerating machineries is concerned with the reduction of dangers, attempts to lessen A and to decrease possible consequences of accidents B. The result of an estimation A = 0 (i.e. refrigerating machineries is absolutely safe) is ideal, but hardly accessible.

According to a set of equations (A) and (B), it is possible only when all individual given parameters are equal to zero, that can never be in practice. Therefore it is necessary to try to as possible as – minimized the degree of danger – $A_{min} \neq 0$, and,

$$P_A = A - A_{min},$$

where P_A - reserve of reducing danger;

A - number characterizing an actual degree of danger of a concrete refrigerating machine.

Reserve of reducing consequences of accidents is:

$$P_B = B - B_{min},$$

where B - number characterizing actual consequences of emergencies on a concrete refrigerating machine of a concrete vessel.

Taking into account, that the common parameter A or B is formed by specific (individual) given parameters A_i or B_i, it is necessary to use reserves of reducing individual parameters $P_{Ai} = A_i - A_{i\ min}$ and $P_{Bi} = Б_i - Б_{i\ min}$, in order to reduce a total degree of danger and consequences of accidents. Thus, it is necessary to bear in mind, that realization of reserves is connected to certain difficulties (financial, organizational, etc.), that's why one should decide a problem of optimization of realization of these reserves through transformation of "tree of estimations) " of qualimetric model into " a tree of the strategies ".

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