BIG DISASTERS ANALYSIS IN PROBLEMS OF TECHNICAL SYSTEMS SAFETY

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Abstract. The development of methods and systems for the analysis of technical, nature and human factor during industrial catastrophes, terrorist and counterterrorist actions can be among the basic developments on risk analysis and safety procurement. When considering risks of accidents at the technological facilities we have to assess damages and losses on the one hand, and the return periods (probabilities, frequencies) of their occurrence on the other hand. In this context it is important to categorize the accidents and disasters according to their scale, facilities, and levels of danger. For development of the safety norms for technical systems the methods of the fracture mechanic have priority importance. Limiting dangerous condition (fracture) is achieved at extreme loading and critical strain or stress. When with regular situations and emergencies the cyclic loadings will act, the analysis of life and safety will be carried out with use of complex nonlinear dependencies as with definition of stress-strain states, and number of cycles both before cracks initialization stage, and at crack propagation stage.

1. General analyses of big disasters

During the 2-3 last decades counteraction to big disasters in technogenical sphere has moved beyond national borders and became one of the urgent problems of the international cooperation with active involvement of the leading international organizations such as the UN, the NATO, the Collective Safety Treaty Organization, OSCE and International Congresses and Conferences.

Assessing the problems of international and national safety and security we should note a number of levels of the national safety management system. Management in case of nature and industrial catastrophes, terrorist attacks is an important part of this system. Among the threats there are accidents and catastrophes of natural and technological character that are strongly related to dangerous natural and technological factors and do not essentially depend on the human factor. Yet there are also some complex anthropogenic threats induced by single person such as an operator, or a group of people – personnel [1,2].

Speaking about problems of safety and security we should note that complex nature, engineering anthropogenic threats include:

- complication of technical systems and growth of potential danger;
- errors of designing, manufacturing, operation, and flaw detection control of dangerous facilities;
- unauthorized human impacts on these facilities;
- deliberate dangerous impacts without human victims;
- terrorist impacts of different levels on facilities, operators, personnel, and population leading to considerable economic losses and casualties.

All that creates a great threat to national security.

We would like to note the difference in the structure and the role of anthropogenic factors in the known accidents at nuclear power plants – Three Mile Island (USA) and Chernobyl (USSR). One

can say that Three Mile Island accident was caused by the wrong engineering (design) decision while Chernobyl disaster resulted from unauthorized actions of operational service managers and operators, i.e. the human factor.
A major accident at Sayano-Shushensky hydroelectric power station took place in Russia on August 12, 2009. More than 70 persons were killed. The accident also resulted in huge destructions of machinery. These consequences were caused by the lack of the control over the station and errors of operators and managers of the station at the stage of its transition from emergency state to catastrophic one.
Same big catastrophes in India, Mexico, USSR, USA, Russia were connected with the petrochemical factory, with the low requirements to the inspection of the factory's technological pipeline, pressure vessels and bolts elements.
Heavy accidents were at an oil-extracting platforms in the North Sea (Norway) and the Gulf of Mexico (USA), as result from the lack of knowledge in the field of protection and low technological discipline.
Now about the latest developments at Fukushima 1 nuclear power station in Japan (Fig. 5). It is clear that there were most complicated combinations of damaging factors, i.e. an insufficient level of power station design taking into account extreme tsunami waves. This level corresponded to the level accepted more than forty years ago. Then the possibility that such tsunami waves overcome protection buriers was not taken into consideration.

2. Basic parameters of big disasters

In [1-7] are shown the results of analysis of major big disasters in Russia and abroad that occurred over the last 50 years such as Sovezo and Bhopal chemical plants; Three Mile Island and Chernobyl nuclear power plants; explosions at the intersections of pipelines and main transportation arteries near Ufa and Arsamas; catastrophes at Thrasher, Komsomolets, and Kursk atomic submarines; radiation accidents at nuclear facilities Mayak and Tomsk-7; at Space Shuttles; explosions with a great number of casualties at ammunition depots, large airliners, and offshore oil-producing platforms – allowed one to develop the theory of manmade disasters and risks, and create the foundations of protection methods and systems.
The number of manmade disasters initiated by terrorist actions has not been great so far. Airliner explosions and blastings of aircraft carriers, apartment houses, railway stations, hotels, and embassies in Russia and US, and explosions at railways and trunk pipelines should be mentioned here. Acts of technological terror against World Trade Center and Pentagon on 9.11.2001 had the most national and world response. However, due to a number of fundamental (civilization, ethnic, religious, social, political, and economic) reasons the growth of the number of technological terrorism attacks and the increase of the severity of their consequences can be predicted.
Taking into account that technological accident prevention is 10-15 times more effective than the elimination of the consequences; the main attention should be focused on the research, diagnostics, monitoring, prediction, notification, and prevention of terrorist attacks. That trend of Russian national policy is reflected in The Conception of RF National Safety and in a number of federal laws to ensure safety in different spheres.
When considering risks of accidents at the technological facilities we have to assess damages and losses on the one hand, and the return periods (probabilities, frequencies) of their occurrence on the other hand for nuclear power plants (NPP), liquefied gas processing (LGP), hydropower plant (HPP), main pipelines (MPL), oil and gas industry (OGI), thermal power plant (TPP). In this context it is important to categorize the accidents and disasters according to their scale, facilities, and levels of danger. Here accidents and emergencies that occurred at a given facility or its site should be considered (Fig. 1). If the disaster expands to the adjacent territories, it is classified as a regional one, and if its consequences expand further, then such disaster can be referred to national, global, or planetary.
Considering the categories of national and global disasters such as Chernobyl and Fucushima it

should be noted that their real losses are measured in billions of USD. Initial calculations for their nuclear reactors envisaged that such the probability of such disasters would not exceed $10^{-6} – 10^{-7}$. Three Mile Island and Chernobyl disasters demonstrated that the probabilities equal $2·10^{-3}$, and that the calculated expectations proved 10000 times more optimistic.

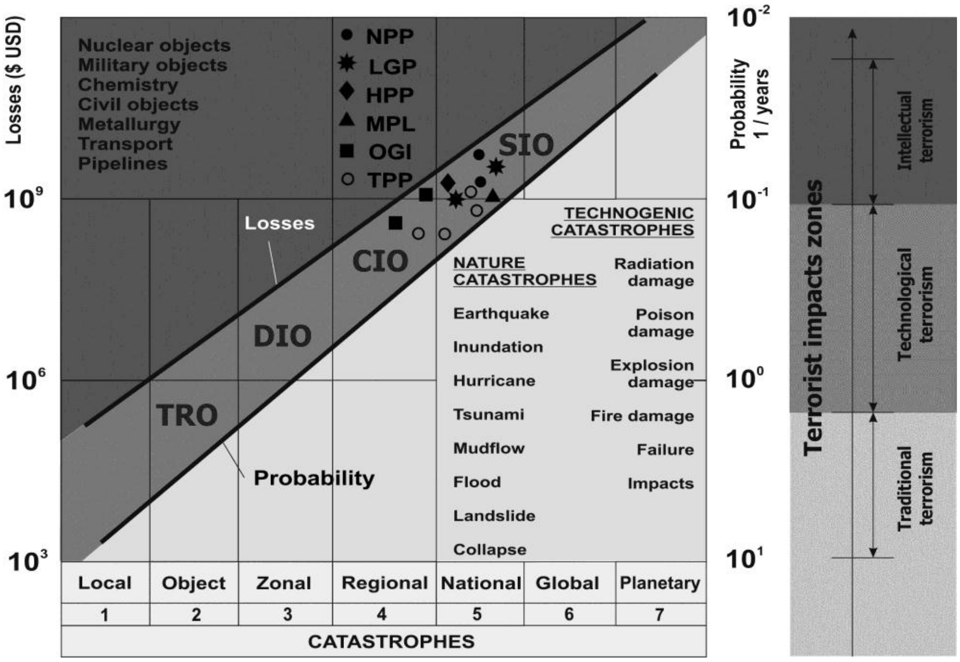

Fig. 1. The losses and periodicity of natural and manmade disaster, and terrorist action occurrence for technical regulating objects (TRO), dangerous industrial objects (DRO), critically important objects (CIO) and strategically important objects (SIO)

Considering the Fukushima disaster the risk for Fukushima NPP is about $3·10^{-4}$, i.e. the 25-year experience after Chernobyl was required for the risk only to be diminished 10 times. In other words, the return period of such major catastrophes equals not to thousands (or hundreds of thousands) of years, but only tens and hundreds of years. Thus we can assume that to reduce risk by a factor of a hundred about 50 years of work in this direction will be needed. It appears from the above that it is problematic to offer mankind such way for ensuring acceptable level of nuclear power plants safety.
Loss estimation plays an essential role in the assessment of risk of such serious accidents. Thus, in case of Chernobyl it was initially supposed that initial losses would be only losses related to facility destruction (about one billion of USD). But subsequent economic costs of people resettlement and creation of new residential infrastructure increased the losses to national economy tenfold, and the further rehabilitation of territories led to its growth in one or even two hundred times. The example shows that due to secondary and cascading effects risks of major disasters can be essentially higher than expected (calculated) ones. Similar conclusions could be made for assessment of losses inflicted by terrorist attacks.
The tendency of changing the number of emergencies *N* of technogenic/manmade (the dotted line), natural (the solid line), and terrorist (dash-dot) nature for the last several decades is shown in Fig. 2. If we analyze manmade accidents at industrial facilities, we will see that their number tends to grow. The natural disaster trend character is less stable. The analysis of terrorist attack number shows their rapid growth, especially at the present period, and this circumstance requires special attention to the problem considered.
Terrorism is another dangerous manifestation of anthropogenic (or the human) factor. The classification of terrorism was presented in papers [2-5] and shown in Fig. 3: Terrorism can be divided into three types: traditional, technological, and intelligent.

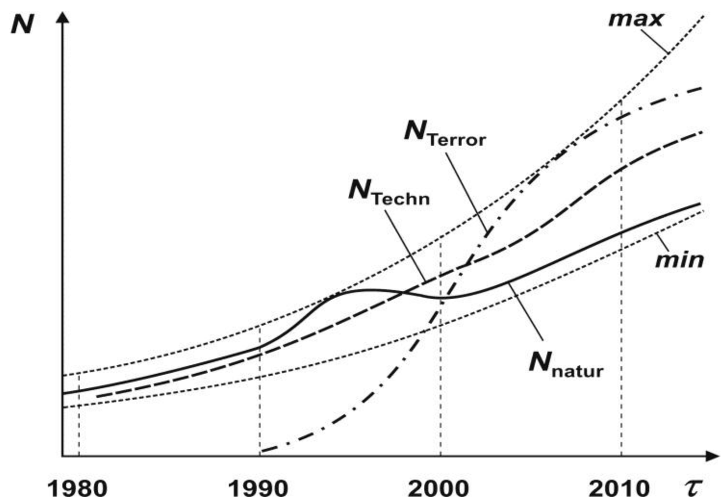

Fig. 2. Changes in the number of emergencies of different nature.

In case of traditional terrorism the main losses are inflicted to people and technological objects by the initial damaging factors, i.e. explosions, fires, shooting. The technological terrorism implies acts of terrorism at which the major losses are inflicted not by initial impacts but by subsequent failures of technical objects.

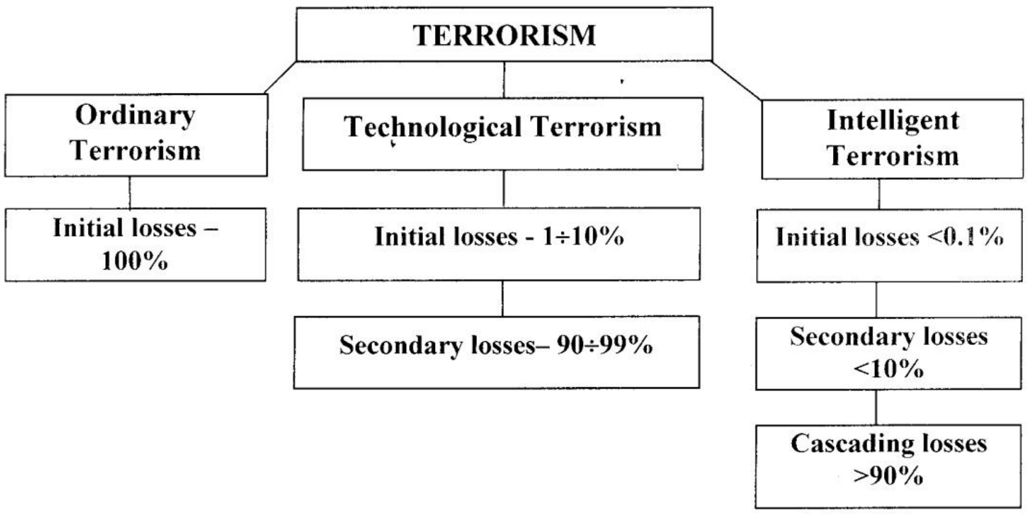

Fig. 3 Types of modern terrorism

The data cited above undoubtedly indicate the key role of the human factor (errors and unauthorized impacts on objects) in transition of technical facilities, on transport infrastructure from normal conditions into emergency and catastrophic ones.

It should be noted that the Russian railways carried out a high skilled analysis of terrorist attack at Neva-express train using advanced mathematical methods and mathematical modeling. This work was conducted to prevent such accidents of terrorist and technogenic character, but it was shown here that human interference that had not been considered before can essentially change all protection solutions.

The WTC attack in New York of 9.11.2001 had a special and obviously expressed terrorist orientation. This attack was a typical example of modern terrorism. There was all three basic components of terrorism: traditional, technological, and intelligent ones. The American and Russian scientists carried out a detailed analysis of the attack and got a number of important results [5].

Realization of the above threats will result in: long-term disruption of national and regional economic and technological processes; atmosphere of fear and panic; large human toll; and technological and environmental losses. The degree of potential danger of the technological facility determine whether the emergency caused by acts of technological terrorism will be of transfrontier, federal, regional, territorial, or local character

Initial, secondary and cascade damaging factors of technological terrorism include:

- exposure to radiation;
- poisoning and contamination by dangerous chemical substances;
- bacteriological contamination;
- blast waves and shock actions;
- heat radiation and heat loads;
- mechanical effects and mechanical loads;
- impulsive acceleration and loads;
- electromagnetic loads;
- kinetic effects of flying debris and parts of objects.

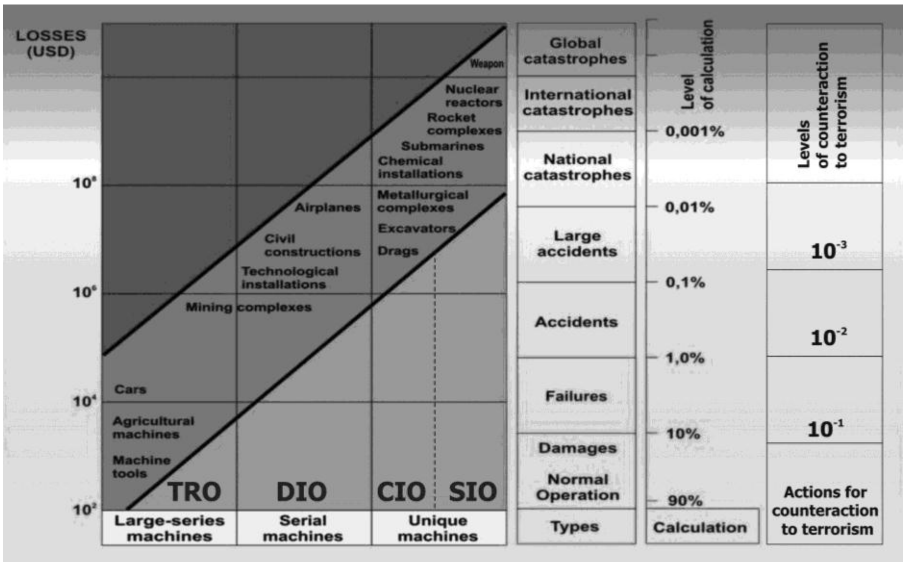

Fig. 4. Loss levels in disasters at different types of facilities

Each of the indicated damaging effects of technological terrorism, or their combinations should be characterized and determined by quantitative indexes at different stages of accidents and disasters development. Of essential importance is the type of the technological facility at which the terrorist action is aimed. The targets can be either unique industrial facilities whose number is small, but the potential loss from the lay-up proves significant (Fig. 4); or large-scale production facilities of large number.

A comprehensive obligatory program that would define the composition, sequence, organization, basic foundation, content and stages of fulfillment of measures to ensure the target level of protection and safety, is one of the important elements of ensuring the safety of technological system functioning. The program can be developed either for a component of the system or for a group of complex facilities integrated by their functional importance or technological process. Such program should describe:

- the required levels of protection for technological systems including those in emergencies;
- ways to achieve the required level of protection for technological systems (reasonable design and structural solutions; the use of reliable and good equipment and its reservation);
- protection systems ensuring the required level of error-free operation of personnel etc.;

- ways to maintain the required level of system operability in emergencies including the use of protection systems (disaster management);
- ways to mitigate consequences of the accident at the facility or protection system;
- methods to achieve the required level of training of personnel (safety culture);
- the system of accounting, enumerating, and analyzing the reasons for failures, unauthorized and terrorist actions during the technological system operation;
- responsibility of operating organization;
- independent control and supervision structures;
- the experience of operation, testing and studying of protection systems.

In developing programs and program measures on methods of analyzing and preventing terrorist and unauthorized actions it is necessary to account for different levels of fundamental and applied developments in this sphere. The following studies can be labeled as fundamental:

- development of the theory of and new methods for modeling manmade disasters with the allowance for terrorist and unauthorized actions that cause strong perturbations in social, economic, and complex technological systems;
- development of the general and criterial base of strategic risks and analysis of the interface between the technological terrorism risks and other kinds of strategic risks;
- development of scientific, principles, legal and economic mechanisms to counter terrorist actions.

Applied studies in prevention of terrorist and unauthorized actions should be aimed at:

- developing interdisciplinary methods for the assessment and management of technological terrorism risks;
- developing systems of technological terrorism monitoring (early on-line and mobile diagnostics, data bases, mathematical modeling of scenarios, risk maps);
- prevention of terrorist impacts on the technological sphere and protection of operators, personnel, population, and facilities (systems of nonlethal action, mobile robots, chemical marking of explosives, programmable fuses, special sprays, etc.).

Considering the complex of civil infrastructure facilities as an example, one can see (Fig.5) that the nature, technical and human factors are a great importance among the factors affecting the possibility of lay-up of those facilities. Here the human factor includes a large set of notions. Among them can be a researcher that defines the functional loading of the facility, an officer that inspects his work, operator, or a political figure. It is clear that each of them should have a specific level of qualification within his or her personal duties. If they do not have enough knowledge, skills, or ability to make adequate decisions in critical situations, it can contribute to creation of conditions for accident occurrence at the facility. In context of technological and intelligent terrorism the first groups of human factors presented in Fig.5 are most vulnerable.

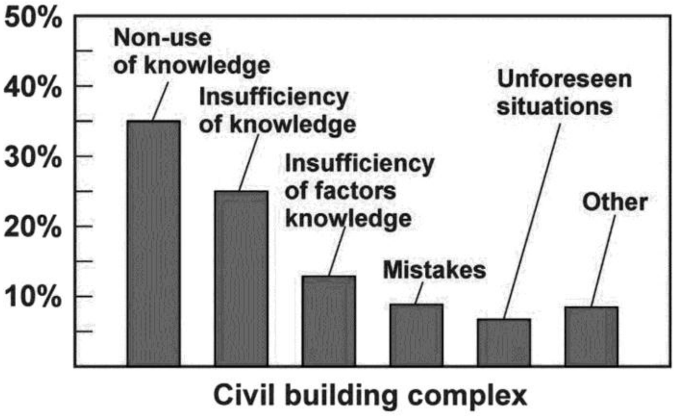

Fig. 5. The structure of human factors' affecting the conditions for the occurrence of emergencies.

The development of methods and systems for the analysis of technical, nature and human factor during industrial catastrophes, terrorist and counterterrorist actions can be among the basic developments on risk analysis and safety procurement (Fig 6). Terrorist and counterterrorist impacts on man of wide rang of types (mechanical, chemical, bacteriological, or psychological ones) and intensities result in the change of human response to those impacts. Under conditions of limited or no time for the scrupulous study of that response attention should be paid to the development of:

- methods and systems of real time complex analysis of changes in spectral characteristics of cardiograms and encephalograms with the application of special operational diagnostics parameters;
- methods and systems of diagnostic radar measurement of diagnostic parameters of human object in normal and abnormal situations with consequent or real-time analysis of the specters of those parameters.

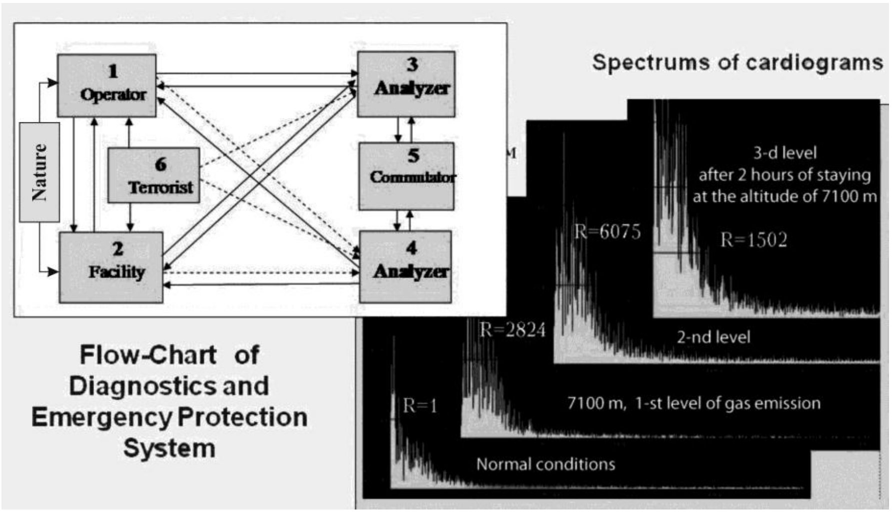

Fig. 6 The system of diagnostics and protection from unauthorized actions of operator in emergencies

The study of the scientific foundations of such methods with mechanical, operative, vacuum, chemical, and psychological actions on man allowed us to create models and prototypes of the corresponding diagnostic complexes [1].

Scheme and results of diagnostics of operator in the pressure chamber with the imitation of his being at the altitude of 7100 m, with the registration of his cardiogram and the calculation on its basis according to the algorithm of his capacity to work *R*. The state of the operator is also influenced by both environmental factors and potential terrorists. The results of such diagnostics whose information value qualitatively increases allow one to essentially protect the object controlled by the operator from unauthorized action. Of importance is the question of selection of parameters meant for such complex diagnostics. We believe that the spectral analysis of such complex dynamic systems as man-machine interfaces, will give very important information. Such analysis carried out at some technological facilities and humans showed that on the whole if the human organism or a technological object goes over to a abnormal or catastrophic state, then the specter obtained after the diagnostics leaves the range of high frequencies for the range of low frequencies, which is the main symptom of their approximation to critical state [1].

Unauthorized and terrorist impacts and technological terrorism as a whole will further be transferred to the complex man-machine systems (airliners, nuclear power plants, space-rocket hardware, underwater and above-water transport complexes, chemical facilities, ammunition dumps etc.). Operators, personnel and high risk technological systems can be subjected to those impacts. Under such conditions the basic targets of research become:

- early on-line diagnostics of man-machine system on the initial stages of actions using new detection methods and systems in real time with high resolution capability;

- automatic engaging systems of functional protection of technological facilities with the development of dangerous damaging factors in man or object.

3. Engineering approaches in structures design

Further development of science and technology progress, implementation of large-scale projects and preservation of ecologically sound environment will entail a hazard of origination of technogenic, natural and natural-technogenic catastrophes causing regional, national and global consequences.

Further development of complex technical systems within the lifetime ranges from seconds (rocket-space vehicles) to 50-100 years (nuclear reactors, engineering facilities) regardless new safety criteria which characterise these systems' transfer to final condition threatening people and environment, should be considered as unacceptable one. Quantitative substantiation for conditions of emergency origination should be calculated not only for normal operation conditions, but also for extremal ones which are caused by fractures, explosions, fires, leakages of radioactive and toxic substances, earthquakes, hurricanes, tsunami, aircraft and space vehicles' crushes, subversive actions. Safety assurance problem will be of vital importance for the nearest decades in Russia due to expiration of lifetime of large number of power units (including atomic ones), chemical and transportation apparatuses, complete replacement or modernization of which requires significant financial and intellectual expenditures.

As was marked above, owing to comparative stability of general mechanisms of emergency propagation at various types of facilities, it would be advisable to foresee two levels of safety norms and standards [1, 2], while forming general safety norms structure (Fig. 7): unified safety norms - USN (for main types of objects); technical sites' safety norms - TSSN (for the given type of object).

The first chapter of materials on USN should contain the following: general requirements for safety analysis of objects; potential hazard level determining for objects; emergencies classification according to their technological; economic, social, political, ecological basic consequences; accidents' type classification according to the reasons of their initiation; accidents' type classification according to probability level of their outburst; accidents' character classification according to relevant groups of affecting factors.

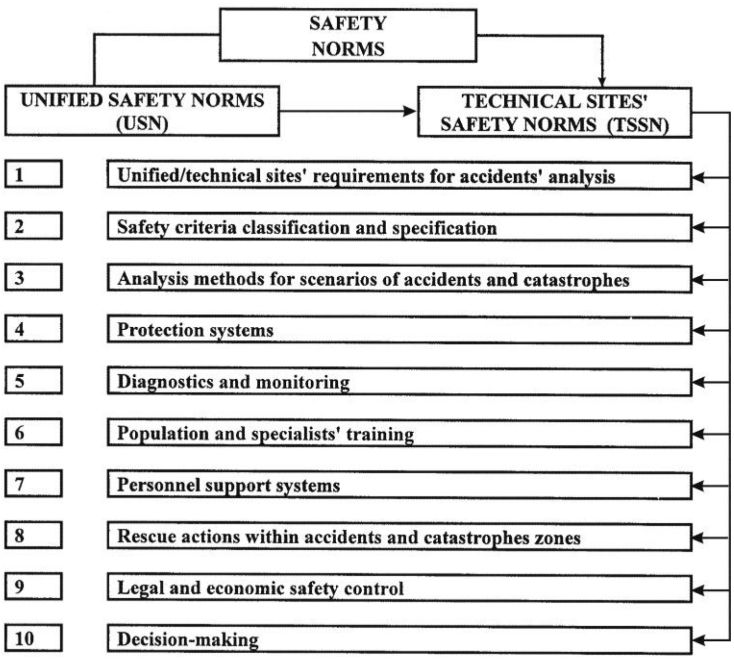

Fig. 7. Structure of unified safety norms

As regards to the 2th chapter of materials on USN, it should contain classification and specifications of both qualitative and quantitative safety criteria. Quantity and combinations of required criteria values should be connected with classes, types and character of accidents and catastrophes.
As regards to the 3rd chapter of materials on USN, it should contain analysis methods of initiation and propagation terms for emergencies' scenarios from the point of view of modern fundamental science, the major attention should be paid to mathematics and physical modelling for emergency propagation and pertinent response to it.
As regards to the 4th chapter of materials on unified safety norms, it should contain general information on selection of emergency protection systems for population, environment and technical sites.
As regards to the 5th chapter of materials on USN, it should contain general requirements for objects' diagnostics and monitoring not only in regular situation but also in emergency. The diagnostics should cover technical facilities, their personnel, population and environment.
As regards to the 6th chapter of materials on USN, it should contain general requirements for training methods for population and specialists' response in emergency (at accidents' initiation and propagation stages).
As regards to the 7th chapter of materials on USN, it should contain systems and means of support, training and retraining of operators at potentially hazardous facilities.
As regards to the 8th chapter of materials on USN, it should contain emergency response measures of personnel, population, search-and-rescue services for accidents' localization and liquidation of their consequences.
As regards to the 9th chapter of materials on unified safety norms, it should contain requirements on legal and economic safety control.
As regards to the final chapter of materials on USN, it should contain general recommendations on decision-making at local, governmental and international levels in emergencies and in the course of their consequences' liquidation.
Concerning materials on technical sites' safety norms (TSSN), they should contain: a list of basic distinctive features of potentially hazardous objects; chosen class, type and character of accidents and catastrophes; quantitative and qualitative safety criteria; recommended assessment methods for prediction of probable emergency propagation; diagnostics and monitoring methods for objects and environment in usual situations and in emergency; population and specialist's training for emergency response measures; personnel life-support methods and means in emergencies; measures on protection of operators, environment and technical sites; recommendations and requirements for actions to be undertaken in emergency areas; legal and economic standards for safety control; recommendations on decision-making at relevant levels.
Thus, while developing the above unified scientific principles of safety standards, there should be taken into account: potential hazard level of the objects, types of accidents and emergencies (regular operating conditions, deviations from normal operation terms, predicted/unpredicted/hypothetical accidents), comprehensive safety criteria system and affecting factors' assessment.
For development of the safety norms the methods of the fracture mechanic (Fig. 8) have priority importance. In a problem 1 (Fig. 7) at the analysis of emergencies a complex of extreme working influence should be determined

$$Q_{\max} = \{P_{\max}, K_{\max}, t_{\max}, \tau_{\max}, N_{\max}\}, \qquad (1)$$

where $P_{\max}$ - maximum mechanical, thermal, electromagnetic, dynamic and other loads at normal operation; $K_{\max}$ - factors of maximum operational loads increase at the beginning and development of emergencies for time τ; $t_{\max}$ - maximum temperatures at extreme loads during development of emergencies; $\tau_{\max}$, $N_{\max}$ - time and limiting cycles number of working loads.

On the base $Q_{\max}$ it to possible to determine the local stress and strain at the concentration zone

$$\{\sigma_{\max e}, e_{\max e}\} = \{K_\sigma, K_e, Q_{\max}\}, \tag{2}$$

where K_σ, K_e - stress and *strain concentration factors* in elastic-plastic state

$$\{K_\sigma, K_e\} = \{\alpha_\sigma, Q_{\max}, m\}, \tag{3}$$

where α_σ - theoretical stress concentration factor, m - hardening parameter for elastic-plastic deformation.

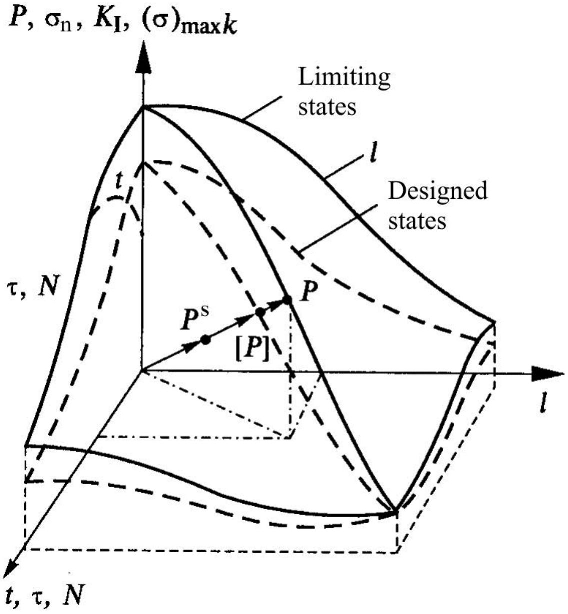

Рис. 8. Scheme of build-up of the limiting and design states and surfaces

For the decision of a problem 2 complexes of safety criteria n_s are selected at determination of margins factors for strength, temperatures and life

$$n_s = F\{n_{p,k}, n_t, n_{\tau,} n_N\}, \tag{4}$$

$n_{p,k}$ - margins factors for critical loads P_c; n_t - margins factors for critical temperatures t_c; n_τ - margin factor for critical time τ_c; n_N - margin factor for critical cycles of number N_c.
These margins are established from the analysis of extreme and critical parameters

$$n_{p,k} = \frac{P_c}{P_{\max} \cdot K_{\max}}, \qquad n_t = t_c - t_{\max}, \qquad n_\tau = \frac{\tau_c}{\tau_{\max}}, \qquad n_N = \frac{N_c}{N_{\max}}. \tag{5}$$

The values of P_c, t_c, τ_c and N_c are calculated by the equations and criteria, accepted in the fracture mechanic (P_c, t_c, τ_c, N_c), long strength (τ_c) and fatigue (N_c).
In the fracture mechanic for the analysis of emergencies traditional and new criteria are used

$$\{P_c, t_c, \tau_c, N_c\} = F\left(K_{Ic}, K_{c\varepsilon}, \delta_c, J_c, \frac{dl}{d\tau}, \frac{dl}{dN}\right), \tag{6}$$

where K_{Ic}, $K_{c\varepsilon}$ - stress and strain intensity factors; δ_C - critical cracks opening; J_C - energy fracture criterion; $dl/d\tau$, dl/dN - cracks growth rate for time τ and cycles number N.
At the analysis of accidents scenarios on item 3 a complete combination of all parameters on the equations (1) - (6) is formed and minimum margins factors on the equation (4) are defined.
The protection systems on item 4 should provide such scenarios and condition, when margins on the equation (4) will be not lower required on item (1).
At development of diagnostics and monitoring methods on item 5 parameters P_c, t_c, τ_c, N_c, l on experimentally determined values K_{Ic}, $K_{c\varepsilon}$, δ_c, J_c should be supervised specially.
The training of the experts on item 6 should take into account continuous development and specification of the engineering decisions on the equations (1) - (6). Thus in control systems complexes of support and the acceptance of the decisions on the basis of models on item 1-6 should include.
If not it is possible to exclude occurrence of emergencies, at realization of emergency-saving works on item 8 it is possible to use also equations (1) - (6). Thus the margins n on item 2 should be determined in view of large and small damages of designs.
At the analysis of economic parameters on item 7 and of accepted decisions on item 8 the whole complex of scientific, design, technological and operational parameters, connected with fracture mechanics, is necessary.

4. General load and fracture conditions for structures integrity
Further development of science and technology progress, implementation of large-scale projects and preservation of ecologically sound environment will entail a hazard of origination of technogenic, natural and natural-technogenic catastrophes causing regional, national and global consequences [1].
Further development of complex technical systems within the lifetime ranges from seconds (rocket-space vehicles) to 50-100 years (nuclear reactors, engineering facilities) regardless new safety criteria which characterise these systems' transfer to final condition threatening people and environment, should be considered as unacceptable one. Quantitative substantiation for conditions of emergency origination should be calculated not only for normal operation conditions, but also for extremal ones which are caused by fractures, explosions, fires, leakages of radioactive and toxic substances, earthquakes, hurricanes, tsunami, aircraft and space vehicles' crushes, subversive actions. Safety assurance problem will be of vital importance for the nearest decades in Russia due to expiration of lifetime of large number of power units (including atomic ones), chemical and transportation apparatuses, complete replacement or modernization of which requires significant financial and intellectual expenditures.
The following classification of these objects can be offered to your attention, which takes into account their design structural peculiarities, the level of potential hazard to people and environment in case of technogenic and natural catastrophes generation: nuclear power engineering sites; chemical plants; special equipment - rockets, space vehicles, computer-aided systems; unique engineering structures; civil engineering sites; traditional and non-traditional power engineering sites; objects of machine building and metallurgy industries; transport systems; main pipelines; equipment for operation in low temperature conditions (Arctic equipment).
Owing to comparative stability of general mechanisms of emergency propagation at various types of facilities, it would be advisable to foresee two levels of life and safety norms and standards, while forming general codes structure [5-7].
For mentioned above structures with general service time from $10^1 \div 10^2$ s to $10^8 \div 10^9$ s it is possible to allocate the following areas of loading cycles number:
$10^0 \div 10^1$ - extreme cycles (start-up, test, breakdowns, catastrophes);
$10^2 \div 10^3$ - operational cycles (starts-up, regulation of capacity, operation of protection systems,

accidents);
$10^4 \div 10^5$ - operational cycles (technological cycles, regulation, accidents);
$10^6 \div 10^8$ - operational cycles (technological, transport cycles, changes of pressure);
$10^9 \div 10^{12}$ - operational cycles (vibration, changes of temperatures and pressure, accidents and damages).
The fatigue of metal constructional materials at numbers of cycles $10^0 \div 10^{12}$, that are used in complex technical objects, has four characteristic kinds:
$10^0 \div 10^3$ - low cycle quasistatic or fatigue fracture at availability of large microplastic deformations in a zone of failure (when amplitude of strsses $\sigma_a >> \sigma_Y$, where - σ_Y is a Yield limit);
$10^3 \div 10^5$ - low cycle fatigue fracture at availability rather small makroplastic deformations in a zone of failure (when $\sigma_e \leq \sigma_a \leq \sigma_Y$, σ_e - a limit of elasticity);
$10^5 \div 10^8$ - classical many cycle fatigue fracture at availability of microplastic deformations in micro and macro volumes near a zone of failure (when $\sigma_a \leq \sigma_e$);
$10^9 \div 10^{12}$ - fatigue fracture on superhigh bases (numbers of cycles) at availability of microplastic deformations in microvolumes near a zone of failure ($\sigma_a << \sigma_e$).
The availability of changes of pressure Δp, changes of temperatures Δt and vibrations gives high-frequency stresses amplitudes σ_{ah} (Fig. 9). It creates two- or frequencies loading with the frequencies relations $f_a/f_{ah}=10^1 \div 10^5$ and asymmetry factor $r_\sigma=\sigma_{\min}/\sigma_{\max}>0$.

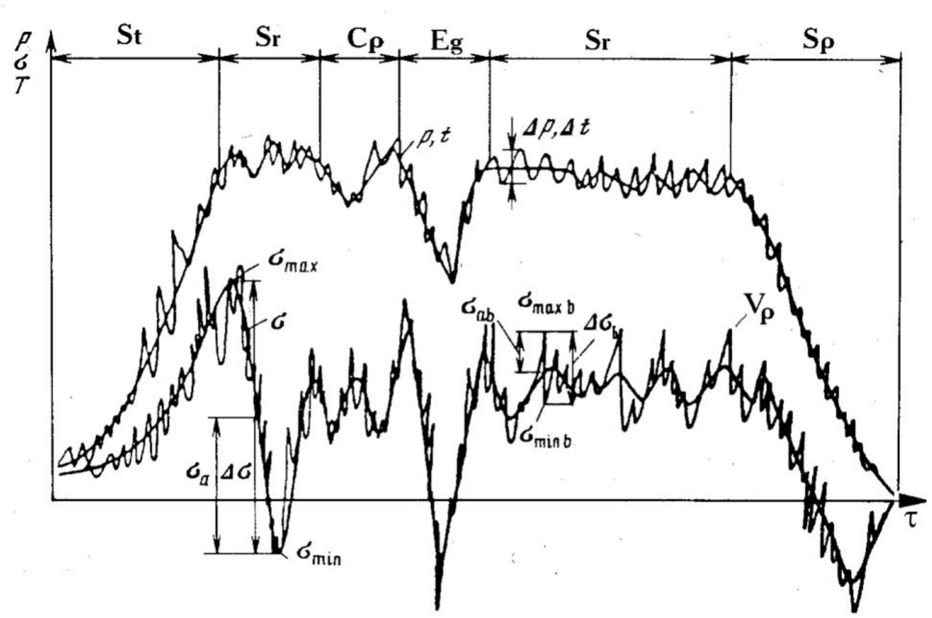

Fig. 9. The diagram for change of service loading parameters

Engineering diagram for generalized fatigue curve for coordinates "σ, σ_a-N" is shown on Fig. 10. On this figure: σ_{ai}, $(\sigma_{ah})_i$ - a amplitude of main and vibrating stresses for an i-mode; n_i, $(n_h)_i$ - a number of cycles for main and vibrating loadings; $[\sigma_a^*]$, $[N]$ - design stresses amplitude and lifetime (number of cycles); $[\sigma_n]$ - design nominal stresses.
These stresses it is possible to determine from a traditional account of static strength on ultimate σ_u and yield σ_Y limits.
The safety of constructions is defined largely by resistance to deformations and fracture of materials in zones of stress and strain concentration (Fig. 7, 8). Thus the analysis of safety is carried out for the following service cases: normal (regular) service conditions (*NSC*); deviation from normal service conditions (nonregular service condition *NNSC*); design accident situations (*DAS*); overdesign accident situations (*ODAS*); hypothetical accident situations *(GAS*).

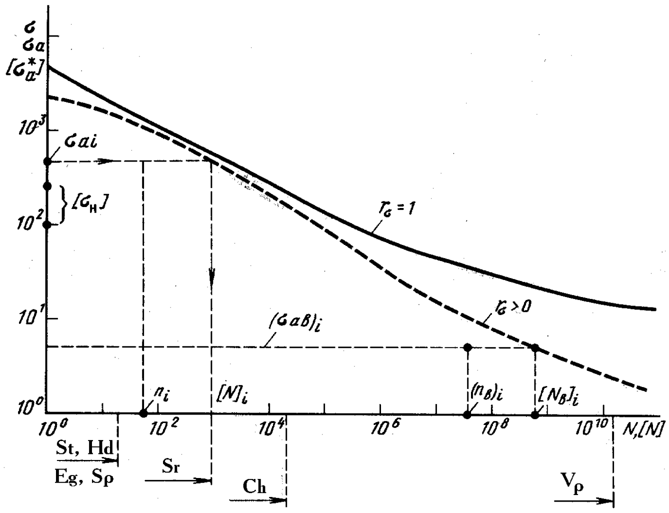

Fig. 10. The diagram for determination of the strength and resource characteristics

Fig. 11 shows dependence between service loadings P^s and stresses σ (strain e) for a pressure vessel. The left figure concerns to dependence of nominal stresses σ_n^s and strain e_n^s for outside concentration zones (curve 1) and for concentration zones (curve 2)

$$\{\sigma_n^s\} = f(P^s). \tag{7}$$

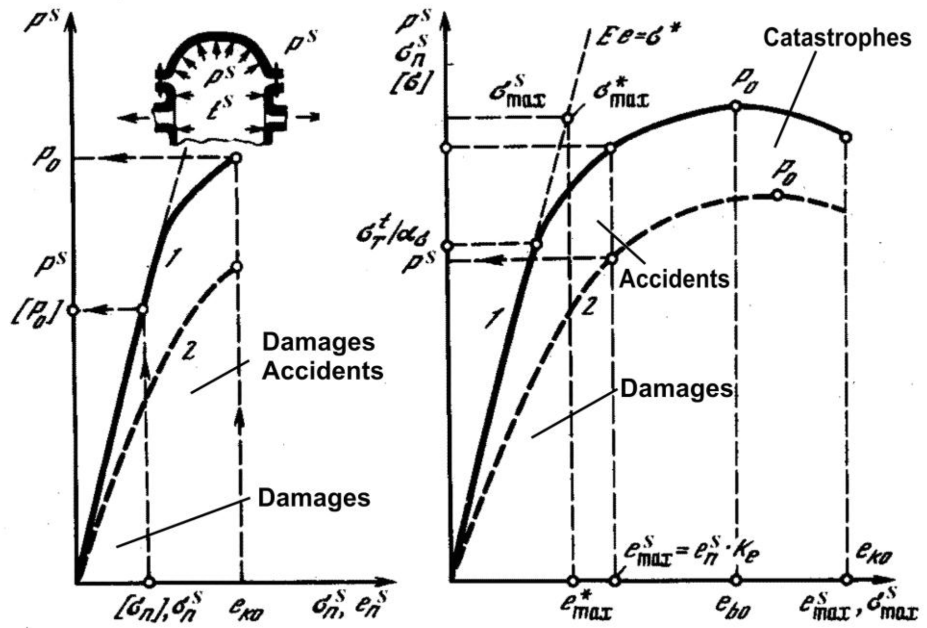

Fig. 11. Dependence between service loading and stresses (strain) for a pressure vessel

Limiting dangerous condition (fracture) is achieved at extreme loading P_o and nominal critical strain e_{ko} (or stress σ_{ko}). The strain e_{ko} is determined by cross narrowing ψ_k, and value ψ_k undertakes as minimal guaranteed value by technical specifications (by the standard).

At designing of structures for normal service conditions *NSC* are entered safety factors *n* and are established the admitted loadings $[P_o]$, stresses $[\sigma_n]$ or strain $[e_n]$ usual

$$\{[P_o],[\sigma_n],[e_n]\} = \left\{\frac{P_o}{n_p}, \frac{\sigma_{ko}}{n_\sigma}, \frac{e_{ko}}{n_e}\right\}. \quad (8)$$

The values of safety factors n_p, n_σ, n_e take usually in an interval from 1,2 up to 2,5. In this case the equation (1) at *NSC* is approximately linear $\{\sigma_n^s, e_n^s\} \propto P^s$.

At transition from nominal to the local stresses $\sigma_{\max}^s$ and strain $e_{\max}^s$ in concentration zones or outside of concentration zones for plasticity constructional metals and with the account of joint action of mechanical and temperature stresses the local stresses and strain become more than nominal stresses $\{\sigma_{\max}^s, e_{\max}^s\} \ge \{\sigma_n^s, e_n^s\}$.

The plastic strain in concentration zones and outside of zones concentration arise at excess by local stresses of a plasticity limit σ_Y^t for given temperature *t*

$$\frac{\sigma_{\max}^s}{\alpha_\sigma} \ge \sigma_Y^t \quad \text{или} \quad \frac{\sigma_{\max}}{\alpha_\sigma \cdot E^t} \ge e_Y^t, \quad (9)$$

where E^t - module of longitudinal elasticity for temperature *t*.

For *NSC* conditions at action of mechanical loadings P^s only it is possible to execute a ratio $\{\sigma_{\max}^s, e_{\max}^s\} \propto P^s$

At *NNSC-GAS* conditions the occurrence of nominal and local plastic strain can take place

$$\{\sigma_{\max}^s, e_{\max}^s\} = \{K_\sigma \cdot \sigma_n^s, K_e \cdot e_n^s\} = f_p(P^s), \quad (10)$$

where K_σ and K_e - are factors of stresses and strain concentration in elastic-plastic area.

The limiting maximal loadings P_o are achieved with large plastic e_{bo} strain. The final fracture occurs with real local strain e_{ko},exceeding this strain under the standard. Thus with at substantiation of structures safety in a *NNSC-GAS* range it is necessary to have an opportunity to analyze the equation (10) at $[P_o] \le P^s \le P_o$ with use of calculated methods (for example, method of final elements), of analytical methods (for example, Neuber-Glinka-Makhutov methods) or of experimental methods (for example, methods of photoelasticity, thenzometry, golography). In analytical methods it is possible to accept

$$\{K_\sigma, K_e\} = F\{\alpha_\sigma, \sigma_n, m\}, \quad (11)$$

where *m* - a hardening parameter for a deformation curve [5-7]

$$\sigma = \sigma_Y (e / e_Y)^m. \quad (12)$$

In process of transition from regular situations (*NSC*) to emergencies (*NNSC, DAS, ODAS, GAS*) specified above margins n_p and n_σ will be reduced in a limit up to 1. Thus margin factors are $n_e \ge \{n_p, n_\sigma\}$

When with regular situations and emergencies the cyclic loadings will act, the analysis of life and safety will be carried out with use of complex nonlinear dependencies as with definition of stress-strain states, and number of cycles before cracks initialisation N_0 (Fig. 12).

The procedure of account will consist of the following stages. On the equation (1) are determined nominal stresses σ_n and strain e_n. On these values and on theoretical concentration factors α_σ and with use of the equations (11) and (12) the concentration factors K_σ and K_e are determined. On curves of static deformation (2σ-$2e$) and on curves of cyclic deformation (S-ε) it is possible to find ranges ($e_{\max}$) and amplitude $\left(e_a = \frac{e_{\max}}{2}\right)$ of strain.

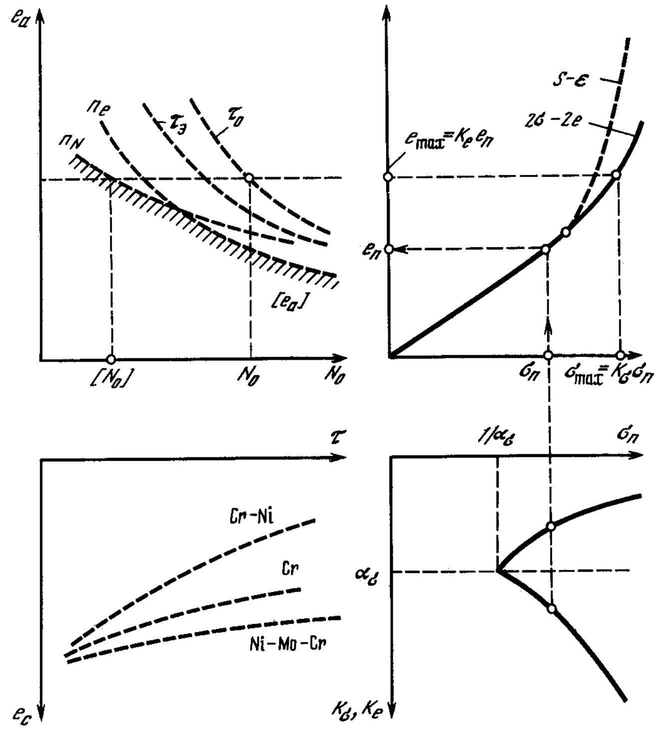

Fig. 12. The diagram for analysis of life-time and safety

Further for initial time τ_0 on base of the Koffin-Manson equations the dependence "e_a-N_0" is defined. If to take into account real time of operation τ_s with temperatures t and change of critical deformation e_c, then by the Manson-Makhutov equation can define the specified curve "e_a-N_0. On this curve with introduction of margins for strain n_e and on number of cycles n_N, the calculated curve "[e_a]-[N_0]" is defined. Usually the margins n_N=N_0/N^s for regular situations *NSC* accept in a range 10-20. With transition to emergencies *NNSC-GAS* these margins are reduced up to 1-3. Then on series of curves "[e_a]-[N_0]" for each emergency it is possible to establish accumulated damages in concentration zones

$$d_i - \sum \frac{N_s}{[N_0]} \le 1. \tag{13}$$

This equation (13) is used for definition of an admissibility of the further operation after occurrence of emergencies.

Russia has started to develop special counterterrorist programs at the national level. A number of documents to outline the scientific basis of the national policy in the sphere of national security is to be developed. The RF Security Council is now considering all complex of scientific, organizational, economic, and administrative questions of overcoming terrorist threats. The federal ministries and the Russian Academy of Sciences participate in this work (Fig. 13).

Concepts of National Safety were developed in Russia and in the United States of America before 2005. The next level of the national document was developed and approved in Russia in 2009. It is called the Strategy of National Safety of the Russian Federation until 2020 [8]. It should be noted that in some articles of the document terrorist threats and measures to decrease risks of terrorist attacks are directly specified. Thus on the basis of the Strategy the program of its realization is being developed. In this regard the RF Security Council session was held last week where the Ministry for Emergencies and the Russian Academy of Sciences put forward a problem on protection of critical and strategic facilities against emergencies of natural, technological, and terrorist character.

Fig. 13. Government Regulatory bodies in the sphere of National Security

When the national documents for the most critical infrastructures are developed the efforts will be focused on hazardous facilities of smaller risk. About two hundred strategically important facilities, about four thousand critical facilities, about three hundred thousand hazardous industrial facilities and millions of facilities subjected to technical regulation will be identified in Russia. Thus for each of the four groups of facilities with specific terrorist risks levels a set of legislative and administrative documents that would regulate safety and security management, procedures for designing, testing and training of personnel will be developed.
These scientific, legal, and standard developments will be worked out during the next years, and carried out at national and international levels.

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