THE EXPLOSION-PROOF CONTAINER, SATISFYING THE IAEA NORMS ON SAFETY

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INTRODUCTION

Safety of radioactive materials (RM) transportation is under strict control of the international norms of IAEA, aimed to ensure non-proliferation of hazardous materials in the environments. At the same time the nuclear countries use much more dangerous transportations of two types of hazardous materials. They include transportations of RM in combination (directly close in construction) with high explosives (HE), as it takes place, for example, in the nuclear weapons (Hansen,1988). According to the IAEA norms, safety of such transportations should be provided by national standards (IAEA norms,1985). Besides, the IAEA norms do not take into account possible terrorist devices, where explosives and radioactive materials can be also combined.

Probability of emergency explosion of HE during transportation and storage of such constructions is not equal to zero. HE explosion can be caused by:

- excess of mechanical effects, allowable by the norms, on an explosive;
- lightning or fire;
- terrorist attack (firing with small arms or an grenade launcher (bazooka));
- radiocontrolled or timecontrolled mechanism in case of the terrorist device.

One can not exclude the threat of terrorist capture and blackmail by radioactive pollution with aimed explosion of HE in the nuclear charge.

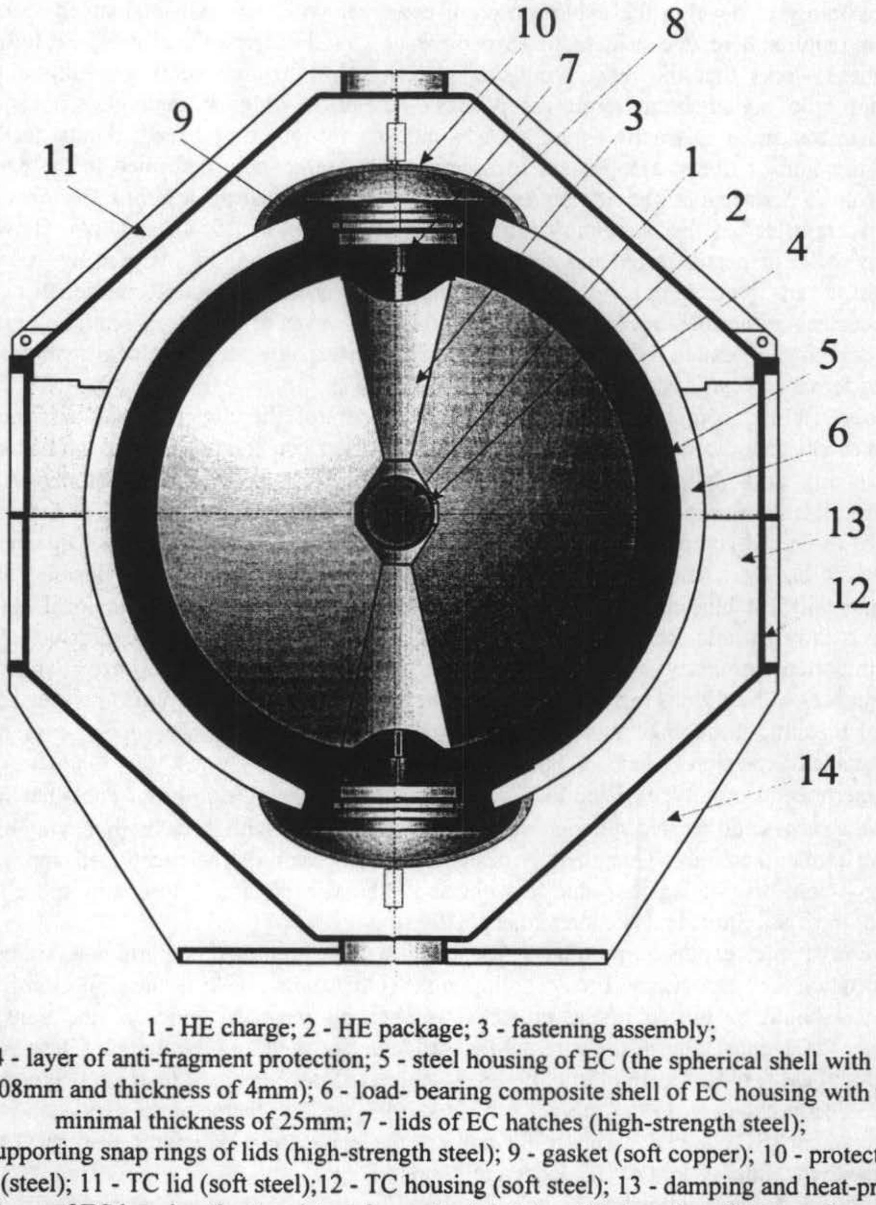
It is obvious that an accident with explosion HE element of the nuclear weapon in an usual container, which meets the IAEA norms, but is not explosion-proof, will result in its destruction, RM dispersal, and inadmissible pollution of the environments.

Therefore, there is urgent need for development of the container, which is able to withstand explosion of HE, placed in it, and to confine released RM inside of it (Ivanov et al.,1995). As this takes place, it is rather desirable to provide the minimal release and dispersal of hazardous materials in the case, when the explosion is caused, for example, by break-through of the container wall from the outside by cumulative jet of a grenade launcher shell. It is obvious that such especially strong container should also withstand usual tests of the IAEA for normal and abnormal conditions of operation (i.e. test for falls, impact and an external fire), since it contains RM.

Let us consider the basic conceptual moments typical for development of the container with the specified properties and some numerical estimations of its constructive characteristics and strength.

The possibility to develop the explosion-proof container with maximal guaranteed specific strength, required here, is considered in (Syrunin et al.,1993,Fedorenko et al.,1995). It follows from these works that the most promising materials for the load-bearing casing of the explosion-proof container are fibrous composites on the basis of high-strength glass fibers of a small diameter and a polymeric binder, used by industry for long time already. Under loading in the direction of fibres arrangement such composites are actually deformed in the elastic manner up to destruction. They do not suffer from threshold catastrophic brittle fractures and strong scale effect of the energetic nature (Ivanov and Tsypkin ,1987), and they allow to perform shells of needed sizes and shape by the winding method. To increase the specific strength at an internal pulse loading, the necessity is experimentally established for reinforcement of the load-bearing shell from within by a layer of soft steel, providing rather quick damping of exited vibrations, which are dangerous due to possible growth of the bending forms and earlier destruction (Tsypkin et al.,1987).
Moreover, fibrous composites give opportunity to control the direction and scheme of reinforcement that allows to develop optimum and stronger constructions of the load-bearing shell, having both cylindrical and more compact spherical geometry (Fedorenko et al. 1991,1995). It is necessary to note on ability to keep constructional intactness after breaking-through of metal-composite vessels under high pressure, used in space engineering (Khaled,1991), by a high-velocity projectile (e.g. a bullet, a fragment). Besides, it is experimentally established (Tsypkin et al.,1981) that glass-epoxy shells with local defect, such as a through hole, keep rather high residual strength against internal explosive effect. This important property of metal-composite vessels allows to minimize dangerous consequences of hazardous materials release from their cavities, if the explosion is caused by external breaking-through of the casing followed by effect of cumulative jet of a grenade launcher shell explosion and etc. on HE.
The experimental prototype of the load-bearing shell of the explosion-proof container (EC) can be the successfully tested spherical steel - glass plastic shell with ⌀=500mm, having high-strength throats and lids. This shell is designed on the basis of the mentioned approach. Having weight of 45-50kg it is able to withstand internal explosion with energy more than 1.4kg of the TNT equivalent (Fedorenko et al.,1995).
To preserve the explosion-proofness property in the abnormal environments during transportation (i.e. impacts and fire according to the (IAEA norms,1985)), the explosion-proof container should be placed in the protective supporting-transport device or the transport container (TC), consisting of the external thin-walled steel shell and the damping heat-proof layer from heat-resistant foam plastic. Figure 1 depicts the developed as analog of (Syrunin et al.,1993,Fedorenko et al.,1995,Carbiner and York,1993) design scheme of the explosion-proof supercontainer (SC), aimed basically for antiterrorist application, satisfying also the IAEA norms with maximal weight of HE, loaded in it, up to 5 kg.
To justify the design parameters of such container, the tests for development and revision of the numerical model parameters were carried out. With use of this model the calculations were performed to calculate loads and the container response to:

- internal explosive effect;
- accidental impacts according to the IAEA norms (i.e. fall of the container against a rigid slab from the height of 9m, against a bar from the height of 1.2m, fall of a steel slab with weight of 500kg against the container from the height of 9m);
- heating in standard fire, including the state of the heat-proof layer after an accidental impact.



1 - HE charge; 2 - HE package; 3 - fastening assembly;
4 - layer of anti-fragment protection; 5 - steel housing of EC (the spherical shell with ⌀=808mm and thickness of 4mm); 6 - load- bearing composite shell of EC housing with the minimal thickness of 25mm; 7 - lids of EC hatches (high-strength steel);
8 - supporting snap rings of lids (high-strength steel); 9 - gasket (soft copper); 10 - protective caps (steel); 11 - TC lid (soft steel);12 - TC housing (soft steel); 13 - damping and heat-proof layer of TC housing (heat-resistant foam plastic); 14 - stiffening ribs of TC housing.

Fig. 1. Supercontainer design scheme.

INTERNAL EXPLOSIVE EFFECT

Correctness of the performed calculations on justification of the container strength against explosive effect was verified by comparison of the experimental and numerical data on time dependence of deformation on the external surface of the foam plastic shell. A small-scale model of EC (⌀500mm) was considered as the object for testing and calculation.

The conducted experiments with the EC model can be divided into two groups according to the loading level. The first group of experiments is associated with loading of the chamber by explosion of HE having low power (the HE weight is 0.15kg of the TNT equivalent), and the second group - by explosion of HE having the power level close to the limiting one (the HE weight is 1.3kg of the TNT equivalent). As this took place, in both the first and the second groups of experiments the object for testing consisted of two explosive chambers (a chamber of type 1 and a chamber of type 2), which were differ in schemes of winding glass threads in the glass plastic layer of the housing. (The 1-st scheme of winding provided 1.8 times thickening of the composite layer in the zone of throats regarding to thickness at the equator, and the 2-nd provided approximately constant thickness of the layer.)

The calculations for determination of gas-dynamic load on the chamber walls were carried out with use of the B-71 program, and for determination of the strain-stress state - with use of the DRAKON program (the both programs were developed in VNIIEF). The numerical scheme of the EC model design is presented in fig.2.

The results of comparison between the experimental and numerical data on time dependence of deformation in the equator zone at the glass plastic shell during explosion of HE with weight of 0.15kg and 1.3kg are tabulated in Table 1. Analysis of this results points to rather satisfactory agreement between them.

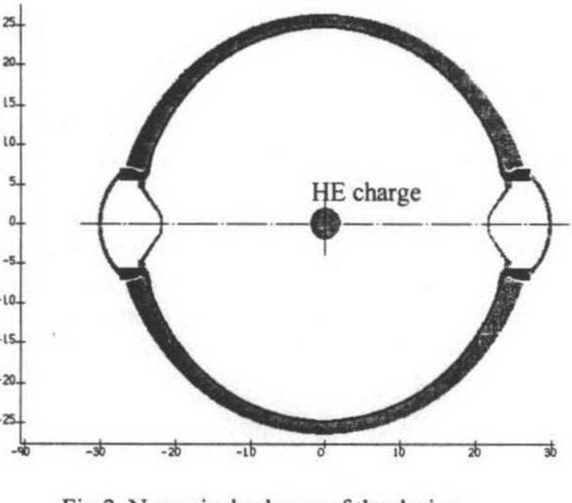
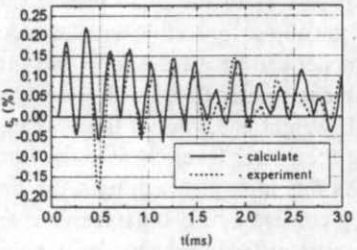
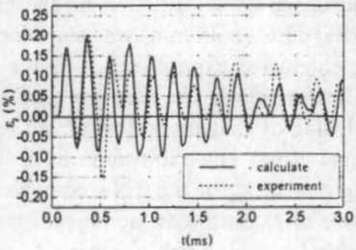


Fig.2. Numerical scheme of the design.

Table 1

<table>
<tr><th>HE weight, kg of TNT equivalent</th><th>Explosive chamber of type 1</th><th>Explosive chamber of type 2</th></tr>
<tr><td>0.15</td><td>
</td><td>
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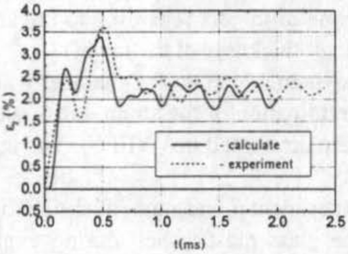
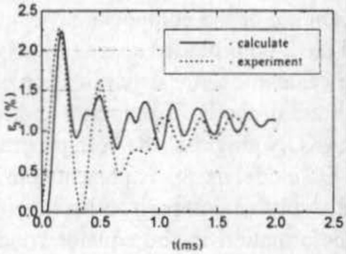
<tr><td>1.3</td><td>
</td><td>
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ACCIDENTAL EFFECTS (ACCORDING TO THE IAEA NORMS)

The program complex DRAKON was used for numerical research of the SC model response to the abnormal environments (fall of SC against a rigid base from the height of 9m, fall of a steel slab against SC from the height of 9m, fall of SC against a bar from the height of 1m). Foam plastic with density of 0.3g/cm³ was considered as a damping material, filling space between EC and TC. According to the performed thermal calculations and experiments the assumed thickness (60mm is the minimal thickness for model SC) and density of foam plastics provide the needed level of EC heat-resistance against fire effect covered by the IAEA norms.

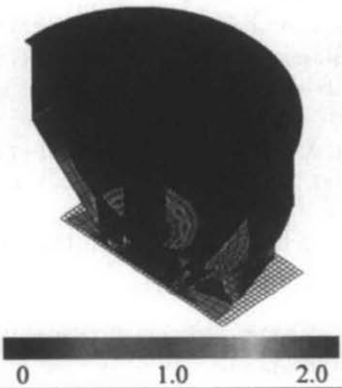
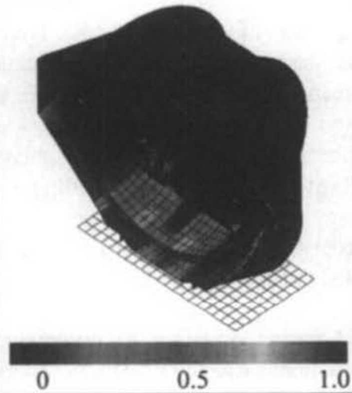
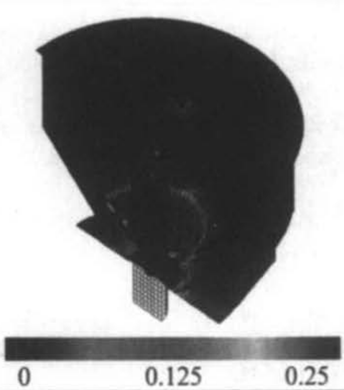
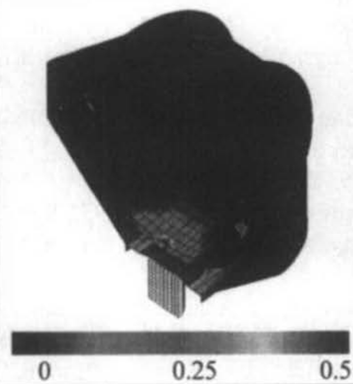
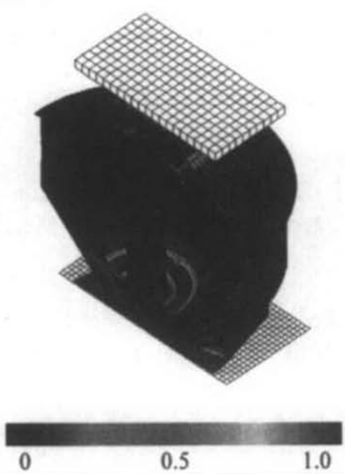
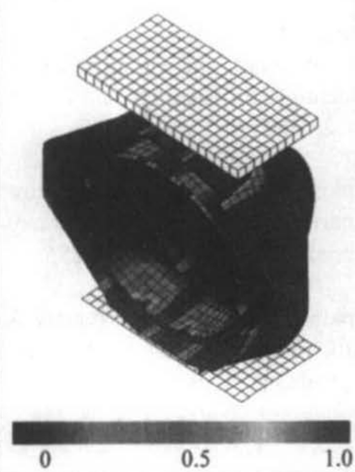
Results of the performed calculations for determination of SC response to the abnormal environments (according to the IAEA norms) are tabulated in Table 2. The table presents the design shape and deformation intensity field distribution character (in %) at the time moment of 15ms, when the process of active deformation of SC is completed.

CONCLUSION

The obtained results confirm that the developed SC design satisfies the IAEA norms for strength in the abnormal environments. In particular, the level of achievable deformations for the load-bearing shell of EC does not exceed the destroying deformations (≈3.5% (Ivanov and Fedorenko,1993)), and the local crumpling of the heat-resistant foam plastic layer of SC does not exceed ≈30%, that is allowable according to the condition of providing protection of EC against heat and EC explosion-proofness preservation after a fire.

The considered design of the explosion-proof supercontainer allows to solve the problem of safety storage and transportation of hazardous cargoes containing radioactive materials and explosives.

Table 2

Fall type	Axial fall	Side fall
Fall against a rigid slab from the height of 9m		
Fall against a bar from the height of 1.2m		
Fall of a steel slab against the container from the height of 9m		

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