Explosive- and Fire-Resistant Steel Concrete Cask for Packaging and Transportation of Radioactive and Hazardous Materials

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INTRODUCTION

Today design of the Steel Concrete RBMK Casks are alternative to using the Ductile Cast Iron - CASTOR RBMK Casks for the transportation and storage of the fuel elements. The Ductile Cast Iron and Steel Concrete Cask were developed by Gesellschaft für Nüklear-Behälter mbH.

The Steel Concrete RBMK Cask has the advantage of being easier to fabricate in countries without high standard heavy industries, eventually at the power station itself, and have a more favorable price.

Scheme of the Steel Concrete RBMK Cask is shown in the Figure # 1. In this cask the high density concrete(≥ 3.5 g/cm ^{3}) is placed between 40 mm thick metal shells. Concrete is the shielding for the nuclear radiation.

The accidental external heating of a cask and the internal heat capacity will cause the vapour explosion of the contents of a cask in the hypothetical conditions. Using the porous concrete(refractory materials - damper) will decrease the heating of the contents from an external source at an interval time and mitigate the blast transmission from an internal explosion to the walls of cask.

This work is an experimental test of the Steel Damper Cask to the internal explosive events.

SETTING UP AN EXPERIMENT

Diagram of the experimental setup is shown in the Figure # 2, where:

A - scheme of the Steel Cask (one-layer cask).
B - scheme of the Steel Damper Cask (three-layer cask).
The total thicknesses of the steel walls in these schemes are equaled approximately. Material of walls was the drawn pipes from the stainless steel X18H10T(Russian). Water and air were the simulations of the cask's contents. Water or water with the air bubbles(3 v %) were a simulations of damper. Diameter of the bubbles was 2-5 mm.
Detonation on an long cylindrical explosive charge(with TNT equivalent) arranged longitudinally with the cask axis simulated an accidental sudden energy release. Detonation of 1 g of TNT released 4.23 kJ energy.
The deformation of the casks $\varepsilon(t) = [R(t)-R_0]/R_0$, where R is the value at time t of the external radius of the cask. R_0 the initial value, was determined by means of photorecords and strain gauges. Moreover the

final deformation of the casks was recorded on a coordinate grid scribed on the outer surface.

For comparison we have given the supplemented results of the experiment about an explosive resisted by the one-layer and three-layer air-filledcasks only.

EXPERIMENTAL RESULTS

The tests were carried out for the single loading.

The determining parameter for investigated events is the ratio of the energy generating of explosive charge mass m to the mass of cask M(on unit length), which must absorb this energy.
The parameter

$$k = M/m_f$$

is a measure of the strength of cask(the limit of absorbed energy), where m_f - minimum mass of TNT for which an external wall of cask was destroyed, M - mass of the wall casks. Practically m_f is the mean of the two closest values of the masses of those charges m for which the external wall of cask fails, and does not fail. This demanded 2 to 4 shots.
It may be shown that

$$k = A/\sigma_f,$$

where

A - Constant,
σ_f - the fracture stress of the material wall.

The appearance of through crack in an external wall of a cask was the criterion of the failure cask at the failure deformation ε_f.

The chief results are the following
1. For the one-layer casks
filled air only

$$0.44 * 10^2 < k < 0.69 * 10^2$$

or approximately $m_f \cong 1.8 * 10^{-2}$ M

$$\varepsilon_f \cong 4\ \%$$

filled water only

$$2.20 * 10^2 < k < 3.45 * 10^2$$

or approximately $m_f \cong 0.35 * 10^{-2}$ M

$$\varepsilon_f \cong 3.5\ \%$$

2.. For the three-layer casks
contents - air, damper - water

$$0.27 * 10^2 < k < 0.43 * 10^2$$

or approximately $m_f \cong 2.9 * 10^{-2}$ M

$$23\ \% < \varepsilon_f < 25\ \%$$

contents - air, damper - porosity water

unstable results $\quad k \sim 0.25 * 10^2$

or $\quad m_f \sim 4 * 10^{-2}$ M

$\varepsilon_f \sim 25\%$

DISCUSSION

The experimental results allow us to answer the important practical questions:

1. What structure of the casks is more suitable for the retention of an internal accidental sudden energy release?

Our results show the strong evidence for the Steel Damper Casks. Of course water or water with the air bubbles was a simulation of damper. The porous concretes satisfied these conditions(density, acoustic impedance of these materials agrees with these parameters for water approximately). But use of the porous refractory concretes will in addition decrease the accidental heating of the casks contents from an external source at an interval time.

2. What structure of the casks is more suitable for resistance under an external fire conditions ?

We have the experimental data about the thermophysical properties for the refractory concretes(chamotte, alumina, zirconium dioxide, silicate).

Limit of a temperature working for the zirconium dioxide porosity concrete is 1700 ^{0}C; for a bulding silicate solid concrete, 500 ^{0}C. Note of 1700 ^{0}C is a temperature burning of many carbon hydrides fuels. Using the method of the similarity(equality criteria Fourier), we can conclude that to exchange the solid building(silicate) concretes for the porous(porosity 50 %) concrete or ceramics on base a zirconium dioxide increases the time of the casks heating 4 to13 times approximately up to the same temperature(coefficients of the heat thermal conductivity(W/m*K): for the silicate concrete - 1.2 to1.3, for the porous zirconia concrete - 0.1 to 0.3).

3. What assessment can be made about the basic parameters of an explosive resistant cask by means of the results of this experiment?

Changing the relative wall thickness of the casks(at diameter = const) does not lead to any appreciable change in the parameter k(e.g., Ivanov and Mineev 1979).

Scale effect(k = f(diameter of cask)) is absent at an explosive fracture of a geometrically similar vessel from the stainless steel(e.g., Ryzhanski et al. 1996).

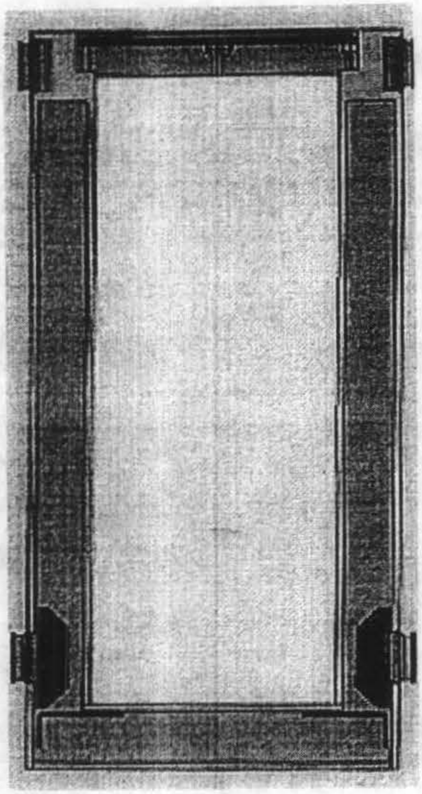
CONCLUSIONS

The results of the present paper are evidence that the using the porous concrete or ceramics on the base zirconia as damper in Steel Concrete Casks will decrease the heating of a contents from external source at an interval time and mitigate the blast transmission from the internal explosion to the walls of cask.

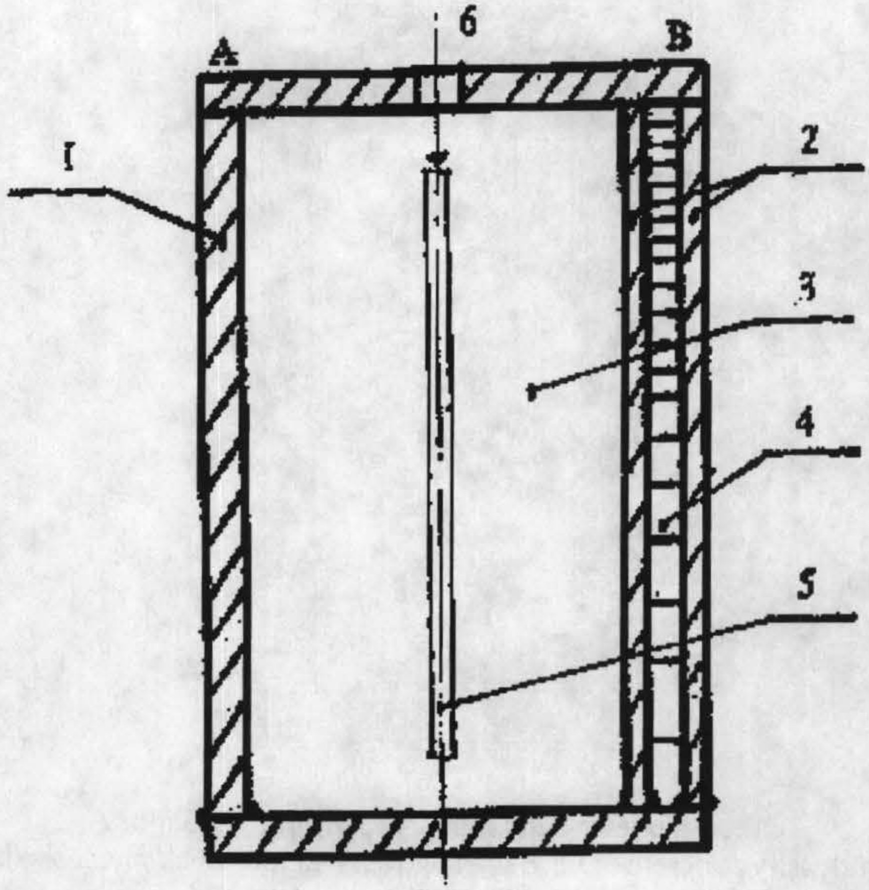
REFERENCES

Ivanov A.G. and Mineev V.N. *Scale Effects in Fracture* . Fizika Gorenia i vzryva, Vol.15, No. 5, pp.70-95, 1979.

Ryzhanski V.A., Ivanov A.G., Zhukov V.V., Mineev V. N. *Resistance Explosion of the Cylindrical Section of Fast Reactor Containment*. To be published in Atomnaya Energia, 1996.



Outer diameter-2260 mm. Total height-4435 mm
High density concrete (≥3.5 g/cm³) between 40 mm thick metal shells.
STEEL CONCRETE CASK RBMK
Figure # 1.



A-Steel Cask(one-layer cask).
B-Steel Damper Cask(three-layer cask).
Internal diameter- 249 mm.
Total height -1500 mm.

1-Steel 12 mm,
2-Steel 6.5 mm,
3-Water and air-simulations of contents,
4-Water or water with air bubbles(3 v%)-
simulation of damper,
5-Long explosive charge-simulation
an accidental sudden energy release,
6-Detonator.

SETUP OF EXPERIMENT
Figure # 2.