

PAPER • OPEN ACCESS

Combined device for suppression of damaging effects of detonation of the condensed media

To cite this article: M V Chernyshov *et al* 2019 *J. Phys.: Conf. Ser.* **1214** 012002

View the [article online](#) for updates and enhancements.

You may also like

- [The effect of geometrical parameters on blast resistance of sandwich panels—a review](#)

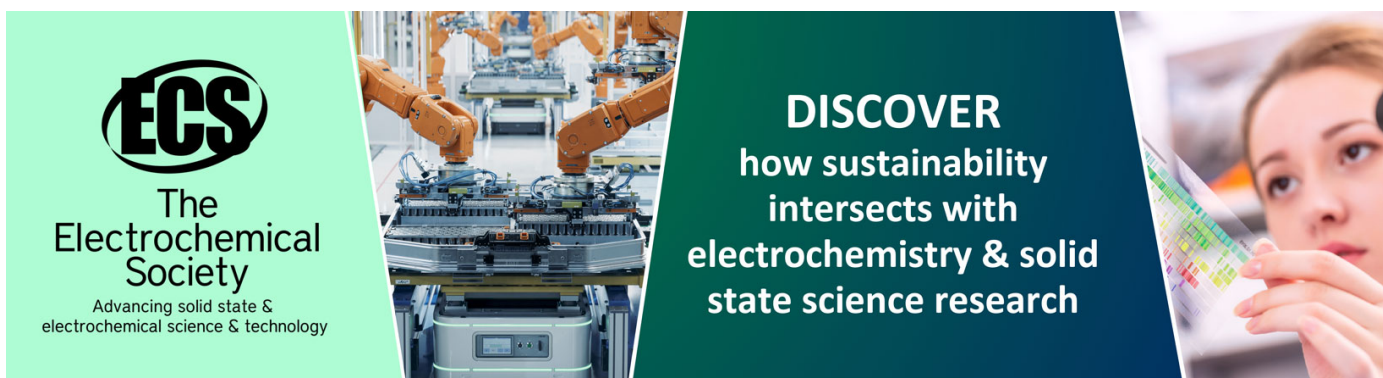
Orhan Gülcan, Kadir Günaydn and Aykut Tamer

- [BLAST: THE REDSHIFT SURVEY](#)

Stephen Eales, Edward L. Chapin, Mark J. Devlin et al.

- [Mechanism of soft x-ray continuum radiation from low-energy pinch discharges of hydrogen and ultra-low field ignition of solid fuels](#)

R MILLS, J LOTOSKI and Y LU



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Combined device for suppression of damaging effects of detonation of the condensed media

M V Chernyshov, A S Kapralova, S A Matveev

Baltic State Technical University “VOENMEH”, 1, 1st Krasnoarmeiskaya Str.,
190005, St. Petersburg, Russia

* E-mail: mvcher@mail.ru

Abstract. A robust blast inhibiting bin is the most often used device for damage blast effects suppression. In particular, a top open cylindrical bin significantly reduces a fragmentation effect resulted from a detonation of an explosive device placed inside the bin. However, reduction of blast wave overpressure and impulse by such cylindrical bins is not sufficient. A reasonable alternative to endless increase of height and thickness of robust blast inhibiting bins is a development of destructible inhibitors having no solid elements in their structure and, therefore, excluding secondary fragmentation. So, the family of “Fountain” inhibitors localizes and suppresses damaging blast effects due to multiphase working system. The present study is analysing data obtained in testing of prototypes of new combined inhibitors. Its structure combines robust elements (bottoms, side surfaces) with elements responsible for blast loads reduction due to multi-phase working system (top and low transverse embeddings) and fairings impeding wave propagation in undesirable directions.

1. Introduction

This study is dedicated to new ways and means of shock wave suppression and to new devices for this purpose and based on new technologies combining both geometrical and physical ways of shock wave mitigation.

The technologies of shock mitigation have a broad scope of applications – from communal services and house-building industry to special anti-terrorist equipment for security structures. These technologies can be also used even in space industry, for example, to mitigate the influence of initial shock wave on rocket nozzle, to quench self-oscillating jet flow interaction with a launch complex. They can be used also to soften a destructing action of blast wave, because some modern devices of spaceship undocking are based on elastic high explosive (HE) compositions (including, for example, such HE like pentaerythritol tetranitrate, PETN). Modern materials absorbing the blast energy and mitigating the shock wave can be used also for rocket nozzle protection from shock influence, as well as at launch complex subject to interaction with supersonic jet flows, sometimes in self-oscillating regimes.

Ways to protect biological and technical objects from shock wave damaging action can be conventionally divided to geometrical and physical. The geometrical methods of shock mitigation are characterized by special shape of solid structures designed to diminish a shock wave overpressure or to form a special direction of shock propagation. The physical methods of shock mitigation are based on specific features of some materials and structures, for example, the energy-absorbing features of



multiphase media. The experimental data on blast-protecting devices which combine both geometrical and physical methods of shock suppression are presented at this study.

2. Materials and methods

Among the numerous methods and devices to suppress the dangerous action of blast wave [1-3], application of multiphase relaxation media in destructible containers without hard elements has shown itself as one of the most effective ways, both in general [4, 5] and in extraordinary conditions, e.g. onboard an airplane [5], including the case of diminished ambient pressure [6]. But for some purposes (for example, garbage bins in cities) hard basis of blast-resistant and blast-protecting device seems to be necessary. It limits the application of the completely destructible containers and convinces us to combine the hard basis and elements of relaxation media.

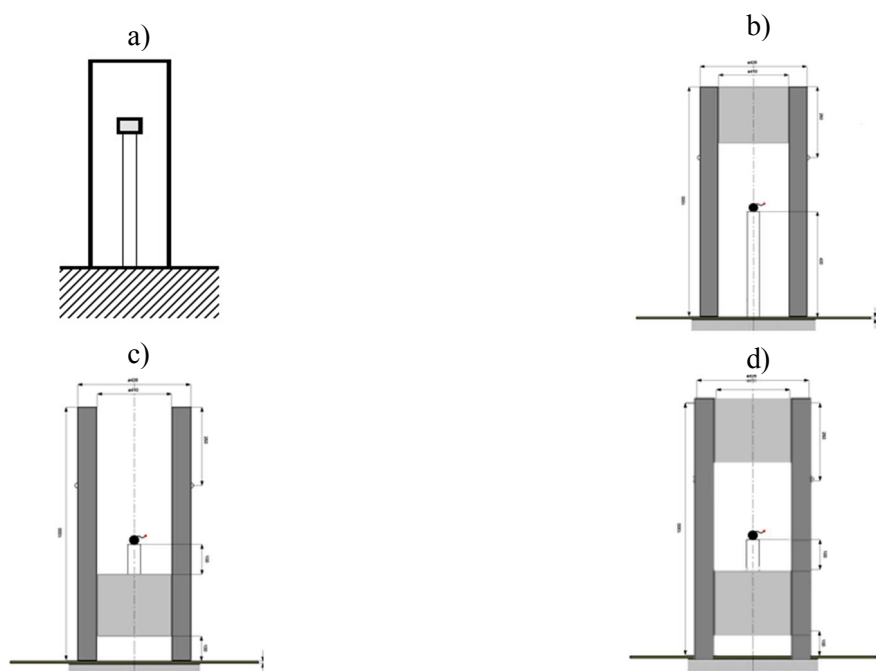


Figure 1. First series of blast-protecting can prototypes tested at small HE charges [7]

Two series of field tests were applied to our objects of study; that were the steel cans with open top and inserted elements of multiphase media (Figures 1 and 2). The first series of field tests were provided with rather small TNT charges (0.2 kg) and four first types of blast-protecting device prototypes (Figure 1,a-d). The basic cylindrical blast-resistant bin (Figure 1,a) was made of steel tube, its diameter was equal to 420 mm, its length – to 1000 mm, its wall thickness – to 8 mm. This basic can has the weight of 82 kg and was welded with massive steel plate what prevented its overturn at blast inside.

Because the calculations by the methods of computational fluid dynamics (CFD calculations) have shown us the small efficiency of similar devices (see, for example, [8]), three other prototypes of blast-protecting devices were elaborating (Figure 1,b-d) including the same steel basis and insertions (Figure 2) made from the same multiphase media which was successfully applied in “Fountain” blast inhibitors [2, 3, 8, 9]. The first modification of the basic device (Figure 1,b) can be characterized by upper insertion location, the second one (Figure 1,c) – by its lower location at some small distance from bottom of the can, the third one – by both upper and lower locations of blast-inhibiting insertions.

Principles of blast mitigation with destructible blast inhibitors are based on the theory of shock interaction with solid and liquid foams. Theory of this interaction and shock mitigation was developed

for the first time in studies [9, 10] and applied to the design of blast inhibitors by B.E. Gelfand and M.V. Silnikov in the 1990s.

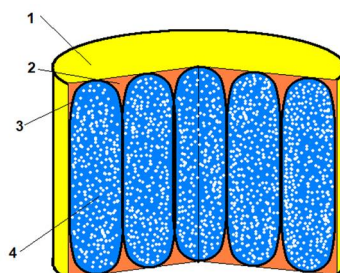


Figure 2. Blast-protective insertion: 1 – covering, 2 – polyurethane foam, 3 – inhibiting elements fulfilled with multiphase media, 4 – multiphase media itself

For larger charges of cast trotyl (TNT), see Figure 3, the element of steel (Steel 20 according to Russian State standards) tube (diameter – 426 mm, length – 1010 mm, wall thickness – 12 mm, weight – 123.9 kg) welded with steel plate was used as the basic construction. The first modification of blast-protective device (Figure 3,b) included the inhibiting insertion (its length was equal to 220 mm, its weight – to 12 kg) at lower position, but at some distance (100 mm) from the can bottom. The multiphase insertion was thickened to 320 mm and was situated immediately at can bottom at the second modification (Figure 3,c). The building-up which can be named as blast-protective flange (Figure 4) was used at the third modification (Figure 3,d). Both flange and the multiphase insertion in its lower position were used at the fourth prototype (Figure 3,e). The bandage made of ballistic clothes accompanied the lower multiphase insertion in the fifth modification (Figure 3,f, the bandage is marked by two slanting St. Andrew's crosses).

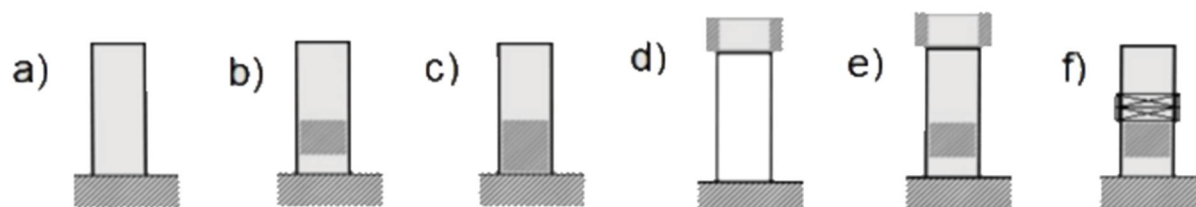


Figure 3. Second series of blast-protecting bin prototypes tested with larger HE charges

Two rows of piezoelectric pressure transducers PD-7-1.5 (four transducers in each row) were situated at the angle of 90° one to another in all experiments (see Figure 5). About 30 TNT charge blasts were performed in both series of experiments, so about 240 overpressure plots were achieved at the PC that registered the electric signal. After integrating, corresponding pressure impulse values were estimated at different distances (from 1.5 to 3 meters) from the blast epicenter at each experiment.

Pressure transducers were amounted at the height equal to 1 m over ground level. Directions of rays (rows) along which they were installed corresponded to prevailing wind direction and normal line to the prevailing wind. It was shown in [12] as well as in numerous analogous experiments that this wind (up to 5 meters per second) does not influence sufficiently the results of measurements.

It was also proven at [12, 13] that the pressure transducers situated at the 0.5 m distance one after another do not interfere the measurements mutually. Protective elements made of steel beams (Figure 6) also do not influence the experimental results, and studies [11] and [12] cover this problem specially.

At the very end of experimental setup description, pressure transducers had successfully shown themselves in blast field tests during the last 12 years, including the experiments with blast-resistant

and blast-protective devices. The height of pressure transducers was 1 m, the distance from the blast epicenter – from 1.5 m to 3 m, the size of sensitive elements (white spheres at Figure 6,b) – about 5 millimetres. Open blasts (without any blast-protective cans) preceded the field tests of all outnumbered devices with corresponding TNT charge weights.

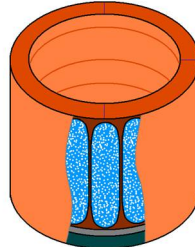


Figure 4. Blast-protective flange construction



Figure 5. Two rows, each composed of four pressure transducers and situated at the plane angle to each other, installed near the TNT charge at the field test [12]



Figure 6. a) one row, composed of four pressure transducers mounted at steel plate and protected by vertical steel corner beam; b) pressure transducers, its sensitive element (white one), and steel protecting beam ahead of it.

HE charges were situated in the geometrical centers of corresponding blast-protective devices. So the blast wave overpressures and pressure impulses registered in the field tests were compared not only with ground blast results, but also with the blasts of the HE charges of the same weights heightened on the corresponding distance above the steel plate.

3. Materials and discussion

3.1. Experimental results: small HE charges

The results of the first series of field tests (with smaller TNT charges, which weights are equal to 0,2 kg here) are shown in Figure 7. The reference results achieved for open blasts (curve 1) corresponds to well-known empirical formula and reference data [13-15] with the error not more than 10%. The experimental data for correspondingly heightened blasts (curve 2) can also be easily checked. The following conclusions about the blast wave pressure variation due to blast-resistant can application can be made:

1. The smallest efficiency of blast wave suppression corresponds to basic modification of the can (without any multiphase insertions). Overpressure was diminished in 1.2-1.5 times (see curve 3). Results for blast wave pressure impulse measurements and calculations (Table 2) are a little better but also far from satisfactory.

This conclusion also corresponds to the numerical study [8] of solid cylindrical bins with open top which seems to be non-effective for blast wave mitigation even if their length is rather large.

2. At the modification 1 (Figure 1,b) the blast wave overpressure diminishes in 19-33 times comparing with the open blast and in 8-20 times comparing with the initial prototype (i.e., exclusively due to multiphase insertion in its higher position). The results achieved allow us to say about the full suppression of blast energy of rather small HE charge (see curve 4 in Figure 7).

3. The lower position of multiphase insertion (as in Figure 1,c) diminishes the blast wave overpressure in 3-5 times comparing with the open blast and in 2.5-4 times comparing with the blast inside the initial prototype (curve 5 in Figure 7).

The results achieved for the bin with multiphase insertion situated lower than the HE charge seems to be non-trivial and compel us to think about the role of blast waves reflected from can bottom, possibilities of its reduction and its influence of blast wave amplitude at the distances important for blast-protecting devices.

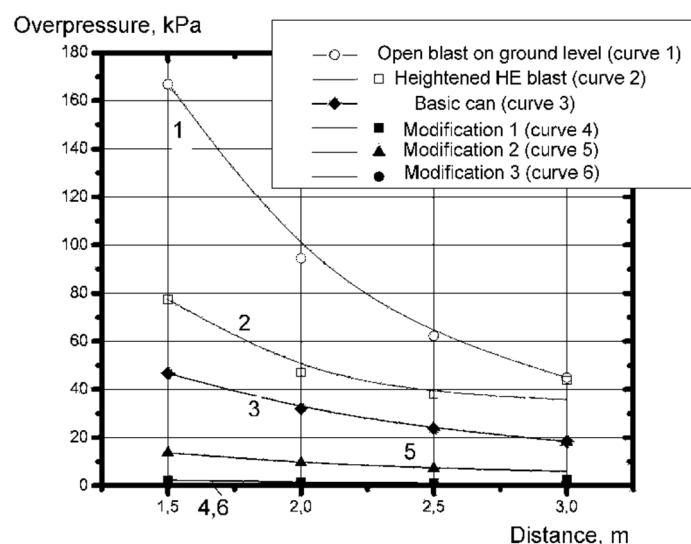


Figure 7. Overpressure data for various blast-protective modification devices at 0.2 kg TNT charge explosion

4. The largest effect of blast wave overpressure diminishing (curve 6 in Figure 7) was achieved in the third prototype (Figure 1,d) due to contemporary application of multiphase insertions in its upper and lower positions. The decrease of overpressure in 40-50 times means, in fact, the full suppression of mechanical action of HE blast.

Data achieved at blast overpressure and pressure impulse experiments with small HE charges are summarized in Table 1 (overpressures) and Table 2 (pressure impulses). Pressure impulse decrease

due to multiphase insertions seems to be enormous at the distance of 1.5-2.5 m and smaller, but also satisfactory at 3 m distance.

Table 1. Overpressure suppression factors at 0.2 kg TNT blast

Distance, m	Overpressure decrease rate			
	Basic can (Fig. 1,a)	Modification 1 (Figure 1,b)	Modification 2 (Figure 1,c)	Modification 3 (Figure 1,d)
1.5	3.57	71.8	12.2	132
2	2.95	58.7	9.94	100
2.5	2.61	52,3	8.63	81.3
3	2.44	18.2	2.45	27.9

Table 2. Pressure impulse suppression factors at 0.2 kg TNT blast

Distance, m	Pressure impulse decrease rate			
	Basic can (Fig. 1,a)	Modification 1 (Figure 1,b)	Modification 2 (Figure 1,c)	Modification 3 (Figure 1,d)
1.5	3.40	98.0	9.75	153
2	3.05	113	8.48	149
2.5	3.09	127	8.50	192
3	3.06	35.1	2.62	63.7

3.2. Experimental results: larger HE charges

Encouraged with the great success with small HE charge (see [16]), we decided to conduct field tests of the blast-protective bin prototypes using multi-phase insertions in its lower position and special flanges at the top of the device as shown in Figure 3. Blasts of HE charge weights of 0.5 kg and 0.8 kg were provided. Data on 0.5 kg TNT charge blast wave overpressure and impulse pressure reduction are summarized in Table 3 and Table 4, correspondingly. Both multi-phase media lower insertion and multiphase media flange increase the overpressure and pressure impulse suppression factors. But their influence is not so radical as for 0.2 kg TNT charges, maybe because the influence of shock wave reflected from the bottom of the bin is not so sufficient now. In fact, the rates of overpressure and pressure impulse decrease differ rather slightly between various proto-types of blast-protecting device. At least, it is a reason to think a little more about blast wave dynamics, including the influence of the shock reflected from the surface at the heightened blast on the general characteristics of blast wave at some distance from the blast epicentre.

The bandage made of ballistic clothes (Figure 3,f) increased the structural resistance of the object and allowed us to perform the field tests with 0.8 kg and, in general, with 1.0 kg TNT charge. The results achieved in these series of experiments are analogous to results achieved with 0.5 kg TNT charge.

4. Conclusion

Field tests of new cylindrical blast inhibiting bin prototypes have revealed significant reduction of shock blast wave parameters due to embeddings with the multi-phase system located both on the top and on the bottom of a small charge (0.2-0.4 kg TNT). Reduction of blast effects parameters due to multiphase working system located inside a blast bin below a charge is rather nontrivial result. While the use of the blast inhibiting bin prototype of a basic modification (Fig. 1,a) showed 2.5-3.5 times reduction of the blast overpressure and 3.0-3.4 times reduction of the impulse, the combined blast inhibitor showed 8.5-12.2 and 8.5-9.8 times reduction of those parameters, respectively.

The excellent results achieved with small HE charges were not confirmed by the field tests where the larger HE charges (0.5 kg and more) were used. The influence of the multiphase elements situated

below the charge is much smaller at rather large HE charge weights. It seems that a deep penetration in shock wave reflection and interaction theory is necessary to explain a great difference between two examples described.

References

- [1] Igra O, Falkovitz J, Houas L, Jourdan G. 2013 Review of methods to attenuate shock/blast waves. *Progress in Aerospace Sciences* **58** 1-35
- [2] Ohtomo F, Ohtani K, Takayama K. 2005 Attenuation of shock waves propagating over arrayed baffles. *Shock Waves* **14** 379-390
- [3] Kitagawa K, Yasuhara M, Takayama K. 2006 Attenuation of shock waves propagating in polyurethane foams. *Shock Waves* **15** 437-445
- [4] Vasil'ev Yu S, Gelfand B E, Silnikov M V. 2004 Impulse-energy technologies assisted with mitigation systems. *Izvestiya Akademii Nauk. Energetika.* **6** 7-19
- [5] Silnikov M V, Mikhaylin A I. 2014 Protection of flying vehicles against blast loads. *Acta Astronautica.* **97** 30-37
- [6] Silnikov M V, Chernyshov M V, Mikhaylin A I. 2015 Blast wave parameters at diminished ambient pressure. *Acta Astronautica* **109** 235-240
- [7] Silnikov M V, Chernyshov M V, Kapralova A S, Mikhaylin AI, Pankov A S, Shishkin V N, Spivak A I, Tyapko A G. 2018 Shock Wave Reflection and Attenuation in the Confined Blast Inhibitors. In: *Shock Wave Interactions. Selected Articles from the 22nd International Shock Interaction Symposium, University of Glasgow, United Kingdom, 4-8 July 2016*. Springer, pp. 45-55.
- [8] Gelfand B E, Silnikov M V, Chernyshov M V. 2010 On the efficiency of semi-closed blast inhibitors. *Shock Waves* **20** 317-321
- [9] Gel'fand B E, Gubanov A V, Timofeev E I. 1983 Interaction of shock wave in air with a porous screen. *Fluid Dynamics* **18** (4) 561-566
- [10] Gvozdeva L G, Faresov Yu M, Fokeev V P. 1985 Interaction of air shock wave with porous compressible materials. *Journal of Applied Mechanics and Technical Physics* **26** (3) 401-405
- [11] Vasilyev N N, Danilov N A, Dmitriev V Ya, Spivak A I, Shishkin V N. 2015 Experimental checkup of protective elements influence on the registered parameters of air shock wave. *Problems of Defense Engineering. Ser. 16. Technical Means of Counter-Terrorism*, No. 1-2, 87-92
- [12] Medvedev S P, Tyrnov E P, Khomik S V, Gelfand B E, Silnikov M V, Mikhaylin A I. 2009 Restoring of blast wave after interaction with detached obstacle. In: *Proceedings of the 27th International Symposium on Shock Waves (St. Petersburg)* Poster presentation 30138 p. 386.
- [13] Baker W E. 1973 Explosions in air (*Univ. Texas, Austin*)
- [14] Gelfand B E, Silnikov M V. 2006 Barothermal action of blasts. *Asterion (St. Petersburg)*
- [15] Gelfand B E, Silnikov M V. 2007 Shock-wave action of blasts. *Asterion (St. Petersburg)*
- [16] Takayama K, Silnikov M V, Chernyshov M V. 2016 Experimental study of blast mitigating devices based on combined construction. *Acta Astronautica* **126** 541-545