FIELD TEST ON THE EFFECTS OF EXPLOSIVELY GENERATED PLASMA ON AERIAL DEPTH BOMBS PLAB- 250-120

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ABSTRACT

In order to gain access to the booster and main explosive charges of PLAB-250-120 aerial depth bombs, i.e. the TNT charge and the TGAF-5M explosive composition of TNT, hexogen (RDX), aluminum powder and phlegmatizing agent respectively, Explosively Generated Plasma (EGP) devices were used to perforate their steel bodies. EGP devices were made in two versions. The first used a cylindrical TNT charge, while the second used a cylindrical charge shaped from SEMTEX PW4 plastic explosive. The explosive charges were supported by waveguides with conical cavities tapering towards the bomb. The structural components of the EGP devices, i.e. the bodies housing the explosive charges and the waveguides, were made of plastic by 3D printing. The effects of the EGP on the bomb were studied depending on the explosive material used, its mass and the distance of the EGP device waveguide from the side surface of the bomb. Simultaneous firing of an array of two EGP devices inserted with SEMTEX PW4 explosive, contacted their waveguides with the bomb, resulted in its detonation, while simultaneous firing of the analogous array of the same type two EGP devices inserted with SEMTEX PW4 explosive, with their waveguides at a distance of 10 mm from the bomb, resulted in perforation of two circular through-holes in the bomb body. Firing single EGP device inserted with TNT, being in contact through its waveguide with the body of the bomb, resulted in local rupture of the bomb body with crushing the bomb explosive charges, so allowing easy access to bomb explosive charges and sampling them.
Keywords: aerial depth bomb, PLAB-250-120, explosively generated plasma, EGP, EGP devices, perforation, TNT, TGAF-5M.

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INTRODUCTION

At the Military Institute of Armament Technology (MIAT), works are carried out to test the explosives contained in military ammunition for which the guarantee period granted by the manufacturer has expired. A necessary step in these works, is to dismantle such munitions in order to gain access to the explosive charges and then take samples of them for laboratory testing. Unfortunately, in the case of PLAB-250-120 aerial depth bombs manufactured in the former Soviet Union, access to their booster and main explosive charges, is difficult because these charges are permanently, hermetically sealed in the steel body of the bomb. In view of these difficulties, Explosively Generated Plasma (EGP) devices have been developed and manufactured at the MIAT to perforate the bodies of such type bombs so that the booster and main explosive charges of the bombs are not detonated or burned/deflagrated as a result. Described below are the construction and operation of PLAB-250-120 aerial depth bombs, the EGP devices known from the state of the art and those developed at WITU and used to perforate these bombs, as well as field tests of the effect of the newly developed EGP devices on PLAB-250-120 bombs.

AERIAL DEPTH BOMBS PLAB-250-120

The PLAB-250-120 aerial depth bombs (Fig.1) are medium-weight ones, each with total mass of 120 kg, a length of 1500 mm and a diameter of 240 mm. They are designed to destroy submarines being in submerged or not submerged position [1].

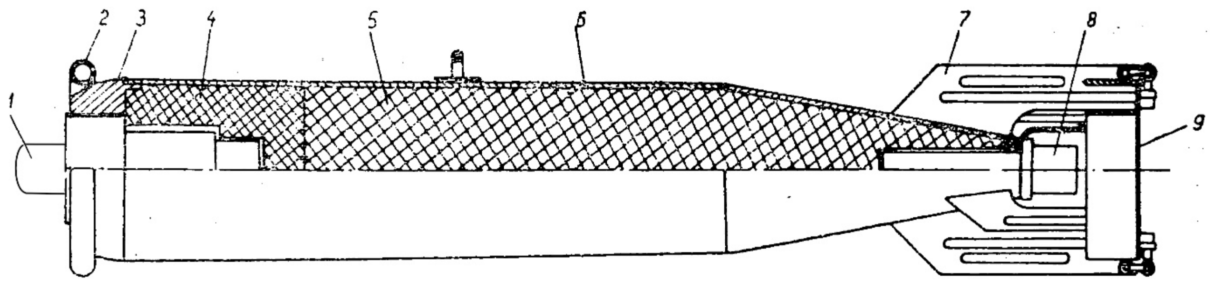


Fig. 1 Half-view-half-section of the PLAB-250-120 aerial depth bomb: 1 - front (proximity) detonator, 2 - front braking ring, 3 - warhead, 4 - booster explosive charge (TNT), 5 - main explosive charge (TGAF-5M or MS), 6 - thin-walled body, 7 - stabilizer, 8 - bottom (hydrostatic) detonator, 9 - rear braking ring [1].

The booster explosive charge of the bomb is made of TNT, while the main explosive charge, located in the middle and rear of the bomb body, is an explosive composition of TNT, hexogen (RDX), aluminum powder and phlegmatizing agent, marked as TGAF-5M or MS, depending on the quantitative composition. The quantitative compositions and physicochemical properties of the above explosive compositions commonly used in large-size naval munitions, including underwater munitions, are presented in a review article [2] and a book [3].

In order to avoid ricochets when hitting the water surface, the front part of the bomb is flat and takes the form of a massive steel head, to which a front ring is attached by special screws to act as a brake. The same function is performed by a rear brake ring attached to the bomb stabilizer. The braking rings reduce the bomb rate of descent to a certain value determined by its strength. A description of the bomb construction, with particular reference to the front and rear braking systems, is presented in the patent description of the Russian invention RU 2277219C1 [4]. On impact with the water surface, due to the dynamic pressure of the water, the braking rings fall away from the bomb, so that the bomb submerges relatively quickly. The submerging velocity of the bomb does not exceed 10 m/s. The frontal (proximity) fuse operates at the specified distance of the bomb from the submarine, while the bottom (hydrostatic) fuse operates at the specified depth of the bomb submergence.

EGP DEVICES KNOWN FROM THE STATE OF THE ART AND DEVELOPED AT MIAT

Some of the first EGP devices and their operation are shown in patent descriptions: GB 855932 [5] and US 3159102 [6]. Example diagrams of EGP devices according to the present inventions are shown in Figure 2.

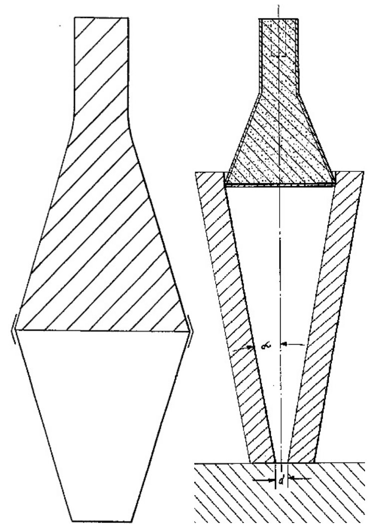


Fig. 2 Example EGP systems according to the inventions given in the patent descriptions: left - GB 855932 [5] , right - US 3159102 [6].

These systems consisted of an uniform charge of brisant explosive with an outer funnel shape, made, for example, of RDX/TNT explosive composition, inserted in a thin-walled housing. Such an explosive charge was set with its conical base on a waveguide with a conical cavity converging towards a steel plate. The waveguide was made of metal or plastic. The use of EGP devices to neutralize munitions destined for destruction, has been presented relatively recently, e.g. in patent descriptions of inventions [7, 8] and in the article [9] and final report [10] of research conducted for the US Navy.

A number of EGP devices have been developed at MIAT for sapper and research works. EGP devices of type I (Fig. 3) and type II (Fig. 4), whose structural components were made of plastic (polylactide - PLA) using the FDM 3D printing method, were used for this research.

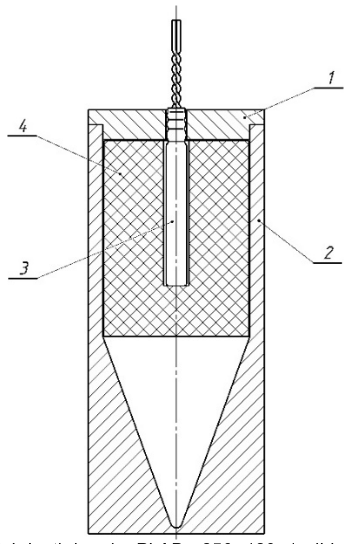


Fig. 3 EGP type I device used for perforation of bodies of aerial depth bombs PLAB - 250- 120: 1 - lid with central hole for Erg electric detonator, 2 - body with conical waveguide cavity, 3 - Erg electric detonator, 4 - cylindrical TNT charge.

The EGP type II device (Fig. 3) consists of a cylindrical, pressed TNT charge of 200 g placed in a body with a conical cavity under the TNT charge, forming a waveguide with an apex angle of 40°. The TNT charge rests with its lower edge against the conical surface of the waveguide and is covered from above by a lid with a central hole for the Erg electric detonator.

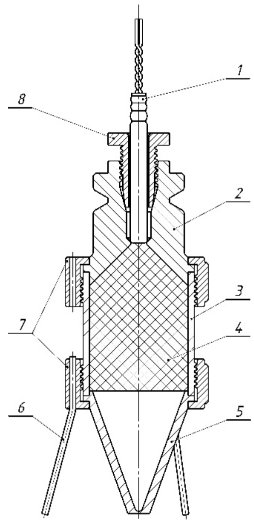


Fig. 4 EGP type II device used for perforation of bodies of aerial depth bombs PLAB- 250- 120: 1 - Erg electric detonator, 2 - lid, 3 - body, 4 - charge of plastic explosive SEMTEX PW4, 5 - conical waveguide, 6 - leg, 7 - nuts, 8 - screw.

FIELD TESTS OF EGP EFFECTS ON THE BODIES OF AERIAL DEPTHS BOMBS - PLAB250120

Four PLAB-250-120 aerial depth bombs, for which their warranty period had expired, were tested for their neutralization (destructive tests). The tests were aimed at establishing a configuration: an EGP device or array of two EGP devices - an aerial depth bomb, allowing access to the bomb explosive charges - an booster one made of TNT and a main one made of the explosive composition TGAF-5M. To this end, the PLAB-250-120 bombs were transported from storage to the MIAT Proving Ground, and then their detonators (located in the tail section) and warhead mockups were removed. Then, based on the documentation of the PLAB-250-120 bomb, two locations of the bomb body were selected to be perforated, one at a distance of approximately 150 mm from the bomb forehead (opposite TNT charge) and the other at a distance of approximately 750 mm from the bomb forehead (opposite TGAF5M charge).

The tests were divided into two stages. In the first, EGP type I devices were used, while in the second, EGP type II devices were used. The EGP devices were positioned so that the axes of their explosive charges were collinear with the diameter of the bomb body. EGP devices were fired individually or in pairs, either keeping a distance of 10 mm from the side surface of the bomb or by applying them directly to the bomb surface.

For bombs No. 1 and No. 2, EGP type I devices were positioned from touchdown and fired individually (four shots). The EGP type I device was fired first over the TGAF-5M charge and then over the TNT charge. Each such firing resulted in a local rupture of the bomb body, with crushing and partial scattering of the bomb explosive. Configurations: EGP devices type I – bomb, and examples of the effects of EGPs from these devices on bomb No. 1 and No. 2 are shown in Fig. 5-7.

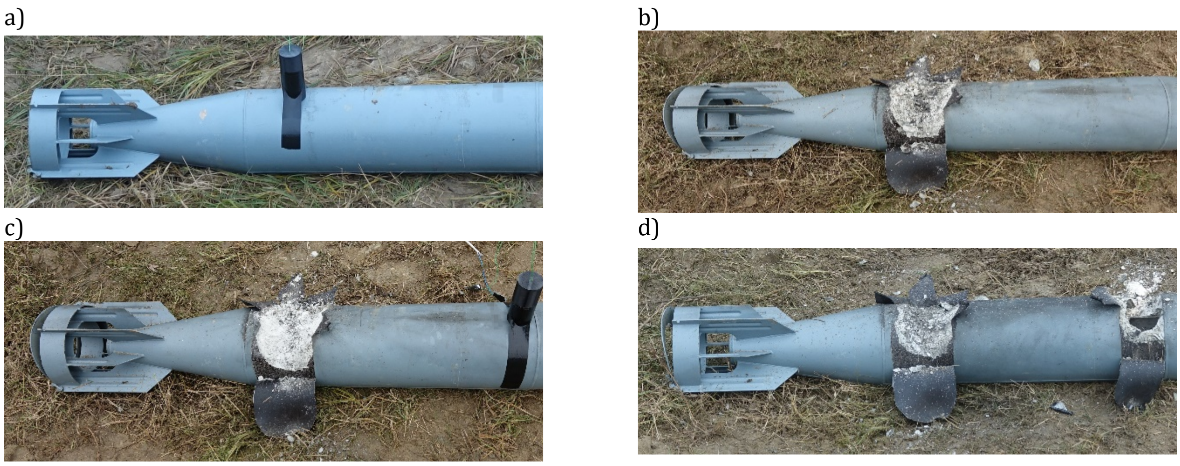


Fig. 5 (1).Test of the configuration of the EGP type I device - bomb No. 1:
a - positioning of the EGP device over the rear part of the bomb (shot 1),
b - effect of the EGP on the rear part of the bomb,
c - positioning of the EGP device over the front part of the bomb (shot 2),
d - effect of the EGP on the front part of the bomb (with the effect of the earlier fired EGP on the rear of the bomb).

a) b)

Fig. 6 Detail view of the perforation and local rupture of the body of the rear part of bomb No. 1 and the penetration and shattering of the TGAF-5M charge by EGP from the EGP type I device (shot 1): a - top view, b - side view.

Fig. 7 Detail view of the perforation and local bursting of the front part of the bomb No. 2 body and the penetration and shattering of the TNT charge by the EGP type I device (shot 4): a - top view, b – in the foreground, a view of the edge of the sheet metal of the bomb body with an arched fragment, indicating that the perforation of the body in the form of a circular hole took place first, followed by its bursting.

In the case of bomb No. 3, two EGP type II devices were positioned from touchdown (Fig. 8a and 8b) and fired simultaneously. The EGPs from both EGP type II devices resulted in the detonation of the bomb explosive charges (Fig. 8c).

a)

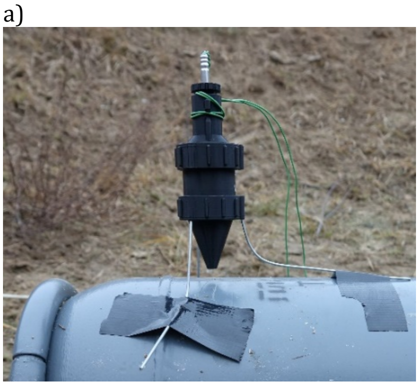
b)

c)

Fig. 8 Configuration testing: two EGP type II devices (ready to simultaneous firing) - bomb No. 3 (shot 5): a - alignment of two EGP type II devices in relation to the bomb, b - general view of the test set-up, d - effect of bomb detonation

In the case of bomb No. 4, two EGP type II devices were positioned at a distance of 10 mm from the surface of the bomb body (Fig. 9 (a,b)) and detonated simultaneously. The use of a distance of 10 mm instead of touchdown was dictated by the need to weaken the impact of the EGPs on the bomb body to prevent detonation of its explosive charges (TNT and TGAF- 5M).

a)



b)

c)

Fig. 9 Configuration testing: two EGP type II devices - bomb No. 4 (shot 6): a - detailed view of the positioning of the EGP device situated at the distance 10 mm from bomb surface, opposite its TNT charge, b - position of two EGP type II devices in relation to bomb surface, c - effect of two EGPs on bomb.

The intended effect was achieved, there are obtained two perforations of the bomb body in the form of two circular holes opposite the TNT and TGAF-5M charges of bomb No. 4, approximately 30mm and 35mm in diameter respectively (Fig. 10).

b)

Fig. 10 Detailed view of the perforation of the rear part of the body of bomb No. 4 by the EGP from EGP device type II (shot no. 6): a - top view, b - side view.

In Fig. 10, the different nature of the effect of the EGP on the bomb, is clearly visible in comparison with previous cases - the edges of the circular holes are turned inwards, while a bulge in the body is visible around the hole (Fig. 10b). The explosive inside the bomb is only slightly crushed.

SUMMARY AND CONCLUSIONS

Below, Table summarizes the configurations used in the field tests: EGP device(s) - aerial depth bomb PLAB-250-120 and its response (reaction) to the EGP generated by these devices.

Tab. 1

Summary of results of tests of the performance of EGP devices on aerial depth bombs PLAB-250-120.

Shot No	Bomb No	Type of EGP device and its position relative to the side surface of the bomb, opposite of its explosive charges		Result of the EGP action towards the bomb
		booster (TNT)	main (TGAF-5M)	
1	1	-	EGP type I, contact	Local rupture of the bomb body
2		EGP type I, contact	-	Local rupture of the bomb body
3	2	-	EGP tpe I, contact	Local rupture of the bomb body
4		EGP type I, contact	-	Local rupture of the bomb body
5	3	EGP type II, contact	EGP type II, contact	Bomb detonation
6	4	EGP type II, stand-off 10mm	EGP type II, stand-off 10 mm	Perforation of the bomb body in the form of two circular holes

From the Table, it can be seen that the tested configurations EGP device or array of two EGP devices - the aerial depth bomb PLAB-250-120, used during the first, second, third, fourth and sixth shots (i.e. except for the configuration used during the fifth shot, which resulted in the detonation of the bomb) confirmed the suitability of using the EGP for bomb perforation and explosive sampling TNT and TGAF-5M from inside the thin-walled bodies of these bombs.

The best access to the TNT and TGAF-5M explosive charges of the PLAB-250-120 bomb was obtained, for the configuration where EGP type I device was in contact with its waveguide tip with the surface of the bomb body, i.e. for configuration used during the first, second, third and fourth shot.

The response (reaction) of a bomb explosive charges to an EGP depends, among other things, on the mass and type of explosive used in the EGP device and the distance (stand-off) of its waveguide from the bomb surface. For example, the effect of distance on the response (reaction) of a bomb to an EGP is distinctly demonstrated by comparing the response (reaction) of a bomb to an EGP as a result of the simultaneous firing of two EGP type II devices either applied to the bomb (shot 5) or 10 mm away from the bomb (shot 6). Introducing a distance of 10 mm between the EGP devices and the bomb surface resulted in local perforation of the bomb body in the form of a circular hole and local crushing of its explosives (shot 6), while touchdown the same devices to the bomb body resulted in its detonation (shot 5).

Based on the available publications [10-13] and the test results obtained, it can be proposed two probable scenarios for the interaction of the EGP with the explosive inside the thin-walled bomb body, i.e. first scenario in the case when EGP device waveguide is in contact with bomb body (Fig. 11) and second scenario when EGP device waveguide is in distance 10mm from the bomb body (Fig. 12).

First scenario

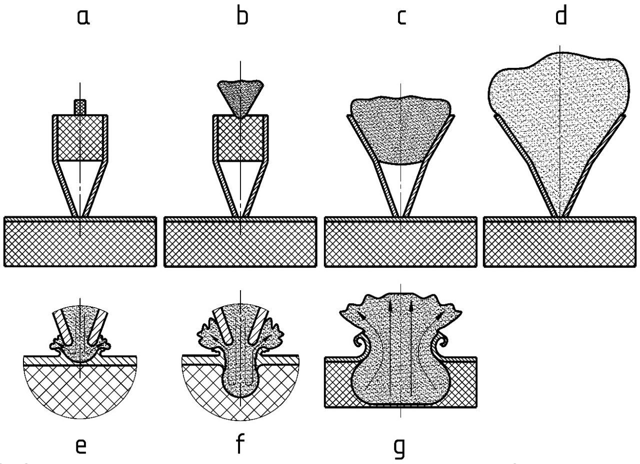


Fig. 11 Proposed mechanism for the effect of EGP on the explosive inside the thin-wall bomb body – the EGP device is in contact with the bomb body.

The waveguide tip of EGP device, is in contact with the bomb body (Fig. 11a). Initiation of the detonator takes place (Fig. 11b). An explosive transformation is initiated in the explosive charge of EGP device. The explosive transformation propagates towards and inside the waveguide until it reaches the lower (free) surface of the explosive (Fig. 11c). In the air inside the waveguide, a shock wave is generated, followed by the ionized products of the detonation, i.e. plasma. As the ionized products propagate through the tapering waveguide, a Mach wave is generated (Fig. 11d). The Mach wave, and subsequently the detonation products, impinge on the bomb body. Due to the short waveguide length, the delay is small. There is a 'washing out' of the body material, during which the characteristically curved edges of the hole are formed (Fig. 11e). Once the body has been perforated, the plasma enters the bomb. Decomposition of the explosive material in the area of direct plasma interaction and heating of the adjacent material occur (Fig. 11f). It is possible to initiate deflagration of the explosive, in accordance with the thermal mechanism. The rapid release of a large amount of gaseous products, causes an increase in pressure and thus local rupture of the bomb body. The subsequent expansion and rapid pressure drop, stop the explosive material deflagration (Fig. 11g).

Second scenario

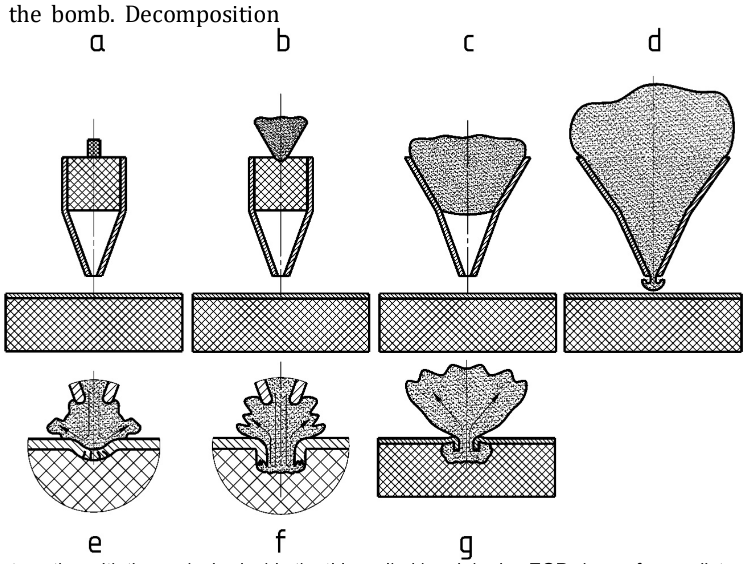


Fig. 12 Proposed mechanism of EGP interaction with the explosive inside the thin-walled bomb body - EGP charge from a distance.

The waveguide tip is 10 mm from the bomb surface (Fig. 12a). The initial stages are analogous to the previously described first scenario (Fig. 2a-c). The resulting Mach wave, together with the plasma, leave the waveguide and propagate further towards the bomb (Fig. 12d). They hit the body with lower parameters than in the previously described first scenario. The deformation velocity of bomb body is lower and, so the scenario of destruction of the body is different. There is deformation of the sheet metal, while on the explosive side the sheet metal breaks (Fig. 12e). Once the body is perforated, the plasma penetrates the bomb inside. Decomposition of the explosive in the area of direct plasma interaction and heating of the adjacent material follows (Fig. 12f). The resulting gaseous products cause an increase in pressure inside the bomb and thus deform the bomb body (Fig. 12g).

In summary, the donor-acceptor systems studied, i.e. the EGP device or two EGP devices - PLAB-250-120 aerial depth bomb, confirmed the suitability of using EGPs to perforate and sample explosives from inside their thin-walled bodies. The intensity of the response (reaction) of the explosive charge inside the bomb depends, among other things, on the type of explosive used in the EGP device and the distance of the waveguide tip from the bomb body surface.

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