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Thermobaric Weapons: Development, Deployment, and Global Perspectives

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Abstract
Thermobaric weapons, that started as fuel-air explosives (FAEs), are specialized munitions that produce high-temperature and high-pressure explosions. This paper offers a comprehensive analysis of their historical evolution, operational use, psychological impact, and ethical implications. It reviews key developments by global military powers such as Russia and the United States and places special focus on Romania's emerging role in thermobaric weapons development. A central contribution of this research is the documentation and contextualization of Romania's readiness to produce a thermobaric PG-9 warhead—a recent advancement not previously detailed in international literature. By integrating national data with comparative international analysis, the paper fills a gap in current research and provides a new perspective on regional innovation in modern warfare technologies.

Keywords
thermobaric weapons, fuel-air explosives, urban warfare, military technology, psychological impact

1. Introduction

Thermobaric weapons represent a class of munitions designed to create massive overpressure and high-temperature explosions by dispersing a fuel-air mixture and igniting it. These weapons have become increasingly relevant in modern military strategies due to their destructive power in enclosed environments and their effectiveness against both infrastructure and personnel [1, 2, 3]. The fallowing image represents the differences in behaviour between a conventional high explosive and a thermobaric one regarding the pressure parameter. While the thermobaric explosives may have a lower maximum pressure point, due to the fact that its effect last significantly longer it offers a higher impulse.

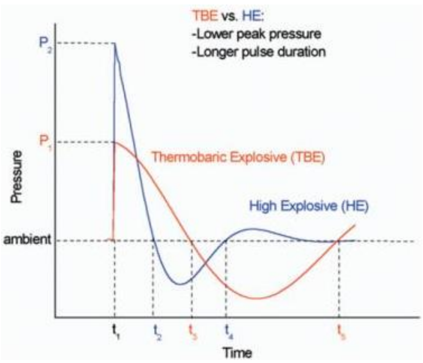

Fig. 1. The pressure wave of a thermobaric explosive in comparison with a conventional one [1]

The core problem addressed in this paper is the gap in understanding both the historical evolution and current application of thermobaric weapons across global military platforms, as well as their safety, ethical, and legal considerations [4,5]. While many nations have explored or adopted thermobaric technology, few comprehensive comparisons exist detailing their respective advancements.

Thermobaric weapons are primarily used in urban combat and bunker-clearing operations. They are notably effective in terrains where conventional explosives might prove insufficient, such as cave systems or fortified compounds. This application field spans infantry warfare, counter-terrorism, and area denial operations.

Research in this domain has progressed through several key stages: early Soviet experimentation with FAE-type munitions, Cold War development, post-9/11 U.S. operationalization, and ongoing proliferation and modernization, including recent Romanian efforts [6, 7, 8]. Methods of analysis in this paper include historical review, weapon system comparison, and assessment of experimental data from Romanian testing grounds [8, 9].

The results demonstrate the significant performance and tactical benefits of thermobaric systems, especially in asymmetric warfare. Additionally, this study highlights how psychological and ethical dimensions influence deployment decisions [5, 10].

Other researchers have documented the physical and strategic roles of thermobaric weapons [2,3], and defence manufacturers have promoted continuous innovation [4, 5]. However, this paper provides a structured synthesis of these developments while also introducing newly updated information from Romanian sources, which represents the original contribution of this work.

What is new in this study is the inclusion of Romanian defence sector initiatives, especially the preparation for production of thermobaric PG-9 munitions—an area largely absent in international literature. My contribution lies in assembling and analysing these developments through both Western and Eastern European lenses to offer a balanced, comparative perspective.

2. Historical Development

2.1. Soviet Pioneering Efforts

The Soviet Union was at the forefront of thermobaric weapons development, motivated by the need to gain a technological edge in Cold War conflicts and regional wars [3, 11]. These weapons were initially used for deforestation and mine-clearing, later adapted for direct combat use due to their destructive effects in enclosed spaces [12].

The TOS-1 system (Figure 2), developed in the early 1980s, marked a significant milestone. Mounted on a T-72 tank chassis, the TOS-1 was capable of launching 30 thermobaric rockets within 15 seconds, devastating an area of up to 80,000 square meters [13]. Soviet use of these weapons expanded during the wars in Afghanistan and Chechnya, where systems like the RPO-A Shmel demonstrated their effectiveness in urban combat scenarios [11]. However, this system has a major drawback, that being the low range and reduced mobility.

Fig. 2. TOS-1A thermobaric multiple launch system [5]

2.2. United States Development

The United States began serious development of thermobaric weapons in the early 2000s, prompted by battlefield challenges in Afghanistan [14]. The XM1060 thermobaric grenade and SMAW-NE launcher were key tools, designed for use in enclosed spaces where conventional munitions were less effective [7].

3. International Systems

3.1. Russian Arsenal

RPO-A Shmel and Variants

Approved for military use in 1988 but not mass-produced until after the Chechen Wars, the RPO-A Shmel has become a cornerstone of Russian thermobaric capability [11]. Until after the Chechen Wars, the RPO-A Shmel (Figure 3) has become a cornerstone of Russian thermobaric capability. It is classified as a flamethrower, though it is in fact a shoulder-fired rocket launcher. The more recent RPO-M variant includes a 3 kg thermobaric warhead with a TNT-equivalent of 5-6 kg, improved optics, and a reduced total weight of 8.8 kg.

Fig. 3. RPO-A Shmel and thermobaric warhead [11]

TOS-1 and TOS-1A

TOS-1 was first deployed in 1988 and proved highly effective during the Soviet-Afghan War [13]. TOS-1A, introduced in 2001, improved upon the original with fewer launch tubes but increased range (up to 6 km) and optimized launch sequences. NATO currently has no direct equivalent to this system.

Kornet-E and Metis-M1 (Figure 4)

Originally designed for anti-tank roles, these systems were later equipped with thermobaric warheads [6]. The Kornet-EM variant is vehicle-mounted and automated, offering high precision and effectiveness against buildings, light armour, and personnel. The warheads used can deliver a TNT-equivalent of up to 10 kg.

Fig. 4. Kornet-E rocket launcher [6]

GM-94 and RG-60TB

GM-94 (Figure 5) is a versatile grenade launcher used in urban combat, capable of firing various types of ammunition, including thermobaric, rubber, and smoke projectiles [4, 5]. The RG-60TB is a thermobaric hand grenade with a TNT-equivalent of up to 660 g and a lethal radius of 7 meters, significantly more difficult to defend against than traditional grenades [10].

Fig. 5. RG-60TB Thermobaric grenade [10]

3.2. United States Arsenal

SMAW-NE (Figure 6)

This U.S.-made weapon was specifically designed for urban warfare [14]. Its thermobaric warhead is effective against personnel in bunkers or buildings and has a TNT-equivalent of approximately 3.6 kg. However, real-world application revealed limitations in wall-penetration capabilities.

Fig. 6. SMAW launcher ready to fire [14]

M72 LAW Thermobaric Variant (Figure 7)

An upgraded version of the classic anti-tank rocket system, this variant is now used for anti-personnel purposes in fortified environments [15]. Its compact size and powerful thermobaric warhead make it highly effective in asymmetric warfare.

Fig. 7. M72 LAW Launcher [15]

4. Romanian Development

While Romania currently lacks operational thermobaric systems in its armed forces, development is underway [8]. A thermobaric grenade for the AG-7(Figure 8) launcher has been prototyped, boasting a lethal radius of 6 meters and a direct fire range of 100–150 meters. Additionally, the PRND 122 mm unguided rocket (Figure 9) has undergone initial testing, showing promising results with an overpressure of 16.74 bar recorded during trials [8].

Fig. 8. Thermobaric AG-7 [8]

Fig. 9. Thermobaric component of the PRND 122 mm [16]

Earlier efforts, such as the MINSECA FAE mine (Figure 10) and the LAPGECA-99 grenade launcher, reached prototype stages but are not yet deployed. Additionally, Romania is now prepared to commence production of a thermobaric PG-9 warhead, indicating progress toward equipping its forces with domestically produced thermobaric munitions [7].

Fig. 10. MINESCA FAE mine [16]

Other ammunitions are produced by Romanian manufacturers; however they are yet to be mass produced [10].

5. Tactical Use and Safety

Thermobaric weapons are unique in their ability to inflict severe damage in enclosed spaces [15]. However, they require specific safety parameters to ensure operator survival. Each system comes with minimum safe distances based on overpressure and shrapnel effects [17]. For example, the Kornet-EM has a safe operating radius of over 110 meters from shrapnel and 44 meters from the shock wave.

Despite their effectiveness, thermobaric weapons are not suitable for every combat scenario [4]. Their destructive potential in urban areas can lead to significant collateral damage, making them controversial under international humanitarian law [18].

6. Psychological and Legal Aspects

Beyond their physical effects, thermobaric weapons have a severe psychological impact [10]. The intense heat, prolonged pressure wave, and near-total destruction they cause can demoralize enemy troops and cause lasting trauma [19]. Russian military doctrine explicitly mentions the psychological utility of thermobaric systems as part of its CBRN (Chemical, Biological, Radiological, and Nuclear) strategy [16]. While thermobaric weapons are not explicitly banned under international law, their use in civilian-populated areas is heavily scrutinized [18]. Watch and the International Committee of the Red Cross have raised concerns about their compliance with the principles of proportionality and distinction under the Geneva Conventions [5, 18].

7. Original Contributions and Own Results

The central original contribution of this study lies in documenting and analysing Romania's emerging role in thermobaric weapons development—an area largely absent from international academic and strategic literature. While prior studies have focused on the Russian and U.S. arsenals, this paper introduces newly compiled Romanian sources, technical reports, and defence press releases to highlight national progress in the field [8].

Identification and contextualization of Romanian prototypes – including the thermobaric grenade for the AG-7, the PRND 122 mm unguided rocket (with overpressure values exceeding 16.7 bar during trials), and the readiness to begin production of the PG-9 thermobaric warhead [8, 9].

Comparative assessment of Romanian initiatives against established systems of Russia and the United States, showing how Romania seeks to align with NATO standards while pursuing independent innovation [3, 20].

Integration of national-level defence publications into a structured international framework, offering visibility to results that are otherwise fragmented or inaccessible to non-Romanian researchers.

Analytical insight into dual-use implications – by comparing Romania's developments to global counterparts, the study identifies potential opportunities and risks for small or medium NATO member states investing in specialized munitions.

By combining these original elements with a comprehensive international review, this work contributes both to the academic literature on thermobaric weapons and to policy-oriented discussions about defence innovation in Eastern Europe.

8. Conclusion

This study enhances the current understanding of thermobaric weapons by delivering both a structured review of global systems and an original analysis of Romania's involvement in their development. My personal contribution lies in documenting Romania's emerging efforts, particularly the readiness to begin production of a thermobaric PG-9 warhead—an effort that has not been widely covered in academic or strategic defence literature [2, 3, 8, 16].

The inclusion of Romania's emerging program—particularly the documented readiness to produce a thermobaric PG-9 warhead and the testing of the PRND 122 mm rocket—represents the key original contribution of this research [8, 9]. These findings fill a gap in international defence literature, where smaller NATO-aligned states are often underrepresented despite their growing role in specialized munitions development [4, 20].

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In compiling and analysing available technical reports, testing results, and defence publications, I have positioned Romania's thermobaric program within the broader spectrum of modern military applications used by powers like Russia and the United States [2, 4, 5]. This perspective allows for a clearer understanding of how smaller or developing NATO-aligned nations can innovate in specialized munitions.

Beyond cataloguing systems, the analysis underscores the tactical, psychological, and ethical dimensions of thermobaric weapons [5, 10, 18]. Their effectiveness in enclosed environments and asymmetric warfare is counterbalanced by humanitarian concerns, especially regarding proportionality and distinction under international law [18].

The research demonstrates that Romania's defence industry, though smaller than that of traditional military powers, can produce innovations in thermobaric technology with potential strategic implications [8, 9]. This positions Romania as a noteworthy case study for understanding how medium or smaller NATO states can contribute to alliance capabilities [4, 20].

Additionally, this paper connects operational, psychological, and ethical aspects of thermobaric use in a unified framework. My aim is to support further academic research, encourage transparency in national defence programs, and inform policymakers about the dual-use nature and legal scrutiny surrounding thermobaric technologies [10, 14, 15]. Thermobaric program within the broader spectrum of modern military applications used by powers like Russia and the United States [2, 4, 5]. This perspective allows for a clearer understanding of how smaller or developing NATO-aligned nations can innovate in specialized munitions.

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Due to the actual geopolitical situation the interest in the nonconventional weapons has risen. NATO is willing to invest in new military technologies that could offer a tactical advantage. Further research on the thermobaric explosives and the possibilities that they offer is seen as a key aspect towards increasing the strategical defence both physically and psychological.

Further research on the matter will give a better position both for NATO and Romania and gives the opportunity to increase the national military industry.

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