Aspects of thermobaric weaponry

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Abstract

- Thermobaric weapons are explosives optimised to produce heat and pressure effects instead of armour-penetrating or fragmentation damage effects.
- Use and development of thermobaric weapons have increased over the last decade.
- The weapons are particularly effective in enclosed spaces such as tunnels, buildings and field fortifications. Fireball and blast can travel around corners and penetrate areas inaccessible to bomb fragments. Blast waves are intensified when reflected by walls and other surfaces.
- The primary injury mechanisms are blast and heat, with secondary effects through flying fragments and toxic detonation gases.
- The kill radius for blast is usually greater than the kill radius for burns, so that protection against thermal injuries has little benefit.
- Blast injuries include internal injuries that can be difficult to diagnose and treat without sophisticated medical support.
- With the wide proliferation of thermobaric weapons it is important to gain a better understanding of the injury mechanisms, which will help in medical support requirement planning.

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OVER THE LAST TWO DECADES Russia has developed a new family of weapons based on incendiary and blast effects. Thermobaric weapons have been part of that development. As the name implies they are optimised for heat and pressure effects, whereas typical Western weapon development has been focused on achieving improved fragmentation/penetration effects. Thermobaric weapons are a subcomponent of a larger family of weapon systems commonly known as volumetric weapons, which also include fuel-air explosives. The characteristics of this weapon category are the creation of a large fireball and good blast performance.

Recent conflicts have seen increased use of thermobaric weapons. Russia has employed this type of weaponry extensively in Afghanistan and Chechnya. The best known weapon is probably the RPO-A Shmel rocket infantry flame-thrower,[1] a short-range, shoulder-launched unguided rocket, which was used on both sides of the Chechnya conflict to defeat snipers and dug-in machine gunners, and to clear caves. Thermobaric warheads are also employed in artillery shells and multi-round rocket systems like the GUP TOS-1 (220 mm, 30-round launcher).[2] Weapons of this nature are advertised in arms shows and seem to be readily available to any country or terrorist organisation.

Western countries have only recently directed research and development towards thermobaric weaponry. With wide proliferation of these weapons, the need to develop countermeasures was the initial driver for research. Casualty evaluation methods for operational planning, logistics and prediction of medical support requirements were also important considerations. Since then, the superior effectiveness of thermobaric weapons against bunkers, buildings and tunnels compared with conventional blast/fragmentation munitions demonstrated during the Chechnya and Afghanistan conflicts have led to increased interest in developing similar weapons in the West.

Thermobaric weapons are able to overcome shortcomings of conventional blast/fragmentation and shaped-charge munitions for specific targets. For example, conventional shaped-charge, shoulder-launched rockets effective against armoured vehicles have had only limited success against buildings, field fortifications, machine gun posts and the like. The high velocity metal jet created by a shaped charge has a very narrow damage radius and travels in a straight line. Blast waves, on the other hand, can travel around corners and their effect is not based on penetration. Conventional countermeasures such as barriers (sandbags) and personnel armour are not effective against thermobaric weaponry. Conventional hard-target-penetrating fragmentation bombs have shown shortcomings for defeating tunnels and caves. Fragments can be stopped by walls and do not necessarily penetrate through a tunnel system. The current conflict in Afghanistan resulted in the US developing a thermobaric warhead for the Hellfire anti-armour weapon[3] and the BLU-118/B[4] thermobaric bomb. Similar developments are taking place in the UK.[5]

This article discusses the basic physics of the thermobaric weapon, target effects and countermeasures and the injuries produced by thermobaric weaponry.

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Thermobaric weaponry basics

Detonation of a high explosive device produces a rapid, localised energy release. The formation of a blast wave, thermal radiation, break-up of the munition casing and acceleration of the fragments dissipate this energy. In the case of conventional blast/fragmentation warheads, a large part of the energy is taken up by the break-up of the casing and acceleration of the fragments. Thermobaric weaponry usually has very thin casing and most of the energy ends up as fireball and blast/shock wave. The energy release in explosions occurs over microseconds and is governed by the detonation velocity of the explosive. Detonation velocities of thermobaric explosives (3–4 km/s) are similar to those of mining blast explosives, and considerably lower than those of military high explosives (about 8 km/s).

Explosives used in thermobaric weapons are generally oxygen-deficient; additional oxygen from the air is required to achieve complete combustion of the charge. Only part of the energy is released during the initial detonation phase, which generates high levels of fuel-rich products that undergo "after-burning" when mixed with the shock-heated air. The energy released through after-burning and combustion lengthens the duration of blast overpressure and increases the fireball. In conventional blast/fragmentation TNT-based munitions, no significant after-burn occurs. Fragments inhibit the mixing of detonation gases with air and the rapid expansion of the detonation has a cooling effect before mixing with atmospheric oxygen occurs.

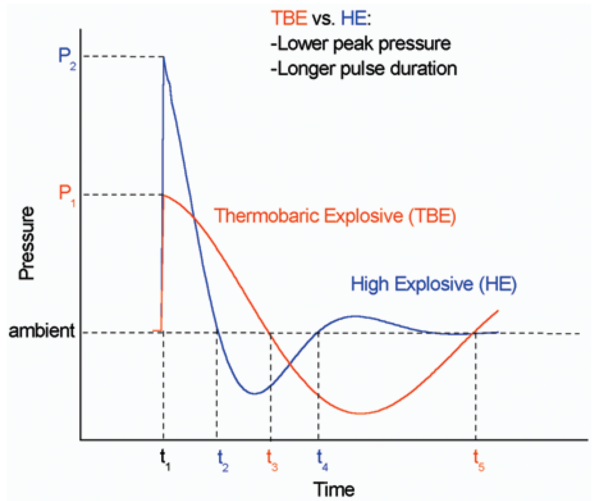
All explosions form a blast wave, which travels faster than the speed of sound. Box 1 shows typical pressure histories for a conventional high explosive and a thermobaric explosive observed as the expanding shock front moves outwards from the centre of explosion. A shock front originates at the interface between detonation products and the surrounding atmosphere. There is a dramatic increase in pressure across the shock front (time t_1 on the graph), which has a crushing effect on objects in addition to an instantaneous lateral force. As can be seen in Box 1, the peak overpressure is much higher for the high explosive detonation (P_2) than for the thermobaric detonation (P_1), but this pressure drops much more rapidly. The positive phase is followed by a negative phase below atmospheric pressure. The negative phase results in a reversed-blast wind and causes human targets to be bodily lifted and thrown. This phase can be longer in a thermobaric detonation than a high explosive detonation. Thus, despite the lower initial blast pressure, the total impulse (represented graphically in Box 1 by the area under the curve) can be comparable or even higher for thermobaric explosives compared with high explosives. Target effects are dependent on peak blast overpressure as well as on the duration (impulse) of the event. Animal research indicates that tolerance to blast overpressure progressively decreases with increase in pulse duration.[6]

Target effects and countermeasures

Box 2 shows the injury mechanisms for detonation of an explosive charge in the open. The mechanisms are the same for high explosives and thermobaric explosives.

Thermal injuries usually occur close to the origin of the explosion. The lethal range for burn injuries is defined by the size of the fireball. The lethal area for blast injuries overlaps and exceeds the area of thermal injuries. As pressure effects decline over distance, the blast injury lethality also decreases. The lethal range for fragment/blunt trauma events extends far beyond the lethal range for blast. Typical fragment velocities for conventional blast/fragmentation warheads are 1500 m/s and fragments often travel for kilometres.

1: Pressure history of high explosive (HE) and thermobaric explosive (TBE) detonations

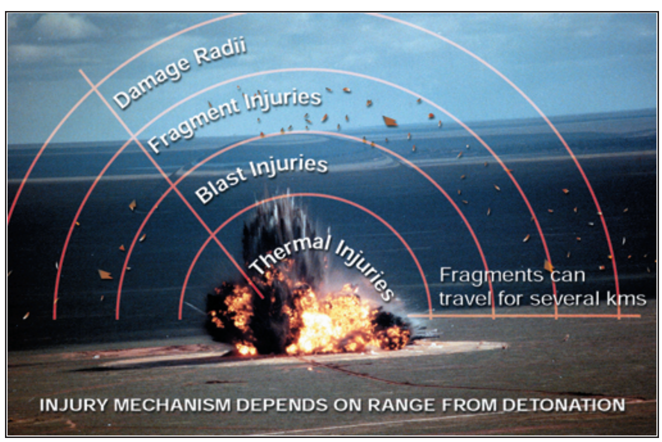


This implies that thermobaric weapons used in the open have limited lethal radii — which can be an advantage in situations where civilians or friendly forces are in the vicinity of the enemy position.

The target effect changes when explosives are used in a confined space (Box 3). Fireball and blast wave can travel around corners and penetrate into areas where fragments cannot. Fragments can be stopped by walls, sandbags and personnel protection. Furthermore, blast waves are intensified when reflected by walls and other surfaces (Box 4). Personnel inside a confined space will be subjected to much higher pressure and impulse levels than they would at the same distance from the charge in an open environment.

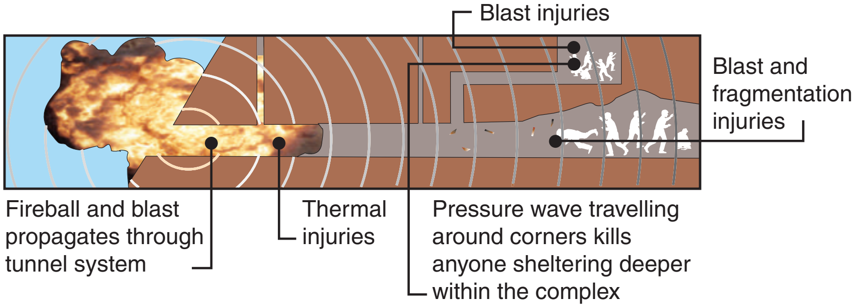
Countermeasures can be used against flying fragments. For example, increasing the thickness or changing material properties of a target may reduce fragment penetration. Personnel armour, sandbag barriers or armour on vehicles can be effective countermeasures against fragments. Countermeasures employed

2: Injury mechanisms in an unconfined explosion



against thermal injuries (burns) may involve protective fire-resistant clothing. However, in most thermobaric explosions, the kill radius for blast is larger than that for thermal injuries and protection against thermal injuries has little benefit. Protection against blast injury is very difficult to achieve. Research has shown that conventional personnel protection (bulletproof vests) might even increase injuries,[7,8] enhancing blast effects by increasing target surface area and changing the effective loading function on the thorax. Current research is investigating possible decoupling mechanisms by using layers of materials with different densities in personnel armour to mitigate blast effects by disrupting the stress wave and reducing the amount of energy transmitted through the body wall.

3: Injury mechanisms in a confined explosion



Injury mechanisms

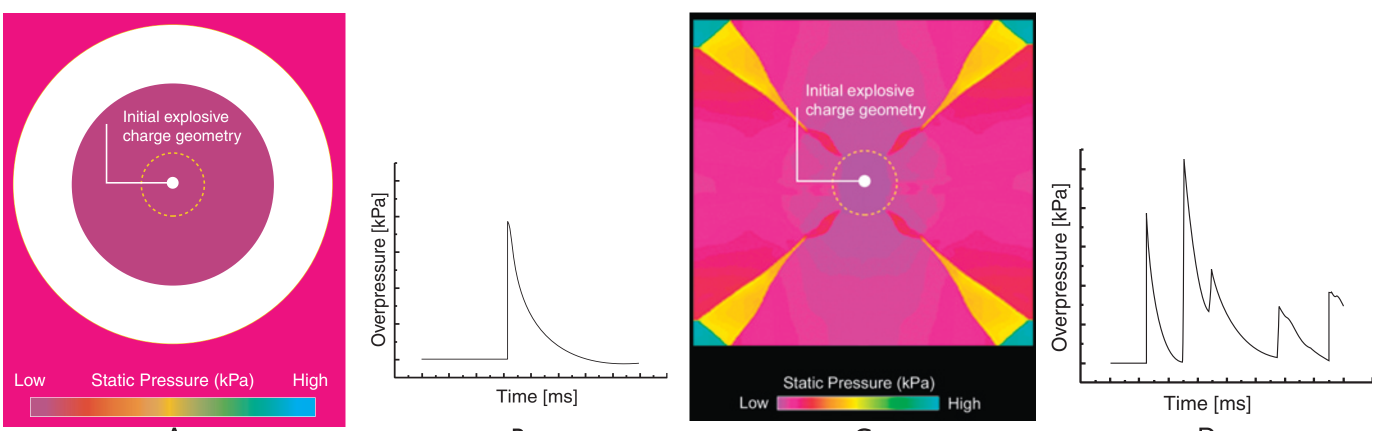
The primary injury mechanisms of thermobaric weapons are blast and heat. Secondary injury mechanisms are flying fragments created by interaction of the blast with structures (eg, flying bricks, glass and metal debris) and suffocation through the generation of toxic gases and smoke.

The level of structural damage and injury caused by blast is dependent on the peak pressure, impulse (a function of time and pressure), the overall shape of the pressure–time curve, and the elastic–plastic strength and natural period of oscillation of the structure or body. In the human body, the shock wave/blast interacts with many types of tissues (eg, skin, fat, muscle and bone) that differ in density, elasticity and strength. Each tissue type, when interacting with a blast wave, is compressed, stretched, sheared or disintegrated by overload according to its material properties. Internal organs that contain air (sinuses, ears, lungs and intestines) are particularly vulnerable to blast. The whole body may also be thrown by blast wind, which can result in fractures. Besides the obvious blast injuries, recent research has shown that there are neurological, biochemical and blood chemistry changes caused by blast effects.[10-11]

During the 1950s and 1960s the US Defense Agencies and Laboratories carried out extensive studies on explosive blast loading to estimate casualty effects. The aim of the experiments was to assess nuclear explosion loading. The effects of blast loading on dummies in the open air, as well as animal shock tube experiments, were studied. These studies generated a range of survivability curves that can be used to predict blast injury levels, such as temporary to permanent hearing loss, bronchial and

4: Blast wave effects in a confined space

These images were generated in a mathematical simulation of the blast of a bare explosive charge in the open and in a confined space using computational fluid dynamic tools.



A B C D

Figure A depicts pressure contours for a spherical bare explosive charge detonated in the open at a specific time after detonation. The pressure wave spreads without disturbance radially around the charge. Figure B shows a typical pressure–time curve for this case.

Figure C depicts the same explosive charge detonated in the centre of a room. The shockwaves are reflected by the walls, producing zones of amplified pressure, in particular at the corners. Figure D depicts the pressure–time graph for this case. Unlike the uniform decline of pressure over time shown in Figure B, the pressure oscillates over time. The effect is non-linear; shock reflection in corners can multiply the peak pressure several times.

gastrointestinal rupture, or major bone breakage. The data were further analysed by Baker et al[12] to include variations due to altitude, atmospheric pressure and body weight. The underlying experiments were based on conventional high explosive and free field conditions. Applicability of the data to thermobaric explosions and enclosed spaces is limited. Current research is using a variety of methods, including instrumented human surrogate targets and mathematical modelling to assess blast damage to personnel.

Current medical support requirement planning is focused on injuries caused by conventional fragmentation weapons, but diagnosis and treatment[13] of blast injuries may require computed tomography, which might not be readily available in the battlefield. Detailed understanding of thermobaric injury mechanisms will help the medical community to develop appropriate casualty evaluation methods, logistical support and prediction of medical support requirements.

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Risk assessment: exposure to depleted uranium

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Abstract

- Close proximity to depleted uranium metal, as in storage facilities, carrying shells or driving tanks, even when prolonged, produces negligible internal radiation exposure and levels of external radiation exposure well below the recommended levels for occupational safety.
- The estimates of depleted uranium intake, chemical dose, and radiation dose calculated by the US Department of Defense for personnel exposed to depleted uranium through operations in areas where depleted uranium munitions had exploded, or through clean-up and repair operations on vehicles damaged by depleted uranium munitions, indicate that those veterans experienced air concentrations well below the short-term exposure limits. Estimated exposures were far below any relevant US federal or industrial guideline for chemical or radiation exposure.
- Recent risk assessments by the Royal Society show that, while studies of large cohorts of veterans are vitally important to explore and understand the experiences and exposures which may affect the health status of veterans, most veterans of conflicts involving depleted uranium munitions would have had very low or negligible exposure to depleted uranium.

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RISK ASSESSMENT is the characterisation of potential adverse effects of human exposures to hazardous agents or activities. The size of this potential in relation to chemical–biological–radiological hazards is judged on the basis of population data comparing exposed and non-exposed groups — that is, through epidemiological studies. The harmful potential of an exposure (the size of the risk) will be measured in terms of the dose to sensitive or target tissues. When there is no current or potential exposure there can be no risk.

The potential pathways of exposure for environmental chemicals are the same for depleted uranium as for any other chemical: ingestion, inhalation and skin contact (including wound contamination). These are pathways for external or internal exposure and do not equate with dose. An exposure may occur, but if the agent is not absorbed no dose may be received. It is the dose to the target organs that contributes to the risk of adverse outcomes.

Risk assessment for depleted uranium exposure

External contact

Manufacture and storage of depleted uranium

Based on extensive study of the health of uranium process workers, the risk from depleted uranium manufacture and storage is negligible.