Thermobaric weapon

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Explosive that uses oxygen from the surrounding air to generate a high-temperature explosion

Blast from a US Navy fuel–air explosive used against a decommissioned ship, USS *McNulty*, 1972

A **thermobaric weapon**, **aerosol bomb**, or **vacuum bomb**[1] is a type of explosive that uses oxygen from the surrounding air to generate a high-temperature explosion. In practice, the blast wave typically produced by such a weapon is of a significantly longer duration than that produced by a conventional condensed explosive. The **fuel–air explosive** (**FAE**) is one of the best-known types of thermobaric weapon.

Most conventional explosives consist of a fuel–oxidizer premix (black powder, for example, contains 25% fuel and 75% oxidizer), whereas thermobaric weapons are almost 100% fuel, so thermobaric weapons are significantly more energetic than conventional condensed explosives of equal weight. Their reliance on atmospheric oxygen makes them unsuitable for use underwater, at high altitude, and in adverse weather. They are, however, considerably more destructive when used against field fortifications such as foxholes, tunnels, bunkers, and caves—partly due to the sustained blast wave and partly by consuming the oxygen

inside.

Many types of thermobaric weapons can be fitted to hand-held launchers.[2]

Contents

Terminology[edit]

The term *thermobaric* is derived from the Greek words for "heat" and "pressure": *thermobarikos* (θερμοβαρικός), from *thermos* (θερμός), hot + *baros* (βάρος), weight, pressure + suffix *-ikos* (-ικός), suffix *-ic*.

Other terms used for this family of weapons are *high-impulse thermobaric weapons* (HITs), *heat and pressure weapons*, *vacuum bombs*, or *fuel–air explosives* (FAE or FAX).

Mechanism[edit]

In contrast to a condensed explosive in which oxidation in a confined region produces a blast front emanating from a single source, a thermobaric flame front accelerates to a large volume, which produces pressure fronts both within the mixture of fuel and oxidant and then in the surrounding air.[3]

Thermobaric explosives apply the principles underlying accidental unconfined vapor cloud explosions, which include those from dispersions of flammable dusts and droplets.[4] Previously, such explosions were most often encountered in flour mills and their storage containers, and later in coal mines; but, now, most commonly in partially or fully empty oil tankers and refinery tanks and vessels, including an incident at Buncefield in the UK in 2005 where the blast wave woke people 150 kilometres (93 mi) from its centre.[5]

A typical weapon consists of a container packed with a fuel substance, in the center of which is a small conventional-explosive "scatter charge". Fuels are chosen on the basis of the exothermicity of their oxidation, ranging from powdered metals, such as aluminum or magnesium, to organic materials, possibly with a self-contained partial oxidant. The most recent development involves the use of nanofuels.[6][7]

A thermobaric bomb's effective yield requires the most appropriate combination of a number of factors; among these are how well the fuel is dispersed, how rapidly it mixes with the surrounding atmosphere, and the initiation of the igniter and its position relative to the container of fuel. In some designs, strong munitions

cases allow the blast pressure to be contained long enough for the fuel to be heated up well above its auto-ignition temperature, so that once the container bursts the super-heated fuel will auto-ignite progressively as it comes into contact with atmospheric oxygen.[8] Conventional upper and lower limits of flammability apply to such weapons. Close in, blast from the dispersal charge, compressing and heating the surrounding atmosphere, will have some influence on the lower limit. The upper limit has been demonstrated strongly to influence the ignition of fogs above pools of oil.[9] This weakness may be eliminated by designs where the fuel is preheated well above its ignition temperature, so that its cooling during its dispersion still results in a minimal ignition delay on mixing. The continual combustion of the outer layer of fuel molecules as they come into contact with the air, generates additional heat which maintains the temperature of the interior of the fireball, and thus sustains the detonation.[10]

In confinement, a series of reflective shock waves are generated,[11][12] which maintain the fireball and can extend its duration to between 10 and 50 ms as exothermic recombination reactions occur.[13] Further damage can result as the gases cool and pressure drops sharply, leading to a partial vacuum. This rarefaction effect has given rise to the misnomer "vacuum bomb". Piston-type afterburning is also believed to occur in such structures, as flame-fronts accelerate through it.[14]

Fuel–air explosive[edit]

A fuel–air explosive (FAE) device consists of a container of fuel and two separate explosive charges. After the munition is dropped or fired, the first explosive charge bursts open the container at a predetermined height and disperses the fuel (also possibly ionizing it, depending on whether a fused quartz dispersal charge container was employed) in a cloud that mixes with atmospheric oxygen (the size of the cloud varies with the size of the munition). The cloud of fuel flows around objects and into structures. The second charge then detonates the cloud, creating a massive blast wave. The blast wave destroys reinforced buildings and equipment and kills and injures people. The antipersonnel effect of the blast wave is more severe in foxholes and tunnels, and in enclosed spaces, such as bunkers and caves.

Fuel–air explosives were first developed by the United States for use in Vietnam. In response, Soviet scientists quickly developed their own FAE weapons, which were reportedly used against China in the Sino-Soviet border conflict, and against the Mujahideen in Afghanistan. Since then, research and development has continued and currently Russian forces field a wide array of third-generation FAE warheads.

Effect[edit]

A Human Rights Watch report of 1 February 2000[15] quotes a study made by the US Defense Intelligence Agency:

> The [blast] kill mechanism against living targets is unique—and unpleasant. ... What kills is the pressure wave, and more importantly, the subsequent rarefaction [vacuum], which ruptures the lungs. ... If the fuel deflagrates but does not detonate, victims will be severely burned and will probably also inhale the burning fuel. Since the most common FAE fuels, ethylene oxide and propylene oxide, are highly toxic, undetonated FAE should prove as lethal to personnel caught within the cloud as with most chemical agents.

According to a U.S. Central Intelligence Agency study,[15] "the effect of an FAE explosion within confined spaces is immense. Those near the ignition point are obliterated. Those at the fringe are likely to suffer many internal, and thus invisible injuries, including burst eardrums and crushed inner ear organs, severe concussions, ruptured lungs and internal organs, and possibly blindness." Another Defense Intelligence Agency document speculates that, because the "shock and pressure waves cause minimal damage to brain tissue ... it is possible that victims of FAEs are not rendered unconscious by the blast, but instead suffer for several seconds or minutes while they suffocate".[16]

Development history[edit]

German developments[edit]

First attempts had previously been undertaken during the Second World War by the German Luftwaffe and Wehrmacht, their inventor being Mario Zippermayr.[17]

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The initial weapon – named *Taifun* (Typhoon)—was based on coal dust and concentrated oxygen pumped into a space and detonated. The effect was a development from observing coal mine accidents in the 1920s. It was first used against Russian bunkers at Sevastopol.[18] Taifun B was a development that allowed an aerosol of kerosene, coal dust and aluminium powder to be delivered over the battlefield by bursting rocket propelled canisters launched from half tracks over a target such as a mass of tanks or troops.[19] In 1944, the weapon was positioned behind Calais to aid in a counterattack in the event of a successful Allied taking of the port. Once it became clear that the Normandy landings were the real invasion, the weapon system was moved to counter the American breakout. Immediately prior to its firing, the weapon system was knocked out in a routine bombardment and was never actually used. Replacement of the system proved difficult due to material shortages — principally the pure powdered aluminium. Further developments for delivery by V1 for use as a tactical weapon were not pursued.[20]

Soviet and Russian developments[edit]

An RPO-A Shmel (Bumblebee) rocket and launcher

Thermobaric weapons were developed in the 1960s in the Soviet Union and US; however, the first attempts had previously been undertaken during the Second World War by the German Luftwaffe.

The Soviet armed forces extensively developed FAE weapons,[21] such as the RPO-A, and Russia used them in Chechnya.[22]

The Russian armed forces have developed thermobaric ammunition variants for several of their weapons, such as the TBG-7V thermobaric grenade with a lethality radius of 10 metres (33 ft), which can be launched from an RPG-7. The GM-94 is a 43 mm (1.7 in) pump-action grenade launcher designed mainly to fire thermobaric grenades for close quarters combat. The grenade weighed 250 grams (8.8 oz) and contained 160 grams (5.6 oz) of explosive, its lethality radius is 3 metres (9.8 ft); however, due to the deliberate "fragmentation-free" design of the grenade, 4 metres (13 ft) is considered a safe distance.[23] The RPO-A and upgraded RPO-M are infantry-portable RPGs designed to fire thermobaric rockets. The RPO-M, for instance, has a thermobaric warhead with a TNT equivalence of 5.5 kg (12 lb) and destructive capabilities similar to a 152 mm (6 in) high explosive fragmentation artillery shell.[24][25] The RShG-1 and the RShG-2 are thermobaric variants of the RPG-27 and RPG-26 respectively. The RShG-1 is the more powerful variant, with its warhead having a 10-metre (33 ft) lethality radius and producing about the same effect as 6 kg (13 lb) of TNT.[26] The RMG is a further derivative of the RPG-26 that uses a tandem-charge warhead, whereby the precursor HEAT warhead blasts an opening for the main thermobaric charge to enter and detonate inside.[27] The RMG's precursor HEAT warhead can penetrate 300 mm of reinforced concrete or

over 100 mm of rolled homogeneous armour, thus allowing the 105 mm (4.1 in)-diameter thermobaric warhead to detonate inside.[28]

The other examples include the SACLOS or millimeter wave radar-guided thermobaric variants of the 9M123 Khrizantema, the 9M133F-1 thermobaric warhead variant of the 9M133 Kornet, and the 9M131F thermobaric warhead variant of the 9K115-2 Metis-M, all of which are anti-tank missiles. The Kornet has since been upgraded to the Kornet-EM, and its thermobaric variant has a maximum range of 10 km (6 mi) and has a TNT equivalence of 7 kg (15 lb).[29] The 300 mm (12 in) 9M55S thermobaric cluster warhead rocket was built to be fired from the BM-30 Smerch MLRS. A dedicated carrier of thermobaric weapons is the purpose-built TOS-1, a 24-tube MLRS designed to fire 220 mm (8.7 in) thermobaric rockets. A full salvo from the TOS-1 will cover a rectangle 200 by 400 m (220 by 440 yd).[30] The Iskander-M theatre ballistic missile can also carry a 700 kg (1,540 lb) thermobaric warhead.[31]

Many Russian Air Force munitions also have thermobaric variants. The 80 mm (3.1 in) S-8 rocket has the S-8DM and S-8DF thermobaric variants. The S-8's 122 mm (4.8 in) brother, the S-13, has the S-13D and S-13DF thermobaric variants. The S-13DF's warhead weighs only 32 kg (71 lb), but its power is equivalent to 40 kg (88 lb) of TNT. The KAB-500-OD variant of the KAB-500KR has a 250 kg (550 lb) thermobaric warhead. The ODAB-500PM and ODAB-500PMV[32] unguided bombs carry a 190 kg (420 lb) fuel–air explosive each. The KAB-1500S GLONASS/GPS guided 1,500 kg (3,300 lb) bomb also has a thermobaric variant. Its fireball will cover a 150 m (490 ft) radius and its lethal zone is a 500 m (1,600 ft) radius.[33] The 9M120 Ataka-V and the 9K114 Shturm ATGMs both have thermobaric variants.

In September 2007, Russia exploded the largest thermobaric weapon ever made. Its yield was reportedly greater than the smallest dial-a-yield nuclear weapons at their lowest settings.[34][35] Russia named this particular ordnance the "Father of All Bombs" in response to the United States developed Massive Ordnance Air Blast (MOAB) bomb whose backronym is the "Mother of All Bombs", and which previously held the title of the most powerful non-nuclear weapon in history.[36] The Russian bomb contains an approximate 7 ton charge of a liquid fuel, such as pressurized ethylene oxide, mixed with an energetic nanoparticle, such as aluminium, surrounding a high explosive burster[37] that when detonated created an explosion equivalent to 39.9 tonnes (39.3 long tons; 44.0 short tons) of TNT.

U.S. developments[edit]

A BLU-72/B bomb on a USAF A-1E taking off from Nakhon Phanom, in September 1968

Current U.S. FAE munitions include:

- BLU-73 FAE I
- BLU-95 500-lb (FAE-II)
- BLU-96 2,000-lb (FAE-II)
- CBU-55 FAE I
- CBU-72 FAE I

The XM1060 40-mm grenade is a small-arms thermobaric device, which was delivered to U.S. forces in

April 2003.[38] Since the 2003 Invasion of Iraq, the US Marine Corps has introduced a thermobaric "Novel Explosive" (SMAW-NE) round for the Mk 153 SMAW rocket launcher. One team of Marines reported that they had destroyed a large one-story masonry type building with one round from 100 yards (91 m).[39]

The AGM-114N Hellfire II, first used by U.S. forces in 2003 in Iraq, uses a Metal Augmented Charge (MAC) warhead that contains a thermobaric explosive fill using aluminium powder coated or mixed with PTFE layered between the charge casing and a PBXN-112 explosive mixture. When the PBXN-112 detonates, the aluminium mixture is dispersed and rapidly burns. The resultant sustained high pressure is extremely effective against people and structures.[40]

BEAC Spanish thermobaric bomb project[edit]

In 1983, a program of military research was launched with collaboration between the Spanish Ministry of Defence (Directorate General of Armament and Material, DGAM), Explosives Alaveses (EXPAL) and Explosives Rio Tinto (ERT) with the goal of developing a Spanish version of a thermobaric bomb, the BEAC (*Bomba Explosiva de Aire-Combustible*). A prototype was tested successfully in a foreign location out of safety and confidentiality concerns.[41] The Spanish Air Force has an undetermined number of BEACs in its inventory.[42]

History[edit]

Military use[edit]

US Navy BLU-118B being prepared for shipping for use in Afghanistan, 5 March 2002

The TOS-1 system was test fired in Panjshir Valley during the Soviet–Afghan War in the late 1980s.[43]

Unconfirmed reports suggest that Russian military forces used ground-delivered thermobaric weapons in the storming of the Russian parliament during the 1993 Russian constitutional crisis and also during the Battle for Grozny (first and second Chechen wars) to attack dug-in Chechen fighters. The use of both TOS-1 heavy MLRS and "RPO-A Shmel" shoulder-fired rocket system in the Chechen wars is reported to have occurred.[44]

It is theorized that a multitude of handheld thermobaric weapons were used by the Russian Armed Forces in their efforts to retake the school during the 2004 Beslan school hostage crisis. The RPO-A and either the TGB-7V thermobaric rocket from the RPG-7 or rockets from either the RShG-1 or the RShG-2 is claimed to have been used by the Spetsnaz during the initial storming of the school.[45][46][47] At least three and as many as nine RPO-A casings were later found at the positions of the Spetsnaz.[48][49] The Russian government later admitted to the use of the RPO-A during the crisis.[50]

According to the UK Ministry of Defence, British military forces have also used thermobaric weapons in their AGM-114N Hellfire missiles (carried by Apache helicopters and UAVs) against the Taliban in the War in Afghanistan.[51]

The US military also used thermobaric weapons in Afghanistan. On 3 March 2002, a single 2,000 lb (910 kg) laser guided thermobaric bomb was used by the United States Air Force against cave complexes in which Al-Qaeda and Taliban fighters had taken refuge in the Gardez region of Afghanistan.[52][53] The SMAW-NE was used by the US Marines during the First Battle of Fallujah and Second Battle of Fallujah.

Reports by the rebel fighters of the Free Syrian Army claim the Syrian Air Force used such weapons against residential area targets occupied by the rebel fighters, as for instance in the Battle for Aleppo[54] and also in Kafar Batna.[55] A United Nations panel of human rights investigators reported that the Syrian government used thermobaric bombs against the rebellious town of Qusayr in March 2013.[56]

Russia and Syrian government are using thermobaric bombs and other thermobaric munitions during the Syrian Civil War against insurgents and insurgent held civilian areas.[57][58][59]

Terrorist use[edit]

Thermobaric and fuel–air explosives have been used in guerrilla warfare since the 1983 Beirut barracks bombing in Lebanon, which used a gas-enhanced explosive mechanism, probably propane, butane or acetylene.[60] The explosive used by the bombers in the 1993 World Trade Center bombing in the US incorporated the FAE principle, using three tanks of bottled hydrogen gas to enhance the blast.[61][62] Jemaah Islamiyah bombers used a shock-dispersed solid fuel charge,[63] based on the thermobaric principle,[64] to attack the Sari nightclub in the 2002 Bali bombings.[65]

See also[edit]

- Bunker buster
- CBU-55
- Dust explosion
- FOAB
- Flame fougasse
- RPO-A
- SMAW
- Trocano
- ALAC Brazilian thermobaric weapon antitank (see: IMBEL)

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