Insensitive Munition Test on Artillery ammunition Vulcano 127 mm and 155 mm Ballistic Extended Range (BER) version.

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1. Introduction

Vulcano is a family of new generation ammunitions developed in the last 10-15 years by Leonardo Electronics (former Oto Melara).
Nowadays Vulcano family covers 3 calibers: 155 mm designed for the Army, 127 mm and 76 mm dedicated for the Navy; each calibre has an unguided version and several guided configurations.
Results of the IM qualification tests for the Vulcano unguided 127 mm and 155 mm are presented in this paper; the ballistic version of Vulcano is named **Vulcano BER** (**B**allistic **E**xtended **R**ange)[1].

Vulcano 127 BER (V127BER) is a fixed-cartridge ammunition composed by a propulsion charge (brass cartridge case containing propellant and electric priming tube) clamped to a sub-caliber projectile (through a discarded sabot) having High Explosive (HE) PBX composition ignited by an electronic fuze. The total weight of energetic material is roughly 13 kg.

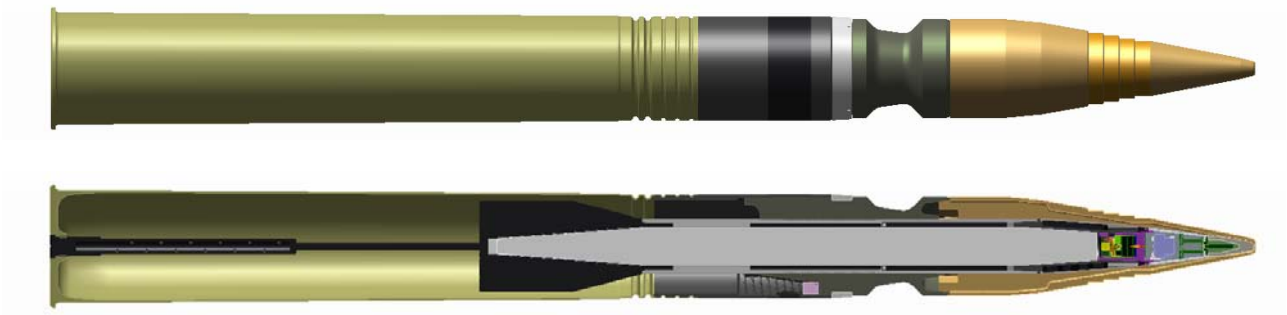
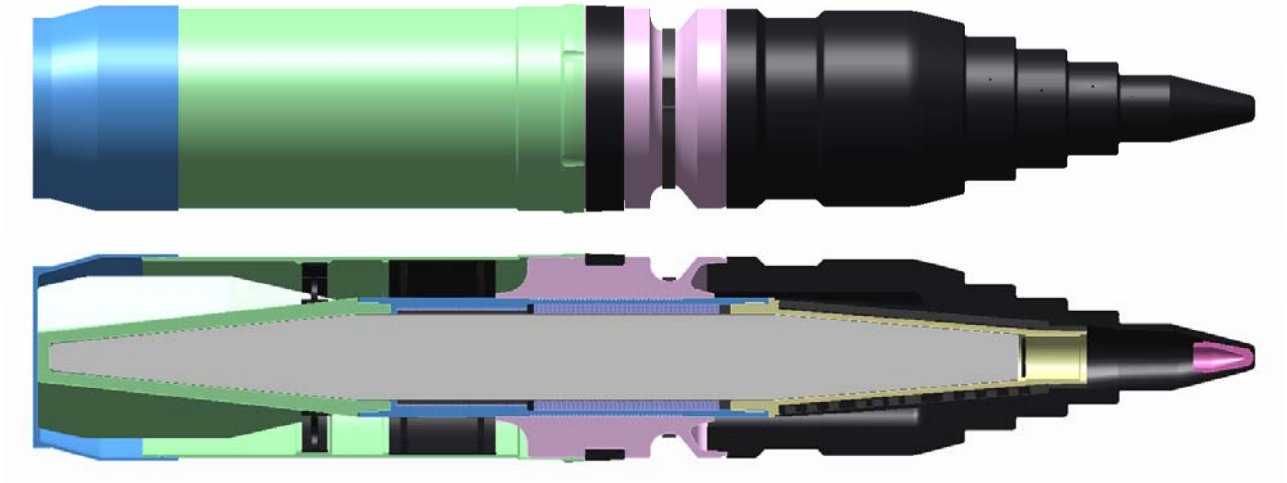


Figure 1: Vulcano 127 BER cartridge and its section, weight about 40 kg and full length about 1.5 m.

Vulcano 155 BER (V155ER) is an ammunition to be fired with the standard propulsion charge (modular charges), the ammunition contains some kg of propellant around the tail (in an additional module embedded with the ammo), the sub-caliber projectile has high explosive PBX composition ignited by an electronic fuze. The total weight of energetic material is around 7,5 kg.



[1] The guided version of Vulcano GLR (Guided Long Range) repeat several of these test in a different contract.

Figure 2: Vulcano 155 BER ammunition and its section, weight about 36 kg and full length about 950 mm.

At the end of the Vulcano development phase, the Italian MoD founded a full qualification contract of either Vulcano 127 mm and 155 mm BER, the following IM tests were part of this qualification process. Due to the original user requirements, in which the IM level were not requested, the test has been done in order to characterise the IM responsiveness of these ammunitions when experienced to the most probable IM threats; as consequence of a threat analysis, the following IM test were chosen for both calibers: Bullet Impact (BI), Sympathetic Detonation (SD), Fast Cook Off (FCO) and Slow Cook Off (SCO).
In the following part of the paper the Vulcano 127 BER is so-called V127BER whilst the Vulcano 155 BER is so-called V155BER.

2. Bullet Impact

The tests were carried out in Nettuno proving ground, facility belonged to ITA MoD. For both calibres, the BI was organize using a 12.7 mm Armour Piercing (AP) projectile fired at 850 m/s from a fixed gun placed at 27m from the ammunition under test. Figure 3 shows the layout of the test for the V155BER, the same procedure and layout were used for V127BER.

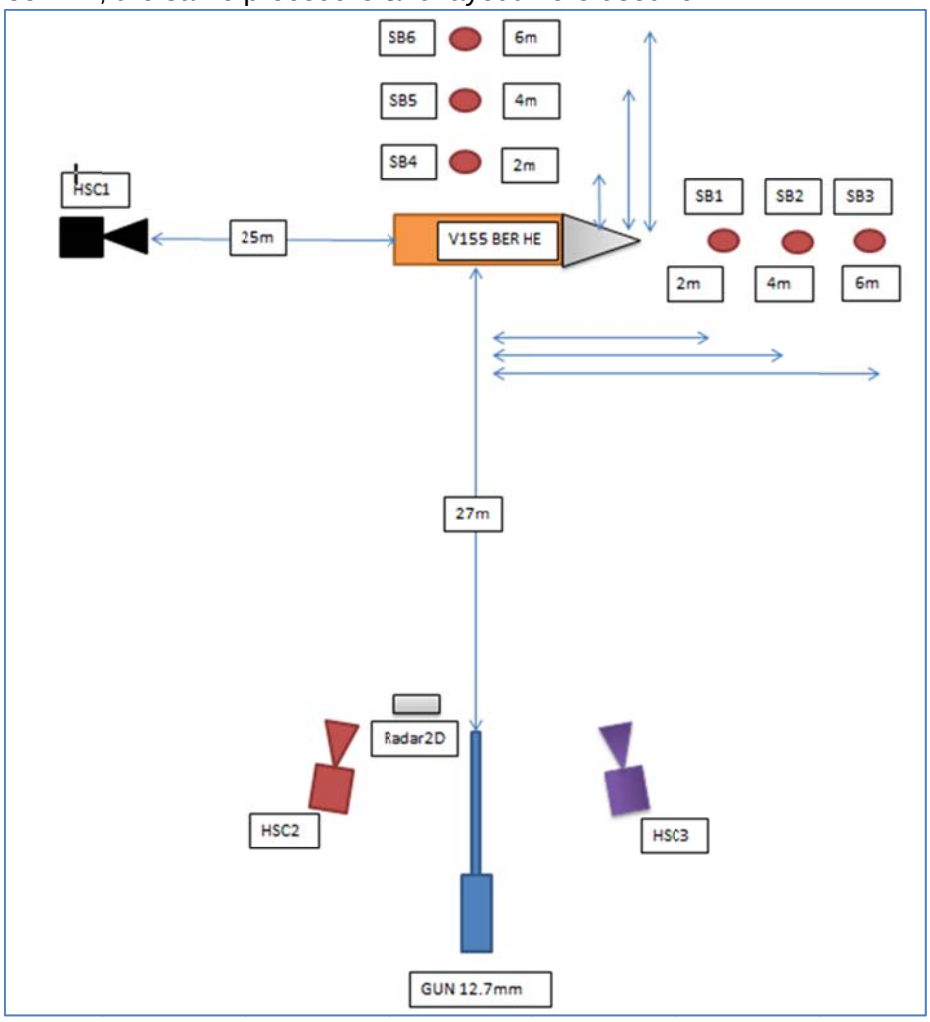


Figure 3. Bullet impact layout.

While for the V127BER it was decided to have three separates[2] impact points: Safety and Arming Device, Warhead and primer tube section, for the V155BER, two separate impact points were identified: Safety and Arming Device and at War Head (WH).

[2] different test with different ammunition

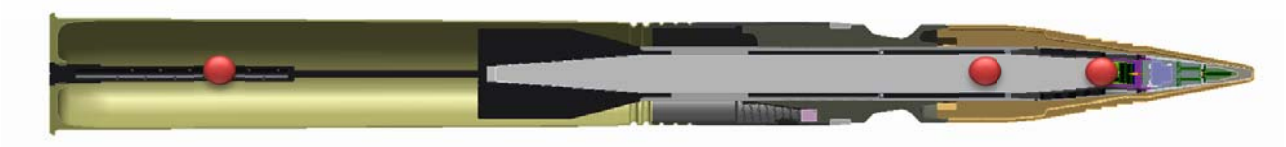


Figure 4. Vulcano 127 BER impact point for the 12.7mm AP projectile. (picture not in scale)

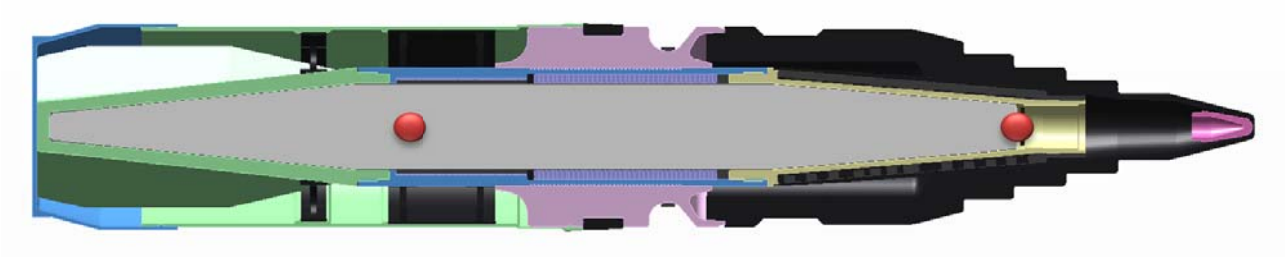


Figure 5. Vulcano 155 BER impact point for the 12.7mm AP projectile. (picture not in scale)

2.1. V127BER Bullet impact results

The impact of the 12.7 mm AP against the SAD section did not cause any reaction; whilst the impact against the primer tube section caused the propelling charge combustion without any propulsion of ammunition parts.
The impact against the WH section caused the combustion of the WH explosive without any propulsion of ammunition parts[3].
No significant blast wave from the reaction was recorded from the above tests.
The final overall result of BI gave the type V signature for the V127BER.

SAD section

Primer tube section

WH section

Figure 6. V127BER results.

2.1. V155BER Bullet impact results

The impact of the 12.7 mm AP against the SAD section did not cause any reaction;
The impact against the WH section caused the quick reaction of the propelling portion around the tail section and a later combustion of the WH explosive without any propulsion of ammunition parts[4].
No significant blast wave from the reaction was recorded.
The final overall result of BI gave the type V signature for the V155BER.

[3] During this test the burning of the explosive WH start a flame in wood support with the consequence that the bullet impact was followed by a sort of fast cook off in the whole ammo with burning of the propelling charge and some propulsion of the brass cartridge and part of the fuze. In the IM characterization this separated fire was not taken into account.
[4] Small plastic fragments having a weight of some grams where propelled at some meters (less than 15 m) from the item under investigation.

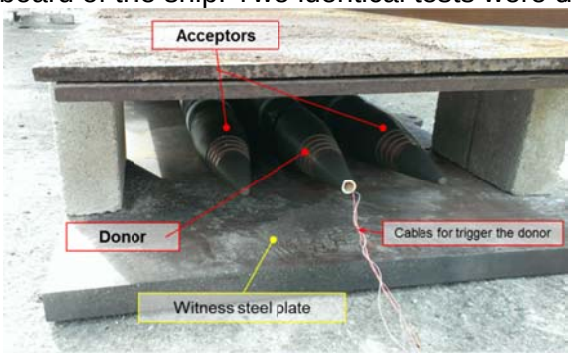
SAD section

WH section

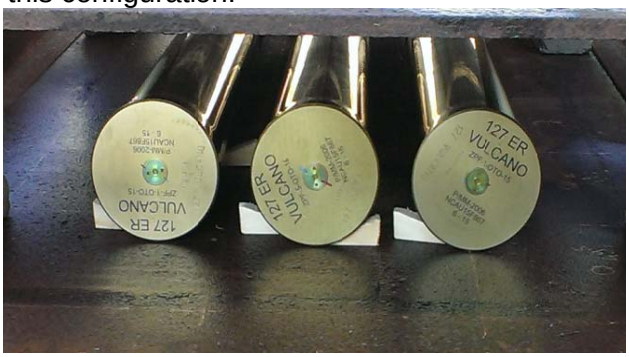
Figure 7. V155BER results.

3. Sympathetic Detonation

The tests were conducted in Nettuno proving ground which is a facility belonged to the IT MoD. For the V127BER the test was structured with one donor and two acceptors, the ammunitions were bare at a distance representative of the relative position of the ammo inside the gun drums on board of the ship. Two identical tests were done in this configuration.



Front view

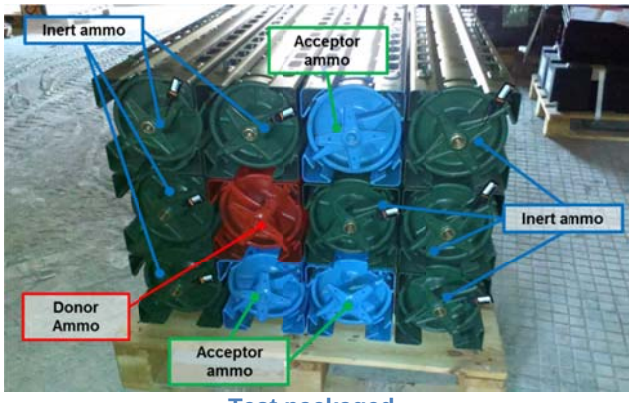


Rear view

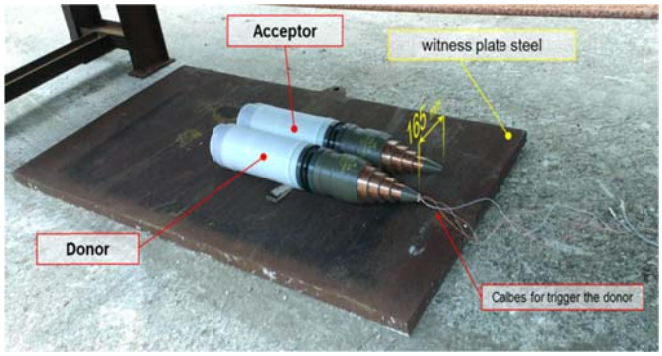
Figure 8: layout of V127BER sympathetic detonation

For the V155BER three tests were conducted:

- two identical tests with the ammo placed inside a representative packaging of multiple ammunitions with one donor and three acceptors (see Figure 9)
- a third test with the ammunitions bare at a distance representative of the relative position inside the PZH2000 magazine.



Test packaged



Test bare

Figure 9: layout of V155BER sympathetic detonation tests

3.1. V127BER Sympathetic Detonation results

As result of the donor detonation several pieces of unreacted explosive and big part of the donors warhead and brass cartridge were found as well as several grains of propellant some meters around the test original position.
The results of the test was a type IV reaction.


Projectile parts (1st test)


Brass cartridge


Projectile parts (2nd test)

Figure 10. V127BER sympathetic detonation results.

3.2. V155BER Sympathetic Detonation results

As result of the donor detonation several pieces of unreacted explosive and big part of the donors warhead and pieces of explosive were found as well as several grains of propellant some meters around the test original position.
The results of the test was a type IV reaction.


Ogive section of acceptor


Big part of warhead section


WH with unreacted explosive

Figure 11. V155BER sympathetic detonation results test packaged.


Ogive section of acceptor with undamaged sabot


unreacted explosive

Figure 12. V155BER sympathetic detonation results test bare.

4. Fast Cook Off

The tests were carried out in Meppen[5] proving ground , facility belonged to the GER MoD.
For both calibres the test was performed with fire generated by gas combustion, the ammo were placed inside a cage in order to keep the fire and ammo component inside in case of reaction

[5] GER and ITA MoD share the qualification phase of the Vulcano Guided (GLR), as consequence also some qualification test of the Vulcano unguided (BER) has been done in Germany.

during the test. Figure 13 shows the test setup for the V155BER, the same layout was used for the V127BER.

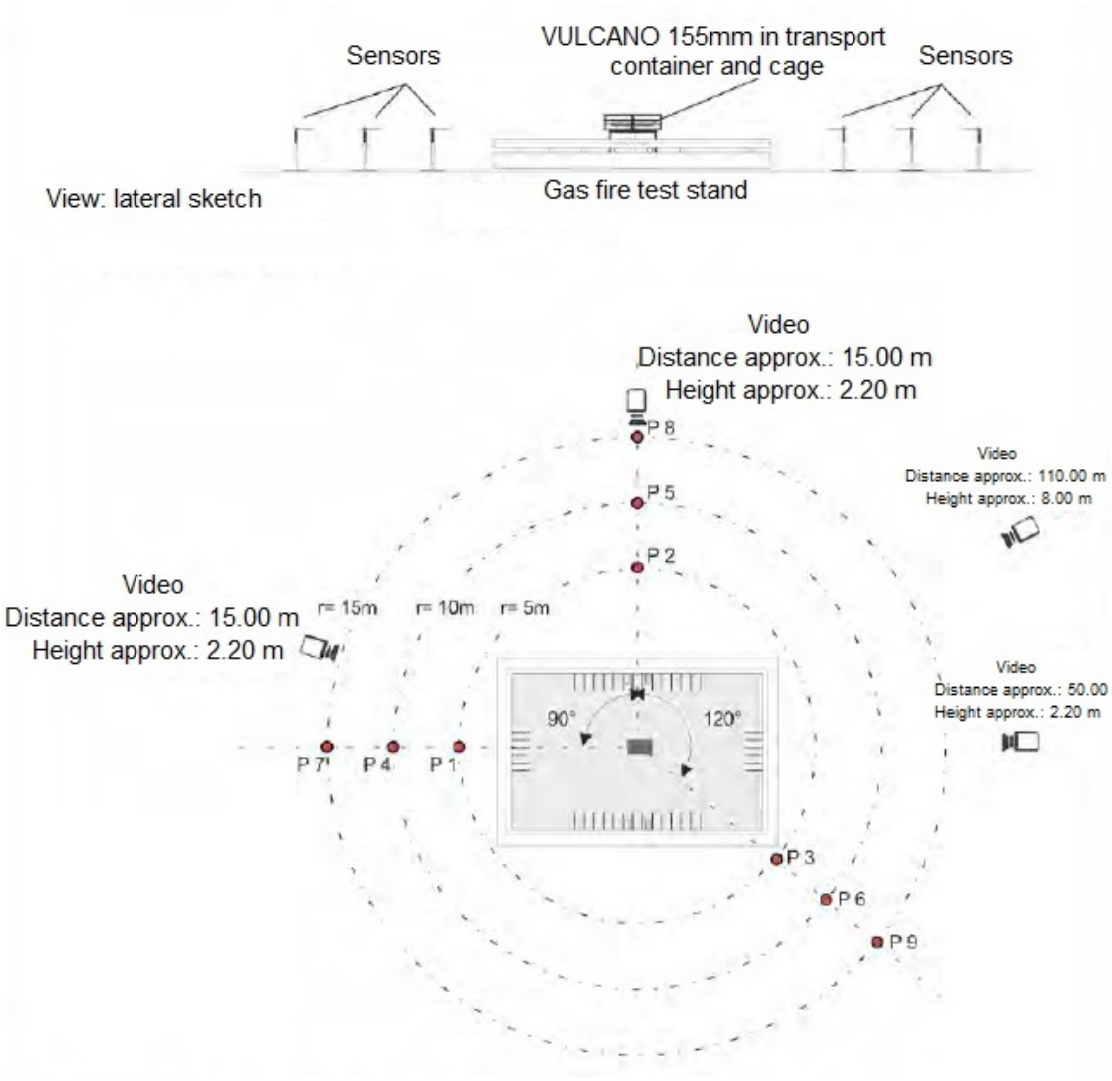


Figure 13. Fast Cook Off layout for V155BER.

For both calibres the test was conducted with packaged ammunition. Figure 14 shows the two ammunitions before the test began.

V127BER packaged

V155BER packaged

Figure 14. V127 and V155 BER inside the cage.

4.1. V127BER Fast Cook Off results

Both tests gave similar results, the first reaction occurred between 4 and 7 minutes from the start of the fire, some projection of metal part took place with one piece of 369 grams that was thrown at 40 m away from the cage, the maximum measured pressure was 214 mbar at 5 m.
According from the AOP39, the assessment of the reaction was type IV.

V127BER cage after the test

V127BER projectile main parts after the test

Figure 15. V127BER test results.

4.2. V155BER Fast Cook Off results

Both tests gave similar results, the first reaction occurred between 5 and 6 minutes from the start of the fire, some projection of metal part took place with one piece of 2 kg that was launched at 51 m from the center point, the maximum measured pressure was 27 mbar at 5 m.
As suggested from the AOP 39, the assessment of the reaction was type IV.

V155BER cage after the test

V155BER projectile main parts after the test

Figure 16. V155BER test results.

5. Slow Cook Off

The tests were conducted in Nettuno proving ground, facility belonged tothe ITA MoD.
For this type of test a special oven was designed. For both ammunitions it was evaluated that the worst case scenario is an ammo in bare condition without its case. For safety rules of the involved proving ground all around the oven concrete blocks were placed in order to limit the dispersion of ammunition parts during the reaction.
Both ammo V127BER and V155BER were testes twice, the ammo inside the oven was heated up to with a gradient of 3.3°/h up to the reaction.

V127BER inside the open oven

Oven closed and insulated

Figure 17: Vulcano ammo inside the oven and the oven insulated before the test

5.1. V127BER Slow Cook Off results

The V127BER reacted at a temperature range between 132°C and 127°C, the reaction started in the propelling charge and the brass cartridge were tear off in several big pieces and the oven was completely destroyed. Nevertheless the projectile with its explosive contents was found intact. From the result of the test the assessment of the reaction was type IV.

V127BER brass cartridge after the test

V127BER projectile still intact after the test

Figure 18. V127BER test results.

5.2. V155BER Slow Cook Off results

The V155BER reacted at a temperature range between 118°C and 128°C, the reaction happens in the propelling charge, due to the plastic confinement of the propelling charge the vehemence of the reaction was low and also in this case the projectile with its explosive contents was found intact. From the result of the test the assessment of the reaction was type V.

V155BER ammo after the 1st test

V155BER ammo still inside the oven after the 2nd test

Figure 19. V155BER test results.

6. Conclusions

The IM tests done on the Vulcano BER, either 127mm and 155mm, were part of a qualification phase that follows the STANAG 4224 guidelines. The IM test achieved were selected after a treat analysis with the ITA Navy and Army. Despite in some parts the tests did not follow accurately the STANAG 4439, it can be summarized that the reaction of the Vulcano 127 and 155 BER ammunition to the BI, SD, FCO and SCO is between IV and V.
Part of these tests had been used also for the transport homologation according the STANAG 4123.
Furthermore it can be studied that for both calibers (155mm and 127mm), against an external stimuli (threats or hazard) the ammunitions reacted in a way to mitigate the collateral damage of the user and surrounding environment (storage area, platform etc).

7. Abbreviations table

BER	Ballistic Extend Range
BI	Bullett Impact
FCO	Fast Cook Off
GER	Germany
HE	High Explosive
ITA	Italy
PZH2000	Panzer Howitzer 2000
SAD	Safety and Arming Device
SCO	Slow Cook Off
SD	Sympathetic Detonation
V127BER	Vulcano 127mm Ballistic Extended Range
V155BER	Vulcano 155mm Ballistic Extended Range
WH	War Head