

NEW INSENSITIVE RIFLED 120-mm MORTAR AMMUNITION
WITH ENHANCED LETHAL PERFORMANCE

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Introduction

The beneficial contribution of IM/Murat ordnance to the general endeavour to limit both loss of human life and platforms vulnerability during conflicts has become so obvious for many end-users that modern Armies express today a great interest in enhanced IM/Murat mortar ammunition. In order to satisfy its customers, TDA Armements has been developing since 2005 new HE & Rocket Assisted rifled mortar projectiles which all exhibit IM performance and enhanced lethal performance compared to the previous munitions. The IM/Murat signature of each mortar ammunition is to be achieved for the full complete round including the fuse and the propelling charges both fitted onto the filled body, keeping for the end-user the advantage of a delivered round ready for immediate use.

Several high explosives and configurations were considered for the IM fill to match the requirement of maintaining the existing level of fragmentation already achieved with the current cast body in order to keep this mortar product affordable. The most significant engineering change was the replacement of the TNT-based fill by a cast-cured PBX from EURENCO called HBU88B which exhibited the best compromise between lethal performance, initiation and insensitivity.

A few accidental aggressions were considered during 2005 to drive the first engineering change proposals due to achieve eventually the level Murat 2* for the two mortar munitions. As a priority the accidental threats which were firstly taken into account were the Slow Cook-off event, the Sympathetic detonation and the Fragment impact event.

Packaging configurations were kept as close as possible to the packaging design used for the existing munitions in order to stay compatible with most logistic constraints from the already 120-mm rifled mortar users.

I - EXISTING AMMUNITION DESCRIPTION AND PERFORMANCE

• HIGH EXPLOSIVE AMMUNITION (HE)

The existing 120-mm rifled HE projectile is designed with a ductile cast iron body shell filled with TNT. The filled projectile is fitted with a detonating fuze and a propelling charge incorporating a cartridge and several increment charges. In detail, a complete round consists of the following sub-assemblies (see Diagram 1 next page) :

- An empty projectile resulting from the assembly of a malleable perlitic (or spheroidal graphite) cast-iron body and a forged steel base. It was demonstrated that the cast iron shell body filled with TNT gives better anti-personnel and anti-light armoured vehicle efficiencies compared to steel bodies filled with either TNT or RDX/TNT.
 - A cast explosive charge made of 4.2 kg of TNT
 - An impact or a proximity detonating fuze (PDM 557 or equivalent)
 - A propelling charge holder consisting of the assembly of a cartridge CL3, 11 double-base propellant increment charges (3 different sizes) and an ejecting charge to separate the tail from the projectile on trajectory.
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- ### **• ROCKET ASSISTED HIGH EXPLOSIVE AMMUNITION (RAP)**

The existing rocket assisted projectile is designed with the same cast iron shell body as those of the HE projectile, but filled with RDX/TNT. A double-base propellant rocket motor is also fitted within the R/T fill. In detail, a complete round consists of the following sub-assemblies (See Diagram 2 next page) :

- An empty projectile resulting from the assembly of a malleable perlitic (or spheroidal graphite) cast-iron body and a light alloy rear-end.
- A cast explosive charge made of 2.7 kg of R/T (50/50)
- A solid rocket motor including a 1.2-kg double-base propellant payload, with a nozzle unit, an ignition unit with a 11.5-s delay element.
- The same fuze and same propelling charge holder as the HE round.

Fragmentation of this round is similar to that of the standard rifled HE projectile. When using the additional propulsion provided by the rocket triggering on trajectory, anti-personnel efficiency is 10 % lower for the RAP round than for the HE round. When the additional propulsion is not required and consequently not selected, the solid rocket motor contributes to the terminal performance on target and the anti-personnel efficiency is equivalent to that of standard rifled HE projectile.

Depending on the end-users, packaging for delivery can be either a wooden box or a metal box. All rounds are fitted in a protective cardboard container then grouped in pairs within the box and delivered on a wooden pallet.

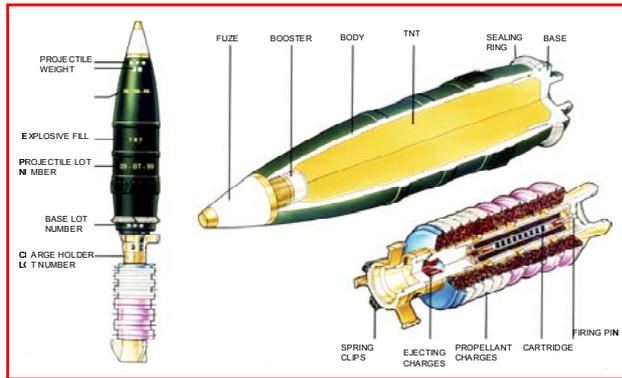


Diagram 1 : HE round description

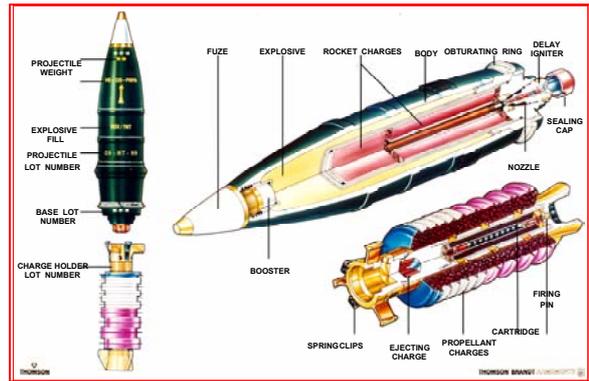


Diagram 2 : RAP round description

• **IM SIGNATURE OF THE EXISTING COMPLETE ROUNDS**

IM test were not performed on the existing HE and RAP rounds as both are considered not to be conforming to the IM requirements due to their TNT-based filling and the lack of mitigation devices included to their designs.

A rough estimation of what their IM signatures could be is summarised in diagram 3 below where an estimation of the reaction level against accidental aggressions is given for both projectiles. The opportunity was taken to compare these signatures to the Murat 1 * specification (acceptable reactions are shown in green) and then to highlight the non-compliance of these projectiles even with the low level IM requirements.

IM Signature of current PR120 HE and RAP									
	EI	Drop	FCO	SCO	BI	SR	FI light	FI heavy	SCII
NR	▲	●	■	■	■	■	■	■	■
V	■	■	■	■	■	■	■	■	■
IV	■	■	■	■	■	■	■	■	■
III	■	■	▲	■	▲	■	▲	■	■
II	■	■	■	■	■	■	■	■	■
I	■	■	■	▲	■	▲	■	▲	▲

▲ Estimation ● From test

Diagram 3: Existing IM signature vs MURAT 1*

• **REQUIRED IM SIGNATURE OF THE NEW ROUNDS**

The replacement of the TNT-based fill of these projectiles and the use of mitigation devices to vent both the projectiles and their packaging box would result to a new acceptable IM signature for the packed complete rounds. New reaction levels against accidental aggressions are given for both projectiles in diagram 4 and provides comparison of these signatures with the Murat 2 * specification. Expected reactions comply to Stanag 4439.

IM Signature OF NEW PR120 HE and RAP									
	EI	Drop	FCO	SCO	BI	SR	FI light	FI heavy	SCII
NR	▲	▲	■	■	■	■	■	■	■
V	■	■	▲	▲	▲	■	▲	■	■
IV	■	■	■	■	■	■	■	■	■
III	■	■	■	■	■	▲	■	■	■
II	■	■	■	■	■	■	■	■	■
I	■	■	■	■	■	■	■	■	■

▲ Estimation

Diagram 4: Required IM signature vs MURAT 2*

II - REPLACEMENT OF TNT

- **SPECIFICATION APPLIED TO THE NEW IM/MURAT EXPLOSIVE**

Decisions were made to keep as close as possible to the current design of the munitions in order to benefit from the existing production capabilities. Therefore the main concern was the challenge of keeping the same cast body and its fragmentation behaviour with a replacement of TNT. It was not an issue to find replacement explosives would have more energy than TNT but the fact that most of these explosives could be too energetic so as to keep an acceptable fragmentation of the cast body was the real concern.

- **SELECTED HIGH EXPLOSIVES CANDIDATES**

After a review of available IM technologies, only two cast-cured PBX 's were selected and subjected to performance testing. Properties are shown in Table 1.

Table 1 : Characteristics of selected PBX's

Explosives	PBXN-109	HBU88B
Formulation	I-RDX/Al/HTPB	I-RDX/HTPB
	64/20/16	88/12
V Detonation	7,480 m/s	8,150 m/s
density	1,662 gm/cc	1,620 gm/cc
Gurney	2,477 m/s	2,650 m/s

- **PERFORMANCE ASSESSMENT**

Performance assessment on standardized targets (lying man, standing man and light vehicle) required the knowledge of splinters velocity and the characteristics of fragmentation of the body shell obtained with every HE candidate. The evaluation of fragmentation of bodies involved underwater static firings with recovery of the whole initial body, followed by a quantitative analysis of the splinters.

- **Fragmentation assessment**

Results from previous experiments show that Composition B is too energetic to keep an efficient fragmentation of the cast-iron body. Consequently several configurations based on HBU88B were tested consisting on interposing an inert liner between the body and the explosive where the liner thickness was the fitting parameter (0.1mm, 2mm and 4mm liners were initially considered). The liners were supposed to behave as a shock absorber in order to control the brisance of the high explosive. Loss of pressure received by the body shell would be proportional to the increase of the thickness of this inert interface. Estimation of pressure levels seen by the body shell are summarised in Table 2 below.

Table 2 : Shock pressure level for several fills.

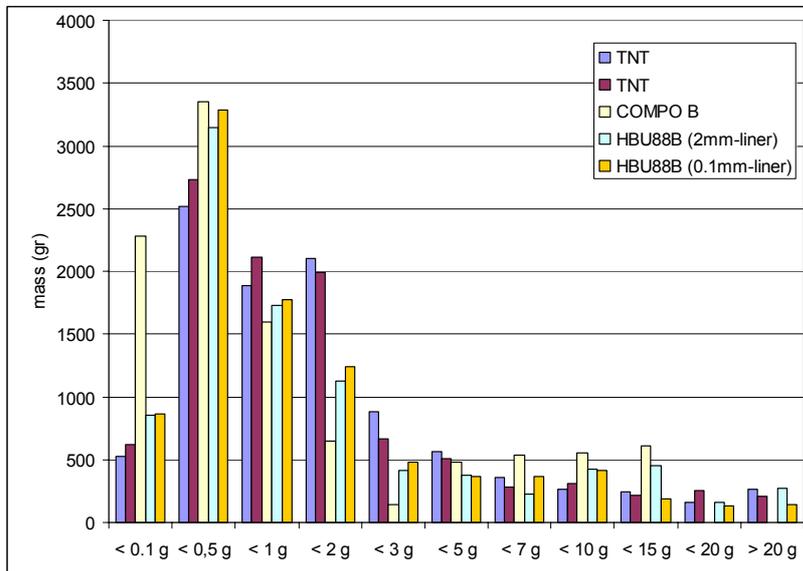
HE Fill	Compo B	HBU88B 0.1mm	HBU88 B 2mm	HBU88B 4mm	TNT
Pressure	370 kbar	340 kbar	330 kbar	310 kbar	280 kbar

Fragmentation tests were performed using an underwater firing pit allowing the total recovery of the splinters (See Diagram 5).

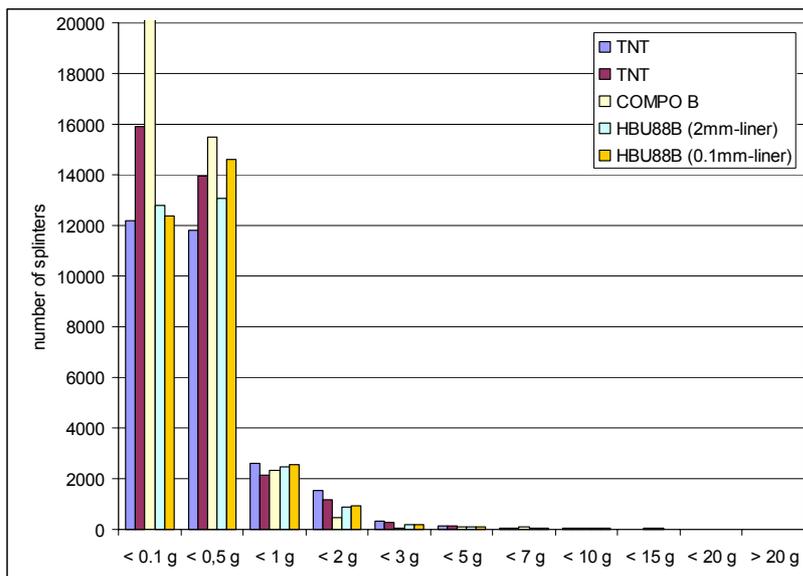
With reference to graphs 1&2, detonation of Composition B within the cast-iron body resulted in a vast majority of small fragments, whereas HBU88B fill performs quite similar to TNT in regards to fragmentation. HBU88B fills do not reduce the individual splinter mass contrary to Compo B. There is also no obvious difference between the versions of HBU88B eased by either 0.1mm or 2mm liners. Both versions offer a fragmentation rather close to that of TNT.



Diagram 5 : Underwater firing pit



Graph 1 : Distribution of splinter mass per class of mass



Graph 2 : Number of splinter per class of mass

- **Splinter velocity**

An estimated average of the splinter velocity was previously drawn up thanks to the tool LS-DYNA 2D using a JWL modelling.

For a such small calibre as 120mm, and due to the quick loss of tightness encountered with cast-iron shells, the reaction of Aluminium from PBXN-109 and the energetic contribution of this ingredient to the global performance were unknown. Two JWL modelling sets were considered depending on the contribution of Aluminium (the two limits 0% and 100 % of Aluminium reactions were considered). Results from the LS-DYNA 2D modelling tool are summarised in Table 3.

Table 3 : Estimation of splinters velocity

HE Fill	TNT	Compo B	HBU88B 0.1mm	HBU88B 2mm	HBU88B 4mm	PXBN-109 100% Al	PBXN-109 0% Al
Velocity Dyna2D	1490 m/s	1700 m/s	1650 m/s	1590 m/s	1530 m/s	1940 m/s	1550 m/s

Arena tests (Diagram 6) were performed with PBXN-109 and only HBU88B covered by the 0.1-mm liner as fragmentation results were already known and considered acceptable with the thinner liner. Fragmentation results with TNT and Composition B were already known.



Diagram 6 : Arena test type configuration

Average splinter velocities are summarised in Table 4.

Table 4 : Average splinter velocities

HE Fill	TNT	Compo B	HBU88B 0.1 mm	PBXN-109
Average velocity from arena test	1500 m/s	1710 m/s	1670 m/s	1530 m/s

Experimental results indicated that the combination of the 120-mm cast-iron body with the PBXN-109 fill would not be optimal for a such fragmentation ammunition as the blast effect doesn't contribute to the velocity performance. PBXN-109 could only offer the performance of TNT in term of splinter velocities.

Following the disappointment with PBXN-109 regarding its ballistic performance within the 120-mm calibre, preference was given to HBU88B for the continuation of the project.

○ **Performance on standardised targets**

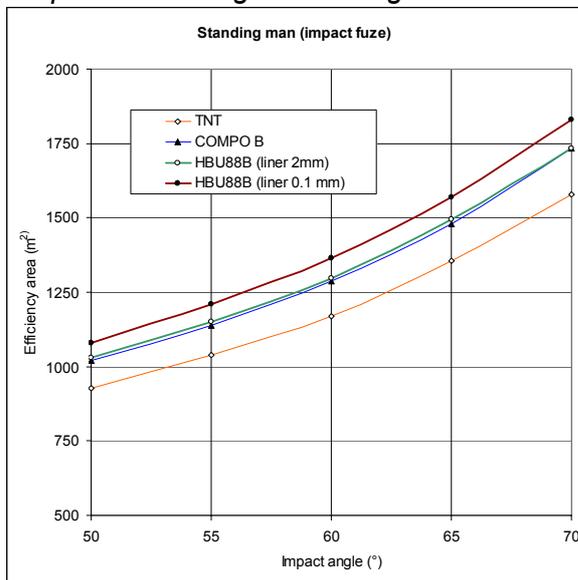
Assessment of on-target efficiency of every HE fill was possible with the characterization of the body fragmentation generated in the explosion and the knowledge of the splinter velocities. The assessment of efficiency on target are calculated with the values of the following splinter velocities given in Table 5, and a common speed of projectile of 250m/s prior to the ground impact.

Table 5 : Splinters velocity taken into account for efficiency assessment

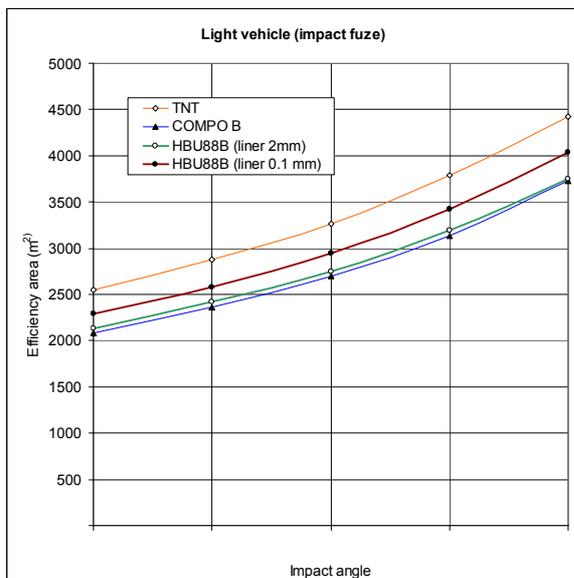
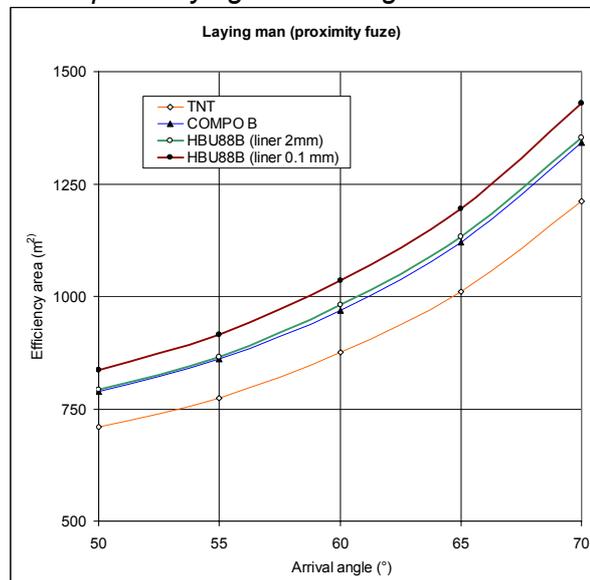
HE Fill	TNT	Compo B	HBU88B 0.1mm	HBU88B 2mm
Splinter velocity	1500 m/s	1700 m/s	1650 m/s	1600 m/s

Comparison of area efficiency was drawn up for 3 types of targets (lying man, standing man and light vehicle). Results are highlighted in the following graphs (*area efficiency versus angle of projectile impact*).

Graph 3 : Standing man is target



Graph 4 : Lying man is target



Fragmentation of the cast-iron body is penalised with aggressive HE. HBU88B appears the optimal high explosive with the 120-mm cast-iron body against human targets and exhibits enhanced performance compared to TNT which continues as the best solution against light armoured vehicles, followed by HBU88B.

HBU88B offers the best compromise of efficiency considering these 3 targets.

Graph 5 : Light vehicle is target

III – NEW TECHNICAL DATA PACK COMPLYING TO IM REQUIREMENTS

The increment propelling charges and the PDM 557 fuze were not identified as the major contributors for failing to meet IM test requirements. The replacement of TNT by HBU88B would solve many issues as well as the involvement of mitigation solutions applied to the HE body, the box and the RAP's rocket motor.

- **PACKAGING IMPROVEMENT**

New packaging consists of the initial metal box, packing a pair of rounds each protected by a cardboard container. An inside material within the box ensures additional protection against mechanical aggressions (sympathetic detonation and impacts) and the thermal insulation necessary to meet the specific “5-minutes no-reaction” MURAT 2* requirement for Fast Cook-Off. Inside the metal box, containers are orientated with a “head-to-tail” position resulting in small recovery of body shells beneficial for internal SR.



Diagram 7 : 2 Containers and metal box

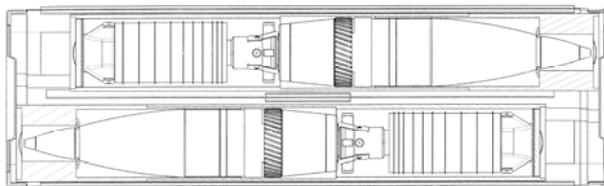


Diagram 8 : “head-to-tail” position of the pair of ammunition

Sympathetic detonation tests were performed considering both the reaction of the internal second round from the same metal box and the reaction of external rounds from a neighbouring metal box, which all gave a reaction no more violent than type III. Reaction of the round from the neighbouring box was more violent as the receiver was opposite to the donor (Diagram 9), whereas the receiver from the same metal box than for the donor was naturally in a “head-tail” position (Diagram 10).



Diagram 9 : Recovery of the receiver's explosive from the neighbouring box



Diagram 10 : Recovery of the receiver's explosive from the same box

- **VENTING SOLUTION FOR THE SHELL BODY**

A set of vents were tested at the front end allowing a reaction type V at SCO and FCO tests without the eviction of the PDM557 fuze (picture 12) . Design was worked involving mock-ups roughly representative of the front full-scale body (picture 11). In SCO conditions, HBU88B reacts at 165 °C prior to the fuze.

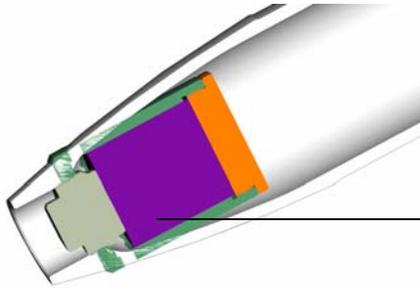
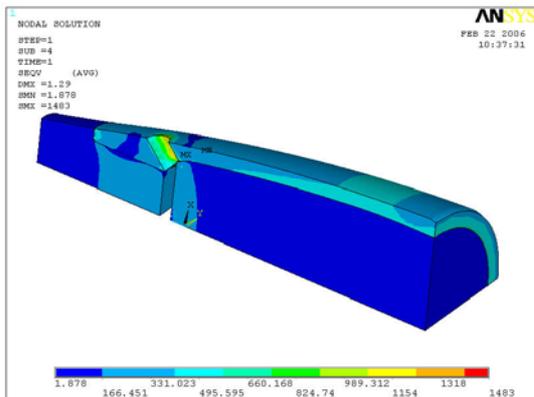


Diagram 11 : SCO mock-up



Diagram 12 : PDM557 fuze after SCO test

Work consisted in researching the optimal venting section area resulting in 3 small vents allowing the combustion of the 4.2kg of HBU88B of the HE round.



This solution withstands the outside pressure resulting from the accidental double-loading of a second round in the mortar tube.

Diagram 13 : double-loading resistance

The same solution is applicable to the RAP round.

- **VENTING SOLUTION FOR THE ROCKET MOTOR OF RAP**

Any venting solution applied to the rocket motor of the RAP round must only trigger in storage life phase. Venting must not trigger after firing the round not to disturb the additional range of RAP.

In SCO conditions, it was found that the double-base propellant reacts at 125°C, prior to the high explosive fill, followed by the eviction of the aft base of the rocket. Under the increasing ambient temperature, HBU88B only burns with a partial eviction of the empty rocket casing.

Tests were conducted with unpacked ammunition and it could be expected that all parts would stay within the metal box.



Diagram 14 : Eviction of the rocket casing



Diagram 15 : Eviction of the aft base of RAP

- **FRAGMENT IMPACT**

Fragment impact tests were also conducted with RAP so as to confirm that the only issue encountered with the solid rocket motor would be with the thermal aggressions. The Impact Fragment test was performed with a standardised 18.6-gr fragment at the velocity of 1900m/s with an unpacked projectile. As the solid rocket motor is made of two propellant payloads, the impact was orientated to the one designed with a central cavity. Both the solid propellant and the HBU88B HE fill burnt. Reaction was considered type V.

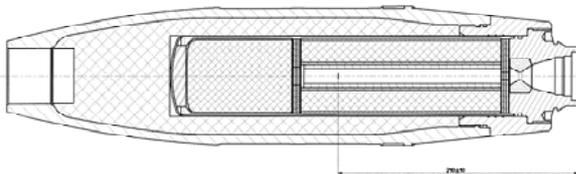


Diagram 16 : Altitude of fragment impact orientated to the propelling payload with central cavity



Diagram 17 : Fragment Impact test

CONCLUSION

This development program is still ongoing in 2006 for the HE projectile only, when a full assessment of the packed complete HE round has yet to be conducted according to Stanag 4439. The initial results already available are consistent with the beginning of compliance to the Murat 2* level.

ACKNOWLEDGMENTS

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