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Fragment Impact Standardization Historical Review

Kathryn E. Hunt[1] and Ernest L. Baker[2]

1) OUSD/AT&L, Land Warfare and Munitions, Pentagon, Washington DC, USA
2) Munitions Safety Information Analysis Center (NATO), Brussels, Belgium

This report describes the results of a review of the history and development of NATO STANAG 4496 Fragment Impact Munitions Test Procedures related to the origin of the threat fragment characteristics and requirements that were first cited in the initial edition of STANAG 4496. The review was performed by completing a literature search of historical papers and documents surrounding the original development for the STANAG. The purpose of the fragment impact test is to assess the reaction, if any, of munitions and weapon systems to impact by a high velocity fragment. The review discusses the technical rationale behind the following aspects of the STANAG requirements: (1) Fragment shape, both a discussion of the effect of yaw at impact as well as a discussion of the merit of various designs and shape factors (2) Fragment size (3) Fragment velocity and (4) Multiple fragments. This study was used to inform the NATO AC/326 SG/B Fragment Impact Custodial Working Group (FI CWG).

INTRODUCTION

As part of the documentation for a revised edition of NATO STANAG 4496 Fragment Impact Munitions Test Procedure, it is important to recognize the basis for previous decisions on modifications of the standard. To that end, this paper covers some historical fragment impact (FI) information as well as the origin of the threat fragment characteristics and requirements that were first cited in the initial edition of STANAG 4496. Prior to the publication of the standard, a variety of different test methodologies existed for evaluating fragment impact.

Number, size, shape, velocity, and the method for projecting the fragment(s) have long been the dominate considerations when discussing fragment impact testing. The earliest fragment impact safety requirement appeared in NAVSEA Instruction 8010.5 in 1985. Multiple half-inch square mild steel cubes were required to be projected at the test item with 3-5 hits recorded and a striking velocity of 8300 fps. This was intended to simulate general purpose bomb fragments [1]. The most commonly used procedures in the 1980’s and 90’s relied on explosively projected the fragments. A mat of preformed fragments were placed on the front face of the explosive charge which was detonated. Neither number of fragment hits nor the fragment orientation were controlled, leading to inconsistent test results. Starting in the mid-1990s the test methods were improved to use gas guns to launch individual fragments to the target.

Table 1 gives an overview of various NATO nations FI test policy and procedure requirements that were in place in 2001 [2]. This represented the Nations’ baseline for the evolution of STANAG 4496.

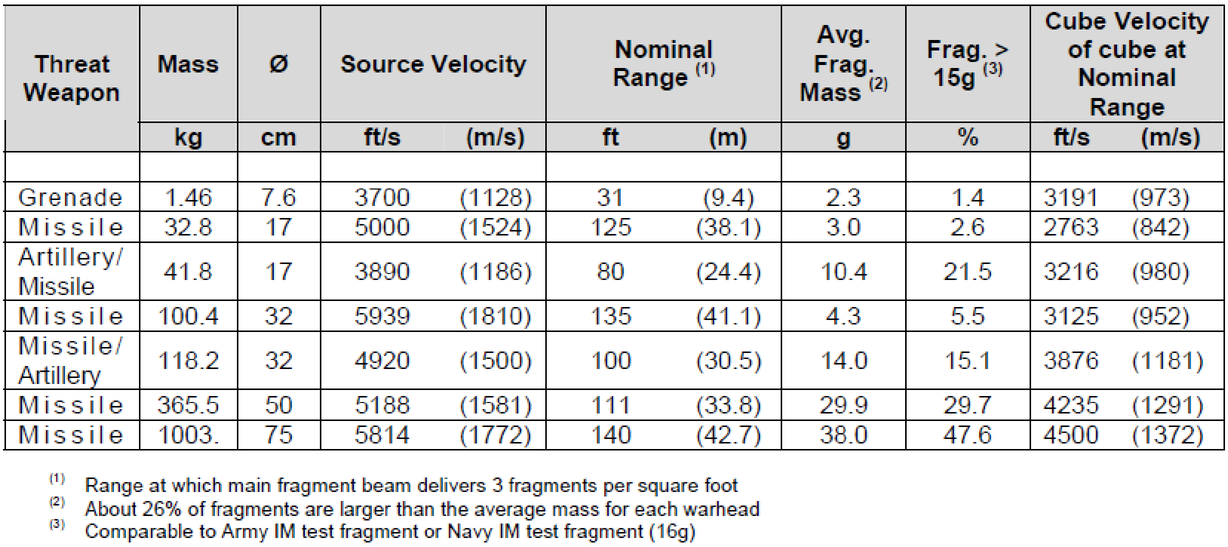
Table 1: Summary of Policy and Procedure Requirements prior to 2001

	NATO	**France Light Fragment**	**France Heavy Fragment**	**UK**	**US Preferred**	**US Alt #1**
Geometry	Conical Tipped cylinder	Cube (NATO fragment used)	Parallelepiped (sphere is used)	Cylinder Ø 12.7mm h=12.7mm	12. 7 mm cube	Conical tipped cylinder
Mass, g	16	20 (16)	250	13.5	16	16
# of Frags	1	3 (1)	1	1	2-5	1
Launcher Type	Undefined	Undefined (gun)	Smooth bore gun	RARDEN gun	Fragment Projector	Undefined (gun)
Velocity Range, m/s	2000	0<v<2000	0<v<1600	400<v<2500	2530 ± 90	1830 ± 60

REPRESENTATIVE THREAT FRAGMENTS

The archival data used to examine the generic threat fragment in STANAG 4496 are summarized in tables 2 and 3 below. The data in table 2, developed by Victor [3] in the 1980s, includes the characteristics of typical fragments projected from several classes of munitions. It is important to note that approximately 26% of all fragments are greater than the average fragment mass, and therefore basing a threat fragment on average fragment mass represents neither the worst case nor the most credible one. The second table shows fragment mass and velocity data for specific weapons were a “worst case” threat scenario [4].

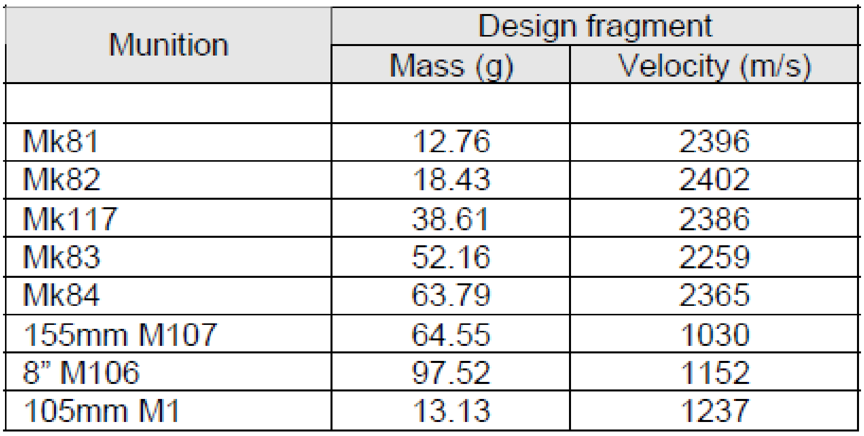
Table 2. Computed Fragments Characteristics (Mott & Gurney)



Threat Weapon	**Mass**	**Ø**	**Source Velocity**		**Nominal Range** (1)		**Avg. Frag. Mass** (2)	**Frag. > 15g** (3)	**Cube Velocity of cube at Nominal Range**	
	kg	**cm**	**ft/s**	**(m/s)**	**ft**	**(m)**	**g**	**%**	**ft/s**	**(m/s)**
Grenade	1.46	7.6	3700	(1128)	31	(9.4)	2.3	1.4	3191	(973)
Missile	32.8	17	5000	(1524)	125	(38.1)	3.0	2.6	2763	(842)
Artillery/ Missile	41.8	17	3890	(1186)	80	(24.4)	10.4	21.5	3216	(980)
Missile	100.4	32	5939	(1810)	135	(41.1)	4.3	5.5	3125	(952)
Missile/ Artillery	118.2	32	4920	(1500)	100	(30.5)	14.0	15.1	3876	(1181)
Missile	365.5	50	5188	(1581)	111	(33.8)	29.9	29.7	4235	(1291)
Missile	1003.	75	5814	(1772)	140	(42.7)	38.0	47.6	4500	(1372)

(1) Range at which main fragment beam delivers 3 fragments per square foot
(2) About 26% of fragments are larger than the average mass for each warhead
(3) Comparable to Army IM test fragment or Navy IM test fragment (16g)

Table 3. Various Munition Worst Case Fragment Characteristics



Munition	Design fragment	
	Mass (g)	Velocity (m/s)
Mk81	12.76	2396
Mk82	18.43	2402
Mk117	38.61	2386
Mk83	52.16	2259
Mk84	63.79	2365
155mm M107	64.55	1030
8" M106	97.52	1152
105mm M1	13.13	1237

VELOCITY

During the time period in which the original fragment impact standard was written, the U.S. utilized the highest fragment velocity, 2530 m/s, which has now become the standard. This fragment velocity, as defined in MIL-STD-2105B and STANAG-4240, Draft 10, originated from a US Navy survey dated 1987 [5]. The velocity chosen for the ½-inch steel cube was 8300 ft/s (2530 m/s) because it represented the upper range of the threat fragment velocity spectrum for a general-purpose bomb. MSIAC (NIMIC at the time) also looked as various munitions fragment velocities and reached a similar conclusion that 2530 m/s is at the very upper bound of possible threat fragments [6]. It also important to note that fragment velocities above 2000 m/s were not observed for ground munitions. Additional work by MSIAC and also work done by J. Starkenburg [7] indicates that fragment velocities for artillery type weapons may only near 2530 m/s when detonated in a stack configuration as initial fragment velocities for stacks of ammunition have been observed to be almost twice as high as for fragments from single-item ammunition.

FRAGMENT GEOMETRY

Because several Nations used differently shaped threat fragments, agreement on the shape of the threat fragment was critical for the STANAG test procedure. The cube shape resembles a preformed fragment present in some munitions. The lighter sphere shape is used in characterizing explosive formulations. The conical type cylinder was created to allow easier launch from a fragment gun. Although the cube most closely represents fragmentation, its angle of attack is not repeatable with face, edge and corner impacts resulting in significantly different shock loadings. Conversely, the advantage of spherical fragments is repeatability, however the spherical fragments were not perceived as a credible threat. Spherical fragments also require either a higher initial velocity or greater mass for the same input of shock duration to the target. As seen in figure 1 [4], the sphere had to be five times more massive than the NATO/MIL-STD-2105B alternate 1 fragment at 10° yaw, in order to maintain a given shock threshold. This was deemed too high for practical testing or to be representative of anything but rogue fragments.

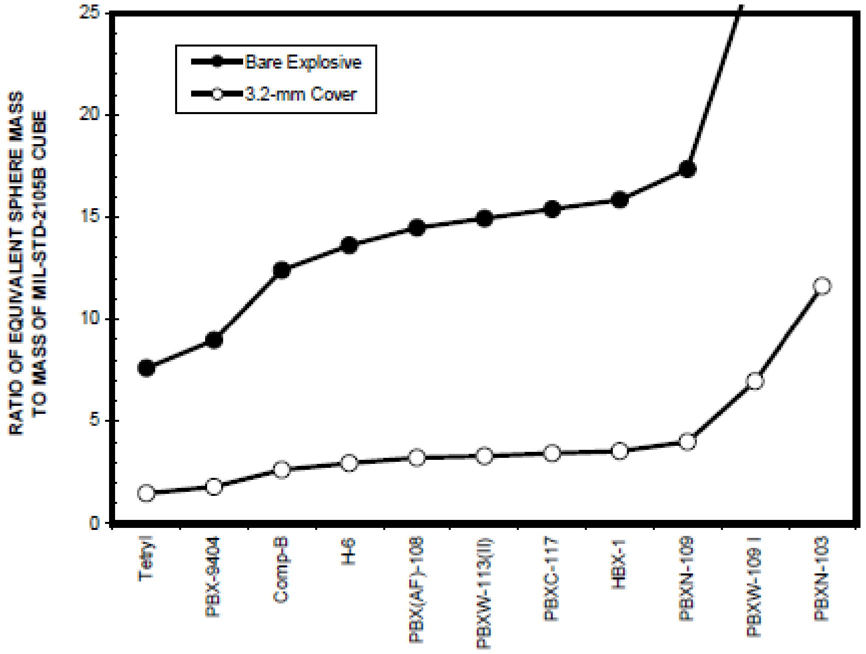


Figure 1. The ratio of sphere mass and the mass of a 10° yawed cube that have the same critical velocity for detonation using the Jacobs-Roslund formula

Returning to look at the cube, the primary disadvantage remained repeatability. An issue which can be mitigated by using a conical tipped cylinder with its 160° included angle face (10° to normal) [4,8]. A cylinder with these characteristics is considered comparable to the cube because approximately 95% of the time a randomly oriented cube will have an impact yaw of greater than 10° with the impact surface. J.Starkenburg created figure 2 which illustrates that a conical typed cylinder (denoted in the figure as Army Frag) significantly reduces yaw effects as compared to the cube.

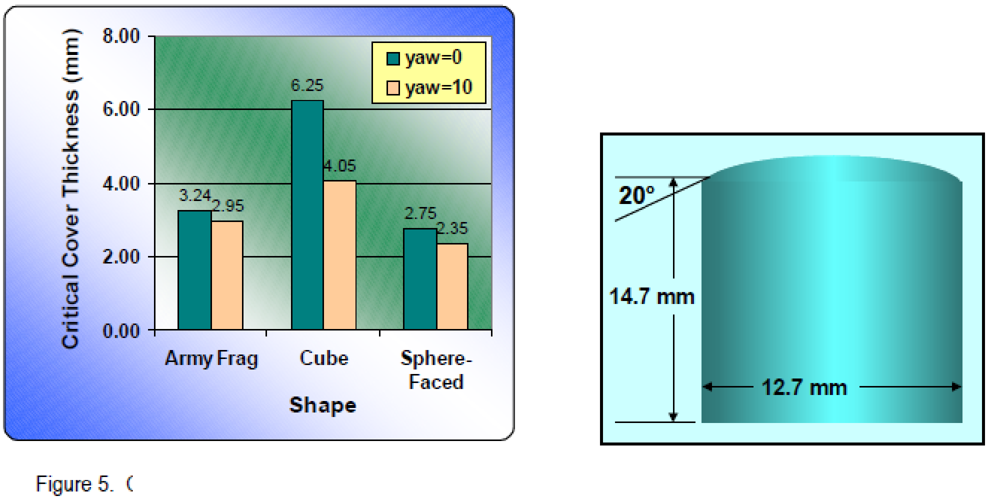


Figure 2. Critical cover thickness as computed by CTH for a Comp-B target impacted at 1830 m/s [8]

In the end, it was determined that the conical tipped cylinder provided the best compromise between fragment realism and repeatability. However, the original authors of this STANAG wanted to ensure that the chosen NATO threat fragment maintained the shock generated by a cubical fragment. Looking back at figure 2, the NATO/ MIL-STD-2105B alternate 1 detonates at a lower cover plate thickness and represents a lower shock level than the cube. Starkenburg completed additional calculations proposing the current STANAG 4496 fragment shape and mass (18.6g) as equivalent to the shock stimulus of the cube.

MULTIPLE FRAGMENTS

In a threat scenario it is perhaps unrealistic to believe that a single fragment will be the only impact, therefore several legacy test procedures called for the impact of multiple fragments. However, for non-detonation reactions, the effect of multiple fragments is un-predictable, sometimes decreasing the reaction severity and sometimes increasing it, providing inconclusive results. This gives no advantage to testing with multiple fragment projections. Thus, there was no advantage to testing with multiple fragment projections. For SDT of damaged material, as in a rocket motor, it was decided at the time that the reaction severity of multiple depended on the degree of damage, the timing, and system conditions. It was felt that a multiple fragment impact test would not be repeatable enough to address these concerns, and that “multiple impacts at a single velocity do not represent reality” [4]. For SDT of neat material, it was shown than any effects of multiple fragment impact are unlikely since the fragments space out very rapidly and then slow rapidly with distance. Figure 3 below shows that the fragment spacing reaches 3 fragment diameters at less than 13-m distance for a representative munition, so the effect of multiple fragment impact on SDT can be neglected [4].

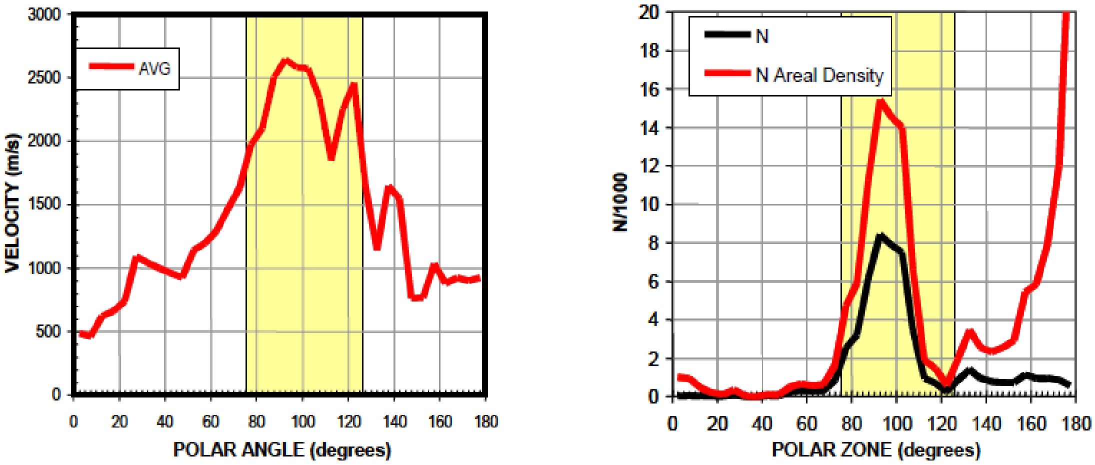


Figure 3. Velocity vs. polar zone (left) and number of fragments vs. polar zone (right) for a particular representative munition.

CONCLUSION

This report describes the results of a review of the history and development of NATO STANAG 4496 Fragment Impact Munitions Test Procedures related to the origin of the threat fragment characteristics and requirements that were first cited in the initial edition of STANAG 4496. In the end, it was determined that the conical tipped cylinder provided the best compromise between fragment realism and repeatability. However, the original authors of this STANAG wanted to ensure that the chosen NATO threat fragment maintained the shock generated by a cubical fragment. The current STANAG 4496 fragment shape, mass and velocity was chosen to provide an equivalent to the shock stimulus of a worst case fragment representative cube. This historical review was used to inform the NATO AC/326 SG/B Fragment Impact Custodial Working Group (FI CWG). The working group has used the review results as part of their process to update NATO STANAG 4496, the technical content of which will be migrated into a new AOP 4496. The historical review are being included in Annex A of the new AOP 4496.

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