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An international review of the STANAG 4496, Fragment Impact Test

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Abstracts

At the request of NATO AC/326 SG/B, MSIAC was tasked to review the STANAG 4496 edition 1 related to the Fragment Impact, munitions test procedure.

To manage this activity, MSIAC has written and sent a questionnaire to the AC/326 community. The questionnaire requests information such as: test procedure, type of launchers, type of fragment, sabot, type of test (high or low velocity), test set-up, measuring equipment and experience. The test facilities were also asked to provide recommendations for an update to the STANAG and to share what is the most challenging part in performing this test.

The paper presents the analysis of the answers received from 17 test centres from 9 different nations. The objectives are to share best practice, to identify difficulties and to propose recommendations for improvement.

1. INTRODUCTION

This document describes the results of an international review of the STANAG 4496 related to the fragment impact test. The purpose of this test is to assess the reaction of a munition impacted by a fragment.

To perform the review, MSIAC created a questionnaire in conjunction with the custodian of this STANAG, France, and sent it to several test centers in most of the AC/326 nations. Moreover, an analysis of similar standards has been done in order to get more consistency in the recommendations.

This document provides an analysis of the answers received, summarizes best practice and provides some recommendations to potentially support an amendment of STANAG 4496.

2. REQUIREMENTS

From a NATO point of view, the requirements for the fragment impact test are defined within three documents: STANAG 4439 [R1], STANAG 4496 [R2] and AOP-39 [R3].

The test 7 (l) from the "UN – Manual of tests and criteria" [R4] specifies a fragment impact test for the classification into the hazard division 1.6.

The table hereafter compares the STANAG 4496, the AOP-39 and the UN Orange Book test 7(l) regarding the fragment impact test:

Table 1: Main differences between the STANAG 4496, AOP-39 and UN orange book test 7(l)

	STANAG 4496 ed.1	**AOP 39 Ed. 3**	**UN 7 (l)**
Alternative procedure	Yes		No
Number of tests	2*		2
Item configuration	Bare or packed, as agreed by the national authority	Normally bare, except for small items that are packed up to the point of use	Transport
Aiming point	Center of the largest presented area of EM, 1 in the most shock-sensitive region (if probable)	Largest explosive component, 1 in the most shock-sensitive component (if probable)	1 in the non-EIS boostering component, 1 in the center of the main explosive load
Firing distance	Not specified	Depend on accuracy and safety	To ensure stability at impact
Impact Velocity	2530 ± 90 m/s** 1830 ± 60 m/s (alternate)	2530 ± 90 m/s 1830 ± 60 m/s (alternate)	2530 ± 90 m/s
Accuracy of impact	Not specified		Not specified

	STANAG 4496 ed.1	AOP 39 Ed. 3	UN 7 (l)
Protection	As necessary		Barricades to protect the gun
Description of test set-up			Yes
Reaction level acceptable	Burning or no reaction		Burning or no reaction

* Could be limited to one test if a strike in the most sensitive area is not probable; could be more than 2 tests if deemed necessary by the appropriate service review board.

**Other velocities may be chosen if it is proved that they may lead to a more severe reaction.

The fragment is the same in the 3 documents.

The main difference between the documents is related to the item configuration:

- In transport configuration for the UN document, which is normal as this document relates to the transport classification of the article
- Bare or packed, as agreed by national authority, in the STANAG, which seems logical as the national authority is able to define when a fragment is more likely to impact the munitions during the life cycle.
- In the AOP: *Normally, the test item will be unpacked. Small stores which are normally packaged throughout the life cycle up to the point of use such as Pyrotechnics, CADS/PADs, Small Arms and Cannon Ammunition, should be tested packaged.* The AOP identifies items that are packed most of their life cycle, and considers the others should be tested unpacked.

An alternative procedure is provided in the STANAG: same fragment but with a lower velocity.

The STANAG provides more details on the test procedure (e.g. preliminary shot, item temperature, …), but does not provide an example of test set-up, whereas the UN document does.

In addition, there are redundancies between the STANAG 4496 and the AOP-39, especially in the observations and reports part. They should be avoided to allow these 2 documents to remain independent. Indeed, the AOP-39 is linked to the STANAG 4439, and it is not automatically updated when there is a change in one of the STANAGs that defines the test procedure, like the STANAG 4496. MSIAC has recently been tasked by AC/326 SG/B to review all these documents to remove redundancies or contradictions and to clarify where the information should reside.

Recommendation: the item configuration should be defined in a unique way in the NATO documentation.

3. QUESTIONNAIRE

The questions deal with the type of launchers and fragments used, the type of measuring equipment used, the test configuration, the standards and procedures, the experience and the potential concerns encountered while performing this test.

4. ANALYSIS

For each question, a statistical analysis of the answers is provided with additional comments.

4.1 ORIGIN OF THE ANSWERS

MSIAC has received answers from 14 nations. Within these answers, some nations acknowledged the fact that they were not performing this test.

Therefore, only the answers from 17 test centers from 9 nations were taken into account for the analysis.

60% of the answers come from governmental test centers and 40% from private test centers.

The following chart shows the origin of the answers by nations:

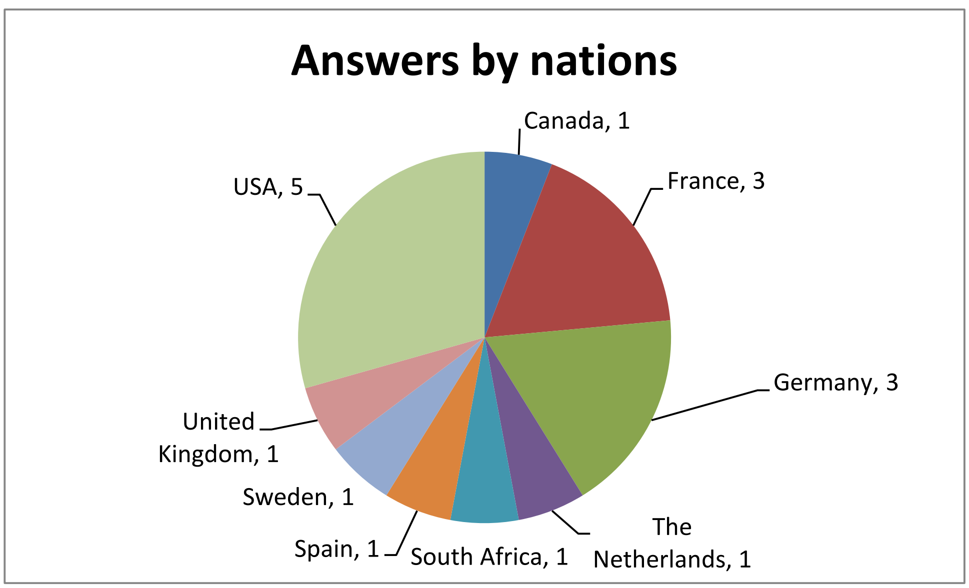

Figure 1: Number of answers received by nations

Answers have been submitted by 7 NATO nations (Canada, France, Germany, The Netherlands, Spain, The UK and the USA) and 2 partner nations (South Africa and Sweden).

The following table presents the complete list of test centers that replied:

Country	Organisation	Status	Comments
Australia	DSTO		No capability at the moment
Belgium			No capability
Canada	Canadian Explosives Research Laboratory (CERL)		Don't perform FI test
Canada	GD-OTS Canada		Use NTS capability
Czech Republic			No capability
Finland			No capability
France	DGA Essais missiles	Government	
France	DGA Techniques terestres	Government	
France	Herakles	Private	
Germany	WTD 91	Government	
Germany	TDW	Private	
Germany	RH Unterluss	Private	
Italy	RWM Italia		No capability
The Netherlands	Centre of Excellence Weapons and Ammunition	Government	
South Africa	Rheinmetall Denel Munition	Private	
Spain	La Maranosa	Government	
Sweden	Bofors Test Center	Private	
United Kingdom	QinetiQ	Private	
United States of America	NAWC China Lake	Government	
United States of America	NSWC Dahlgren D	Government	
United States of America	Redstone	Government	
United States of America	National Technical Systems	Private	Via GD-OTS Canada
United States of America	ARDEC	Government	
United States of America	YUMA	Government	

Table 2: List of facilities and nations who replied to the survey

The Canadian answer was submitted by GD-OTS Canada who are using NTS capability (in the US). Therefore, this answer relates to GD-OTS requirements and does not reflect the capabilities of NTS.

4.2 EXPERIENCE OF THE TEST CENTERS

The test centers were asked to mention their experience in performing this test.

4.2.1 High or low velocity

First of all, they were asked to provide the number of tests performed at high velocity (2530 m/s) and low velocity (1830 m/s), as well as the capability to launch other types of fragments and/or multiple fragments.

The following table indicates the number of tests performed, by test center:

Table 3: Experience of the test centers

Test center	DGA-EM	DGA-TT	Herakles	RH Unterluss	TDW	WTD91	TNO	Rh Denel	ITM la Maranosa	Bofors TC	QinetiQ	NAWC CL	NSWC DD	Redstone	GD-OTS Can	ARDEC	Yuma
High velocity	2	0	0	40	15	>100	Unknown	0	5	Unknown	200	44	>>100	Unknown, since 2004	12	100 per year	25
Low velocity	10 to 20	Unknown	20 to 50	60	25	0	Unknown	220	23 tests (140 shots)	Unknown	>200	0	>>100	Unknown, since 2004	8	100 per year	0

Only 3 test centers acknowledge the fact they never performed the test at 2530 m/s.

The experience to perform the high velocity test ranges from 2 tests to more than 100 tests, and even a hundred per year. The highest experience (more than a 100 tests mentioned) for the high velocity test comes from the US (Dahlgren, Redstone, ARDEC), Germany (WTD-91) and the UK (QinetiQ).

Regarding the low velocity test, 3 test centers (China Lake, Yuma and WTD91) don't perform it; they only carry out the test at the higher velocity. This means they strictly follow the STANAG that recommends the high velocity requirement.

The experience to perform the low velocity test ranges from 20 to more 200 tests and even a hundred per year. The highest experience (more than a 100 tests mentioned) for the low velocity test comes from the US (Dahlgren, Redstone, ARDEC), South Africa (Rheinmetall Denel), Spain (ITM) and the UK (QinetiQ).

Except for the ones who perform only the high velocity test, test centers tend to perform more tests at the low velocity than at the high velocity.

In addition, some test centers mention the fact they also perform the test at other velocities. This type of test is typically a laboratory or an engineering test, to determine the SDT (Shock to Detonation Transition) threshold of an energetic material.

4.2.2 Other types of fragments

Other types of fragments are sometimes used.

One of the well-known fragment is the French heavy fragment (Φ39.5 mm, 252g, 1500 m/s, Steel 35 NCD 16), defined in the French standard NF T 70-512 [R7], and is part of the French IM policy.

Most of the facilities have the capability to launch other types of fragments. Some example of the type of fragments are listed hereafter:

- Surrogate of EFP
- Up to 1kg and 1000 m/s
- Up to 160g and 1675 m/s

In addition, QinetiQ has provided a picture that displays a whole range of fragments:

Figure 2: Picture of several fragments used by QinetiQ

4.2.3 Multiple fragments

A multiple fragment attack is not required by the STANAG. However, in reality, there is a high probability for an item to be impacted by several fragments, especially if a munition fragments near the item.

Half of the test centers (8) said they were able to launch multiple fragments, either with the same launcher, or with a different launcher, or with an explosive launcher. One of the well-known explosive launcher called FRAGMAT was developed by NAWC in China Lake, and is well detailed in the MSIAC L_86 report [R5]. It's basically a fragment projector arrangement, which uses a Comp B explosive charge to launch five ½-in steel cubes at the test item

If launched with a gun, the main limitation is the diameter of the gun: obviously, the dimensions of all the fragments have to be below the gun diameter, including the sabot.

Figure 3: Sabot filled with multiple fragments (courtesy of ITM, Spain)

4.3 LAUNCHER

The STANAG recommends the use of a gun system to reduce the variability due to the yaw.

All the centers that replied use a gun with powder to launch the fragment. Several calibres and lengths of barrel are used, which are summarized in the following table:

Table 4: Main characteristics of the gun in use

Test center	DGA-EM		DGA-TT	Herakles	RH Unterluss	WTD91	TNO	Rh Denel	ITM la Maranosa	Bofors TC	QinetiQ		NAWC CL	NSWC DD	Redstone	ARDEC	Yuma
Caliber	91.5	61.37	30	25	50	60	50	30X 173 Mauser	50	40	rifled 40	rifled 30 RARDEN	40	40	40	40	40
Length	6494	3045	2100		6000	6000	6200		6700	5600			19f 7 in	19f	19f	19.58f	

Most of the guns have been specifically designed for the purpose of this test.

The calibers range from 25 mm to 91.5 mm. The US sites that responded seem to use the same 40 mm guns from Physics Applications.

There is also some variation in the length, although a length around 6 meters is generally used.

For the high velocity requirement, the caliber starts at 40 mm.

To highlight some specificities:

- QinetiQ is using a rifled gun
- TNO pulls a vacuum in its gun before firing to reduce the drag during the acceleration phase in the gun
- NSWC Dahlgren division gun consists of three independent sections (powder chamber, wear section, down-range section). The wear section (48-inches long) is a replaceable component which represents the first 48-inches of the overall barrel.

4.4 FRAGMENT

The fragment is described in the STANAG as a right-circular cylindrical body with a conical noise.

All the test centers are compliant with the dimensions of the fragment as described in the STANAG 4496.

Some test centers have provided the designation of the steel and/or the Brinell hardness of the steel they use. The information is reported in the following table. The values of hardness in brackets were found on the Internet, and were not provided by the test center.

Table 5: Materials and Brinell hardness (HB) used for the fragment

Test center	DGA-EM	DGA-TT	Herakles	TDW	WTD91	ITM la Maranosa	Bofors TC	NAWC CL	NSWC DD	NTS via GD-OTS	ARDEC
Material	Stainless steel	Steeel 35 NCD 16	36NiCrMo16 - NF EN 10098-1/97	30CrNiMo8	Steel C35	AISI 1018	Ovako 280		A36 Steel	AISI 1020	ASTM1018
Hardness (HB)	190 - 270	(285)	269	270		(126)	200	200	119 - 159	(140)	(126)

Even if most of the facilities (11) are satisfied with the level of details provided in the STANAG, several mentioned that the material could be better defined, and the variability of the Brinell hardness could be more controlled (i.e. by defining a lower value).

Recommendation: Define a lower value for the Brinell Hardness of the fragment.

4.5 SABOT

No indication is provided on the sabot neither in the STANAG, nor in the AOP.

On one hand, it seems normal as the sabot is not a requirement, it's just a way to ensure that the fragment will have a proper trajectory after the separation from the sabot.

On the other hand, it is a necessary and a very important piece. It is the interface between the gun and the fragment, and it plays a key role in ensuring the proper release of the fragment at the muzzle of the gun.

Adding guidance is probably something to recommend or at least to discuss within the IM community, as it's the main factor in ensuring:

- an efficient travel in the barrel (to avoid too much friction, ensure permeability to combustion gases and stability in the gun)
- that when outside the barrel, the separation of the parts of the sabot does not affect the stability of the fragment.

The answers received are summarized in the following table:

Table 6: Sabot design in several facilities

Test center	DGA-EM	DGA-TT	Herakles	RH Unterluss	TDW	WTD91	TNO	Rh Denel	ITM la Maranosa	Bofors TC	QinetiQ	NAWC CL	NSWC DD	Redstone	ARDEC	Yuma
Sabot	Double sabot- 4 parts polycarbonate 4 parts Aluminium (7075)	2 HDPE parts	2 parts - plastic polymer	Confidential	8 parts - plastic	4 Parts for sabot and 4 parts for Pusher	Confidential	High dendity Polypropylene - Two 1 mm slots to facilitate breakup	2 parts - Methacrylate or 4 parts - Methacrylate	1 piece Plastic	Plastic	4 pieces clear polycarbonate + pusher plate with silicone grease.	4 parts serrated 40x57.15mm polycarbonate or nylon.	4 parts serrated - ST801 Nylon	4 parts - plastic	4 parts serated, 44 x 76mm Polycarbonate

In term of design, several types of design were reported:

- The sabot could be made of 1, 2, 4 or 8 parts.
- The part in contact with the gun is always made of plastic

- Sometimes, the internal parts of the sabot are made of aluminum
- The materials mentioned are HDPE, high density polypropylene, polycarbonate, ST801 Nylon.
- The one part sabot was made with preformed slots to facilitate rupture

Regarding the design of the sabot, it is strongly dependent on the gun system used. In addition, most of the nations and the test centers have made important investment to achieve a proper design of the sabot in order to reach the test specifications. If there are concerns about the release of information from test centres regarding the design of their sabots for inclusion in the standard then the nations should provide guidance on how to design a sabot.

Recommendation: discuss the addition of sabot design guidance.

4.6 TEST PROCEDURE

4.6.1 Standards / test procedures

Out of the 17 test centers, 13 centers use a specific local procedure in addition to the STANAG; the others use only the STANAG 4496.

Most of the time, the additional procedures are SOP, and provide details on:

- Safety procedure
- Assembling of the gun
- Preparation of the fragment and its sabot
- Test plan specific to the test item
- Installation of measuring equipment
- Adjustment of the aiming point

They are mostly developed to ensure the safety and the performance while carrying out the test. They are also developed to meet quality requirements based upon ISO 17025.

4.6.2 Preliminary shots

In the STANAG, a preliminary shot is recommended to validate the threat (mainly the velocity) and to determine the blast impulse produced by the shot itself.

The centers were asked if they perform preliminary shots, and for what reason(s).

Answers are summarized in the following table:

Table 7: Preliminary shot(s) and reason(s) for it (them)

Do you perform preliminary shots?	Yes : 17 (All)
How many?	1 (x7) 1 to 5 (x1) at least 1 (x2) 1 or 2 (x1) 1 to 3 (x1) 2 or 3 (x1) at least 1, normally 2, often more (x1) number not provided (x3)
Impact velocity adjustment?	14 Yes
Impact point adjustment?	12 Yes 2 No
Effect of firing on instrumentation?	13 Yes 2 No
Check functioning of measuring equipment?	16 Yes 1 No
Assess projection due to impact on inert item?	6 Yes 8 No

All the centers perform preliminary test(s). 7 centers perform only one shot, 7 centers fire one or more preliminary shots. The others have not provided the number of preliminary shots they fire.

Generally speaking, it seems that in most cases, a single preliminary shot is sufficient.

The main reasons to perform preliminary shots are (sorted by the number of times mentioned):

- To check the functioning of the measuring equipment
- To adjust/check the impact velocity of the fragment
- To determine the effect of the firing on instrumentation (especially the level of blast on pressure gauges)
- To adjust the impact location

The assessment of the projection coming from an inert item due to the kinetic impact of the fragment was mentioned only 6 times. Therefore, it's not the main reason for this shot. This is used by some test centers to differentiate the fragmentation due to the reaction of the energetic material to the one due to the kinetic impact of the fragment on the item.

Other reasons to perform a preliminary test were also mentioned:

- Cleaning the gun if it has not being used for a long period of time
- Yaw of the fragment before impact and timing of the pressure from the weapon
- Satisfactory mounting of the gun
- Blast pressure from firing (clarification from “effect on instrumentation”)
- Warm the tube

4.6.3 Firing distance

The STANAG doesn’t identify a firing distance.

Table 8: Firing distances between the gun and the item

Test center	DGA-EM	DGA-TT	Herakles	RH Unterluss	TDW	WTD91	TNO	Rh Denel	ITM la Maranosa	Bofors TC	QinetiQ	NAWC CL	NSWC DD	Redstone	NTS via GD-OTS	ARDEC	Yuma
Firing distance (m)	8 m - high velocity 15m - low velocity	12.9	5 to 15	15	6.5	13	8	13 m - small cal 20 m - large item	15	7 to 10	6 to 10	5 to 11	6.1	8	5	> 7	20-30

11 test centers use a fixed distance to perform the test. This fixed distance is a good way not to change the parameters from one test to another. As a result, the test set-up could remain the same, and the impact velocity is easier to reproduce.

The reasons why some centers change the distance from one test to another are:

- Velocity: Shorter distance for the high velocity, longer distance for the low velocity
- Accuracy: Distance dependent on the size of the item (shorter distance for smaller item to ensure accuracy)
- Protection of the test equipment: longer distance for item with large NEQ to protect the launcher.

The firing distance ranges from 5 meters to 30 meters, but most of the centers use quite a short firing distance from 5 to 15 meters.

The following reasons to use these distances were listed, in order of importance (the number of times the reason was mentioned is provided in brackets):

- Accuracy (x7)
- Management of the impact velocity (x5)

- Protection of the gun (x4)
- Stability of the fragment (x4)
- Minimize the blast effect due to the shot (x2)

Regarding the management of the impact velocity, shortening the distance is a way to reach the high impact velocity of 2530 m/s. For information, two values of the drop of the velocity during the flight were provided:

- For a firing distance of 8 meters: 17.7 m/s/m
- Between 5 and 15 m: 24.4 m/s/m

At the shorter distances, it may not be possible to ensure the protection of the gun, the proper separation of the sabot (and to stop it), and to not affect the measuring equipment (e.g. interaction between the muzzle flash and the video, sufficient distance to ensure velocity measurement).

In a certain way, there is a competition between:

- reducing the distance to ensure the correct accuracy and to reach the required impact velocity and
- increasing the distance to protect the gun and to minimize the effect of the gun on the measuring equipment.

4.6.4 Number of tests and impact point

The STANAG requires 2 tests maximum. The point of impact of the fragment will be chosen in order to generate the worst reaction:

- The center of the largest presented area of EM,
- the most shock-sensitive region (if probable).

Additional tests may be required if deemed necessary by the appropriate service review board.

In term of number of tests, the answers are summarized in the following table:

Table 9: number of tests

Nb of tests	Nb of answers
1	3
1 or 2	2
2	6
Item dependent (1 to numerous)	1
Customer request	5

According to the answers received, most of the test centers follow the STANAG requirement of 2 tests maximum.

More than 2 tests are sometimes performed for qualification purpose or depending on the item configuration.

Regarding the impact points, answers are summarized in the following table :

Table 10: Summary of the impact points

Impact points	Customer request (x5)	If 2, main charge & most sensitive (igniter). If 1, most sensitive with if possible an important part of the main EM.	longest distance in HE and normal to surface	Munition dependant. Mostly Main charge and RM.	Mostly at bulk of EM, even if it's not always the worst case	As prescribed in STANAG	Customer. Mainly center of HE or explosive train. Agreed before firing with IMAP.	Center of largest EM and most shock sensitive.	largest EM amount for projectile. For propelling charge, 2 at the largest EM and 2 at the primer.	Test item dependant.

Generally speaking, it seems the recommendations of the STANAG are followed: the impact point is mostly in the largest area of energetic material, and sometimes on the most sensitive area (e.g. igniter for propelling charge).

It's interesting to see that the impact point is adapted depending on the test item, and is defined by the customer. In some cases, it's even approved before test by the national review board. One can imagine an analysis is done before the test to define the impact location that will generate the worst reaction.

4.6.5 Impact point accuracy

Regarding the accuracy, nothing is mentioned in the STANAG.

In the bullet impact STANAG, the 3 bullets have to be within a 5-cm diameter circle.

If accuracy has to be defined for the fragment, as there is only one shot, the recommendation should be a bit different. Indeed, it should refer to a distance between the aim point and the impact point.

The following table summarizes the answer received:

Table 11: Position of the test centers on the accuracy of the point of impact

Accuracy	Same as for BI, but test consider valid event if accuracy not respected	Not reproducible from 1 test to another.	inside 2 inches disc	5 cm	+-5mm	less than 5 cm	+-3cm	40 mm diameter at 13m. 60 mm diameter at 20m.	Normally 50 mm Diameter as for BI. Mean (x): 0,167 mm Mean (y): 0,333 mm Sd (x): 3,48807 Sd(y): 0,51640	50mm Diameter	Within 1 frag diameter (14.3mm) at 10 m. More accurate at shorter distance.	2 inch diameter circle. If outside the circle, consider no test.	around 25mm	usually within 1 inch circle	typically 12mm	12mm of the aim point.Occasionally worse	less than 0.5 inch
Should accuracy be defined in the STANAG?	Yes	We should but risk to run as "no test" if not respected.	No, but for non violent response, the real impact point would be indicated in the test report	Yes	Yes to avoid discussion	Yes	Yes. Effectiveness of impact change with impact location, especially for thick casing	Possible	No as it doesn't make difference on reaction level.	Why not, as for BI	Yes to maintain a degree of control over the test results.	Yes. A circular probability of error should be established, connected to the diameter of the target.	No	Yes. Although it can vary due to size of article. It may not be critical for large item.	Might be good in some cases.	Need to be discussed with IM community	No
Firing distance (m)	8 m for high velocity 15m for low velocity	12.9	5 to 15	15	6.5	13	8	13 m for small cal 20 m for large item	15	7 to 10	6 to 10	5 to 11	6.1	8	5	> 7	20-30

According to the answers received, it seems achievable to have the distance between the aim point and the impact point of less than 50 mm.

Several facilities are in favor of having a requirement on accuracy. Others are not and some are in between due to the risk to run as "no test".

One of the challenges is the measurement of this distance: it could be measured directly on the test item if this later is not too damaged after the test. If the reaction were too violent, this distance would be assessed by video. This may not be sufficiently accurate, as most of the time the high-speed video is in a plane perpendicular to the line of fire.

When contact screens are used to measure the velocity, one might extrapolate the position of the impact on these screens to determine the impact point location at the target. Again, this is dependent on the survivability of this equipment after the test.

The other challenge will be to properly define the accuracy requirement. An easy way would be to define a maximum distance between the aim point and the impact point (e.g. 50 mm). However, the two examples hereafter demonstrate that in some cases, it will not be appropriate:

- For the most shock sensitive part, if the booster is impacted, then the test should be valid. If the booster is smaller than the "50 mm", then the acceptable distance between the aim point and the impact point should be dependent on the size of the booster.
- For the center of the largest area of EM, some guideline could also be required. The picture below shows an example where the size of the target is dependent on the geometry of the target, and the acceptable deviation is not the same in the 2nd axis:

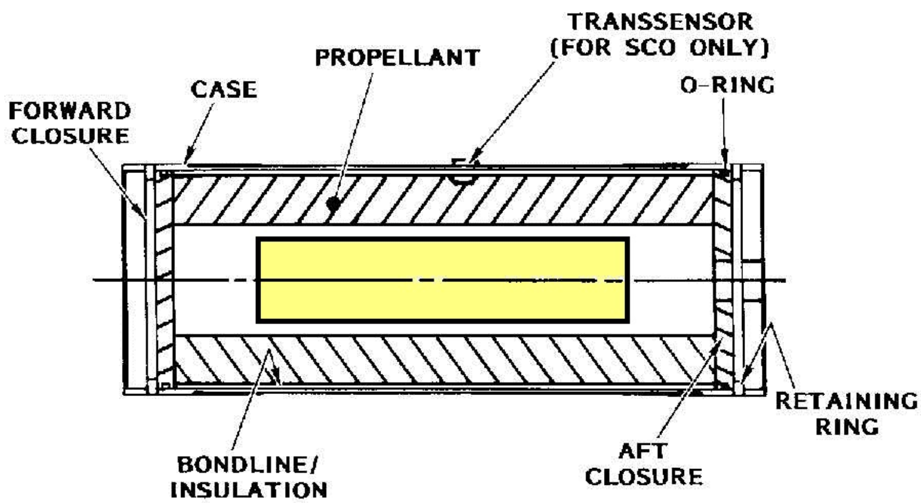

Figure 4: Acceptable impact location on a rocket motor

In this particular case, the most important will be to impact the bore of the rocket motor, to assess if a XDT reaction could occur. The yellow zone will be considered as a valid impact location. In this case, a 50 mm requirement is also not appropriate.

Recommendation: Discuss the need of an accuracy requirement within the IM community. The discussions should include the definition of the accuracy, which should be item dependent, and the way to measure it.

4.6.6 Measuring equipment

A list of minimum observation and records, and recommended equipment are provided in the STANAG 4496 and in the AOP-39.

From the answers we received, the equipment used is in accordance with the STANAG.

The following equipment / observations were mentioned:

- High speed camera for velocity, observation of the point of impact, details and timing of the reaction, yaw at impact
- Velocity screens for impact velocity
- Blast pressure gages
- Witness plates (under the item and also on the sides)
- Normal camera to track fragment trajectory and have a global view of the test site
- Microphone
- Record of meteorological conditions
- Map of debris
- Photography of fragments after the test

More specific equipment are also used when needed:

- Thrust measurement
- Strain gages
- XDT visualization to view in-bore ignition when testing a rocket motor

Several facilities have highlighted the importance of recording as much information as possible before, during and after the test (as listed in the STANAG 4496 and in the AOP-39).

Regarding the orientation of the fragment at impact, the yaw is only mentioned once in the STANAG: "*To reduce the variability due to yaw, a gun system is recommended.*" No maximum value of the yaw at impact is mentioned, even if it is an important parameter that could influence the reaction of the test item.

According to the answers received, the yaw is mostly observed through high speed camera or velocity screens (if they are not destroyed after the reaction of the item). For a laboratory test, the yaw can be measured with X-Ray.

The test centers are generally satisfied with the stability they observe. The values provided relate a yaw of maximum 10° at impact.

However, the yaw is difficult to measure. Most of the time, it is visualized with high-speed camera, or measured via the holes on the velocity screens. The first way provides indication only on one plane, and the other one is not accurate.

Recommendation: have discussion within the IM community about the fragment orientation (yaw/ pitch) at impact (measurement and maximum value).

4.6.7 Protection equipment

The paragraph 13 of the STANAG states that the item can react violently or become propulsive. Consequently, it is the responsibility of the agency conducting the test to ensure the safety of personnel and equipment during the preparation before the test, during and after the test.

The following protections were mentioned:

- A plate to catch the sabot
- Protection of the gun: e.g. heavy wall between the item and the gun, bunker, V shaped or diamond shape blast shields
- Sand bags
- A plate or a wall to stop the fragment behind the item
- Heavy mass to resist thrust when test is performed on a rocket motor
- Pyrotechnic gate on the stripper plate to block the line-of-fire after firing, to avoid that any fragment generated by the test item strikes the gun
- Hydraulic barrier to block the line of fire while loading the gun to prevent a non-intended shot to strike the test item.

In most cases, the gun is protected from the potential effects (blast, fragmentation) due to the reaction of the test item thanks to steel plates and sometimes, concrete walls. The fragment is fired through a small hole in a steel plate. This plate is used to stop the sabot to avoid impact between the sabot and the test item.

The following figure shows impacts of the sabot in the steel plate. One can see that even if they are made of plastic, due to their high velocity, they leave impressive dents in the plate:

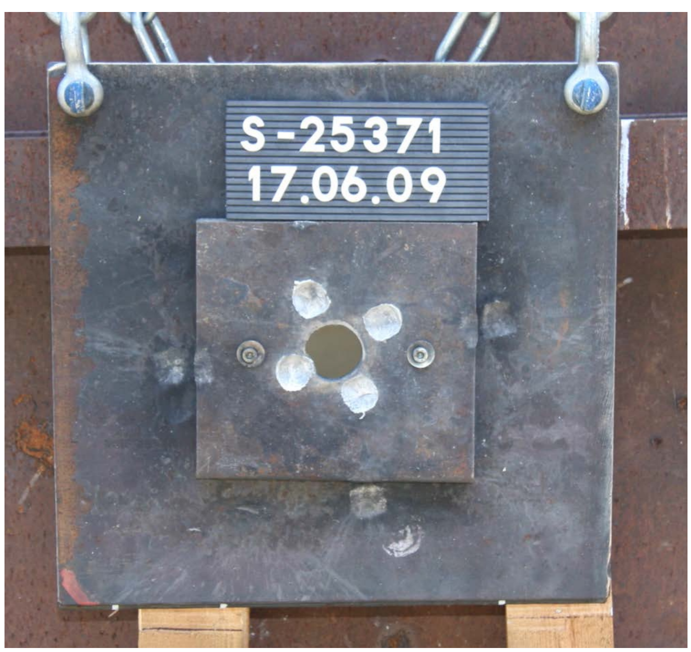

Figure 5: Stripper plate to stop the sabot (courtesy of TDW)

The following figure shows a gun protected in a bunker:

Figure 6: Gun protected in a bunker (courtesy of QinetiQ)

This last figure shows a test set-up with a wall after the target to stop the fragment:

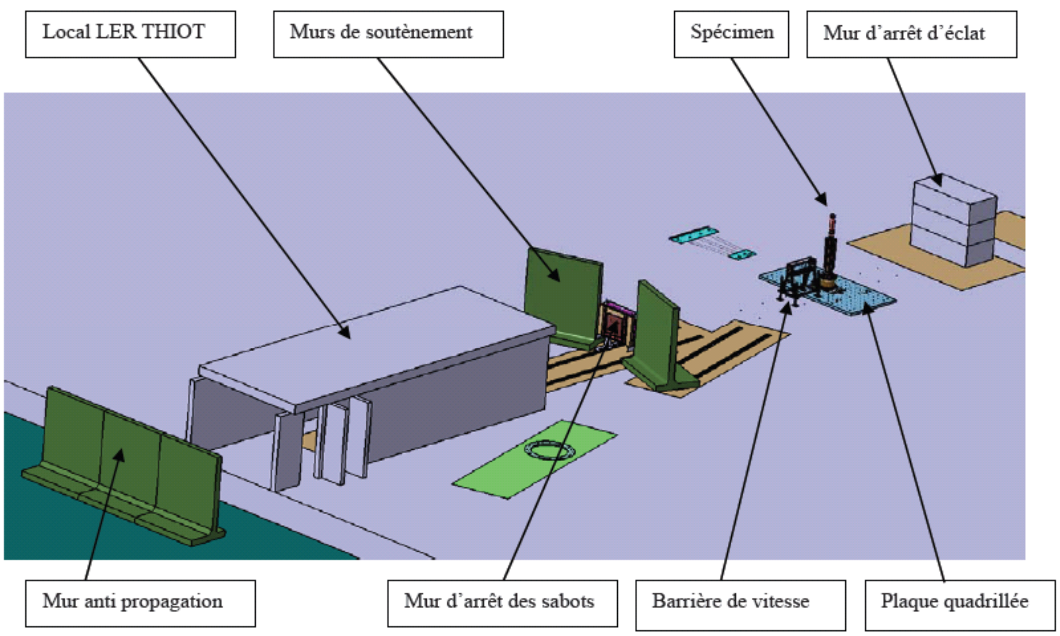

Figure 7: Test set-up in DGA EM with several protective equipment (courtesy of DGA EM)

All of the protective equipment can affect the free fragmentation area.

4.6.8 Test set-up

In the STANAG, no example of test set-up is provided.

9 test centers would like to see an example of test setup in the STANAG.

Having a test set-up example could clarify the need for the protection of the gun, and the fact it could affect the fragment free zone area.

Recommendations:

- **Add an example of test setup in the STANAG;**
- **Clearly mention that protective equipment can affect the free fragmentation area.**

4.6.9 Meteorological conditions

According to AOP-39, 9-H, §2.7 states: "Extreme external conditions (e.g. wind, rain, temperature) that might influence the test outcome should be avoided."

The meteorological limitations mentioned were as follow:

- Positive temperature
- No rain or lightning (especially for the protection of electronic equipment)
- No wind or wind exceeding certain values (10 m/s, 5 km/h, 15 mph)
- Fog or lack of brightness (visibility and bright constraints for the camera)

One should notice that the meteorological limitations are essentially in place for the protection and the good performance of the testing and measuring equipment.

4.7 ANY ISSUES WITH THIS STANAG

4.7.1 Issues with the velocity

Only one issue with the velocity tolerance was mentioned (±90m/s instead of 60m/s for the low velocity). Several centers highlighted the fact it is a challenge to achieve the high velocity requirement.

4.7.2 Most challenging

The nations were asked to report what they consider to be the most challenging part when performing this test (number of times mentioned into brackets):

- Accuracy, and evidence of it (x6)
- Difficulty to reach high velocity requirement (including firing at the peak performance of the gun, and being able to design a gun capable of this performance) (x6)
- Limited yaw at impact, and evidence of it (x3)
- Repeatability (x2)
- To assess the response of the item (x1)
- Protection of the gun which has to stand a few meters from the tested item (x1)
- Tolerance on the small velocity (x1)

This quote is a good summary of the main challenge: "*Achieving the requisite impact in a 2 inches diameter circle with a smooth bore launched non-aerodynamic projectile from a distance such that the gun is not damaged by an energetic reaction is challenging*."

4.7.3 Proposal for change

The centers were asked if they wanted to propose some change in the STANAG. The answers are summarized hereafter (number of times mentioned into brackets):

- Clarification of the fragment material, e.g. minimum value for the Brinell hardness. (x4)
- Fragment orientation at impact (yaw / pitch) should be specified. (x2)
- Accuracy of impact area should be defined. (x2)
- Standardization of the velocity measurement method and requirement on the velocity measurement system accuracy. (x2)
- Sabot and fragment modification to improve flight characteristics. (x2)
- Question on the relevance of the high velocity requirement. (x1)
- Increase low velocity tolerance to ± 90m/s (instead of 60m/s). (x1)
- Mandatory use of piezoelectric pressure transducers, i.e. blast gauges, and reporting of the complete blast gauge histories that include the muzzle blast signature. (x1)

5. SUMMARY OF RECOMMENDATIONS

This is a summary of the recommendations, the explanations have been provided in the core of this document:

- Defining a lower value for the Brinell hardness of the fragment.
- Discuss the need of an accuracy requirement within the IM community. The discussions should include the definition of the accuracy, which should be item dependent, and the way to measure it.
- Have discussion within the IM community about the fragment orientation (yaw / pitch) at impact (measurement and maximum value).
- Add an example of test setup.
- Clearly mention that the protective equipment can affect the free fragmentation area.
- Discuss the addition of a guideline on the design of the sabot.
- Remove redundancies or contradictions and clarify where the information should sit between the STANAG 4496 and the AOP-39 (MSIAC has already been tasked by AC/326 to work on this area).

6. CONCLUSIONS

This study was an efficient way to identify recommendations to further improve the STANAG 4496. These recommendations will be discussed within a working group formed by AC/326 SG/B.

According to the nations, the main challenges to carry out this test can be summarized as follows: "*Achieving the requisite velocity and impact in a 2 inches diameter circle with a non-aerodynamic projectile from a distance such that the gun is not damaged by an energetic reaction is challenging*."

7. ACKNOWLEDGEMENT

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MSIAC also acknowledge the individuals from all the test centers who have contributed to the survey by providing an answer to the questionnaire or information related to this test.

8. REFERENCES

[R1] STANAG 4439, edition 3: Policy for introduction and assessment of Insensitive Munitions.

[R2] STANAG 4496, edition 1: Fragment Impact, Munition test procedures.

[R3] AOP 39, edition 3: Guidance on the assessment and development of Insensitive Munitions.

[R4] UN, Recommendations on the transport of dangerous goods, Manual of tests and criteria, fifth revised edition, amendment 2.

[R5] L_86, Fragment impact testing: MSIAC's review and proposal.

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[R7] NF-T 70-512: impact d'éclat sphérique 250g.