# NORTH ATLANTIC TREATY ORGANIZATION
# ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD

*MILITARY AGENCY FOR STANDARDIZATION (MAS)*
*BUREAU MILITAIRE DE STANDARDISATION (BMS)*
*1110 BRUSSELS*

Tel : 707.43.02

5 November 1998 MAS/418-LAND/4164

**STANAG 4164 LAND (EDITION 2) - TEST PROCEDURES FOR ARMOUR PERFORATION TEST OF ANTI-ARMOUR AMMUNITION**

References:
a. AC/225-D/1392, AC/225(Panel III)D/369 dated 28 June 1996 (Edition 2)(1st Draft)
b. MAS/316-LAND/4164 dated 10 December 1985 (Edition 1)

1. The enclosed NATO Standardization Agreement which has been ratified by nations as reflected in page iii is promulgated herewith.

2. The references listed above are to be destroyed in accordance with local document destruction procedures.

3. AAP-4 should be amended to reflect the latest status of the STANAG (and AP if applicable).

ACTION BY NATIONAL STAFFS

4. National staffs are requested to examine page iii of the STANAG and, if they have not already done so, advise the Defence Support Division, IS, through their national delegation as appropriate of their intention regarding its ratification and implementation.

A. GRØNHEIM
Major General, NOAF
Chairman MAS

Enclosure:
STANAG 4164 (Edition 2)

STANAG No. 4164
(Edition 2)

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

MILITARY AGENCY FOR STANDARDIZATION
(MAS)

# STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: TEST PROCEDURES FOR ARMOUR PERFORATION TESTS OF ANTI-ARMOUR AMMUNITION

Promulgated on 5 November 1998

A. GRØNHEIM
Major General, NOAF
Chairman, MAS

## RECORD OF AMENDMENTS

| No. | Reference/date of amendment | Date entered | Signature |
|---|---|---|---|
| | | | |

## EXPLANATORY NOTES

### AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Chairman MAS under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

### DEFINITIONS

4. Ratification is "In NATO Standardization, the fulfilment by which a member nation formally accepts, with or without reservation, the content of a Standardization Agreement" (AAP-6).

5. Implementation is "In NATO Standardization, the fulfilment by a member nation of its obligations as specified in a Standardization Agreement" (AAP-6).

6. Reservation is "In NATO Standardization, the stated qualification by a member nation that describes the part of a Standardization Agreement that it will not implement or will implement only with limitations" (AAP-6).

### RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page iii gives the details of ratification and implementation of this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions. Page iv (and subsequent) gives details of reservations and proprietary rights that have been stated.

### FEEDBACK

8. Any comments concerning this publication should be directed to NATO/MAS - Bvd Leopold III - 1110 Brussels - BE

STANAG 4164
(Edition 2)

NAVY/ARMY/AIR

NATO STANDARDIZATION AGREEMENT
(STANAG)

# TEST PROCEDURES FOR ARMOUR PERFORATION TESTS OF ANTI-ARMOUR AMMUNITION

Annexes:

A. Firing Procedure - Langlie Method
B. Firing Procedure - Up-and-Down Method (Bruceton Method)
C. Minimum Trials Data to be Reported
D. Description of Target Damage
E. Summary of Measurement Tolerances
F. Modern Armour Containing Brittle Materials

Related Documents:

STANAG 4089 Armour Plate Configuration for Anti-Armour Ammunition Tests

STANAG 4190 Test Procedures for Measuring Behind-Armour Effects of Anti-Armour Ammunition

## AIM

1. The aim of this agreement is to standardize the test procedures for armour perforation tests of anti-armour ammunition.

## AGREEMENT

2. Participating nations agree to use the test procedures defined in this STANAG for armour perforation tests of anti-armour ammunition.

## GENERAL

3. This STANAG specifies procedures to be used in tests to determine the capability of anti-armour ammunition to perforate armour plate targets.

4. This is only one of several types of test to determine the lethality of an ammunition against armoured fighting vehicles. Other types of test that are desirable include:

a. Tests of the behind-armour fragmentation arising from penetration of the armour by a kinetic energy projectile, or from the spall produced by penetration of the armour by a shaped charge.

b. Tests of the remaining penetrative power of the main residual kinetic energy penetrator pieces or the residual jet of a shaped charge.

c. Tests of the ability of high explosive squash head (high explosive plastic) projectiles to produce scabs from armour.

d. Confirmatory firings against real armoured fighting vehicles.

These and other types of test are not covered in this STANAG, but some are covered in other STANAGs.

5. Tests of the types noted at Sub-Paragraphs 4a and 4b can often be combined with the tests described in this STANAG.

DETAILS OF THE AGREEMENT

6. This agreement is divided into three parts as follows:

Part I: Definition of test procedures for kinetic energy projectiles;

Part II: Definition of test procedures for shaped charges;

Part III: Points applicable to both kinetic energy projectile and shaped charge tests.

PART I: DEFINITION OF TEST PROCEDURES FOR KINETIC ENERGY PROJECTILES

7. Tests of kinetic energy (KE) projectiles are to be carried out using the procedures detailed below:

a. Two alternative procedures are given in Annexes A (Langlie Method) and B (Up-and-Down Method (Bruceton Method)). Both are based on the principle of keeping either angle of attack or striking velocity constant throughout a test series, and varying the other parameter. Either procedure can be used regardless of which parameter is kept constant.

b. The Langlie Method (Annex A) has the advantage of providing a better basis for making a statistical estimate of the variability of the penetrative ability of the round.

c. Because it is, in practice, not possible to keep the velocity constant and exactly at a desired mean velocity, variation of the angle tends to be a less accurate method of determining performance than variation of the velocity, for which the angle of attack can be kept virtually constant and on the desired value.

d. Before comparative trials are fired, agreement should be reached on the method to be used.

e. Annex F contains notes on firings at targets representing modern armour containing brittle materials.

f. It is recommended that, in addition to any trials that may fired against targets defined in STANAG 4089, the penetration capability of a KE projectile be measured against a semi-infinite target. The semi-infinite target consists of a series if plates of a quality specified in STANAG 4089 stack face to face to a total thickness which will ensure that the projectile will not produce any disturbance (such as deformation, discolouration etc) on the back of the last plate. It is attacked at zero degrees.

8. Yaw

a. In this STANAG, the term yaw is used to describe any angular displacement between the projectile axis and the warhead velocity vector, irrespective of plane.

b. When firing with reduced charges, the yaw of the projectile may be greater than the yaw likely to be experienced with full charge firings. If possible, the distance from the gun to the target should be determined based on the yaw cycle so that the target is located at a minimum yaw point or at a point where the projectile yaw is damped out. For some kinetic energy projectiles this distance is up to 200 m.

c. Before any test firings an upper limit of yaw should be declared, based either on practical trials experience or on theoretical grounds. During the test firings the yaw shall be determined as near the target as possible, using any suitable method of measurement which must be acceptable to all nations concerned. The upper limit for yaw will be 1 degree for both single and multiple plate arrays at all angles of obliquity.

d. Any round having yaw which exceeds the limit and results in a partial perforation shall be disregarded. A complete perforation will be accepted.

9. Striking Velocity (Variation of Angle)

a. Before any test firing is carried out in which the angle is to be varied, the charges will be adjusted to give a striking velocity, called the desired velocity, equal to that expected at the range represented. The velocity decrement, eg for large calibre KE rounds, the change in velocity corresponding to 1000 m increase in range, will also be estimated for the desired range.

b. During the test firing the velocity of each round will be measured to an accuracy of ± 0.2% using any suitable method. This will be corrected, using any accepted method, to allow for the distance between the point at which the velocity is measured and the point at which the projectile was expected to strike the target, using the velocity decrement, in order to give the striking velocity.

c. If, at the end of firing a test series, the striking velocity of any round differs from the desired striking velocity by more than 20 m/s it shall normally be rejected if either:

(i) it is a complete perforation and the velocity is too high, or

(ii) it is a partial penetration and the velocity is too low.

10. Striking Velocity (Variation of Velocity)

a. The velocity of each round in a firing shall be measured and corrected to give the striking velocity as described in Sub-Paragraph 9b above.

b. When varying the velocity during firing for a V50 ballistic limit, rounds shall not be rejected for departure from the desired velocity.

11. Definition of a "Fair Hit"

a. When a KE projectile strikes an armour plate the metallurgical properties of the plate in a zone surrounding the point of impact are altered. The result of a further round striking in this zone will be affected by these metallurgical changes. A round will only be considered fair if there is at least the diameter of the projectile in flight between the visibly disturbed area surrounding the hole and the visibly disturbed area surrounding the hole made by an earlier shot (measured edge to edge) and at least 2 diameters of the projectile in flight between the visibly disturbed area surrounding the hole and the edge of the plate or of a lifting hole in the plate (see Figure 1). This criterion is to be applied on both faces of each plate used in the target array. If the round fails this test on either face of any plate it should be considered "Not a Fair Hit" (NFH) and should be disregarded. Visible disturbance includes derusting, deformation, discolouration, cracking, etc.

b. The results of rounds considered NFH shall not be used in subsequent calculations, but a further round shall be fired under the same test conditions. However, where a round that was expected to fail does fail and is NFH, it may be accepted at the discretion of the authority ordering the test, provided that, when appropriate, the representatives of any other nation concerned agree.

12. Reporting Results of KE Firing Trials

a. Any report of the results of a firing trial with KE projectiles should include, as a minimum, the information listed in Annex C. Annex D gives a recommended target damage code.

b. Because of manufacturing tolerances in the production of armour plate, the difficulty of adjusting charges to get a desired velocity, the inherent round-to-round variation in muzzle velocity etc, the actual trials results will apply to conditions that differ slightly from the desired conditions. Therefore, in any reports the raw data for each round must be reported together with details of the conditions actually applying when the rounds were fired.

PART II: DEFINITION OF TEST PROCEDURES FOR SHAPED CHARGES

13. a. Firings of shaped charges to determine their penetration capability can be carried out statically, but sufficient rounds should be fired dynamically to check whether there is any significant difference in the penetration performance between dynamic and static firings (as will often be the case with high warhead impact velocities), and to determine any necessary correction factor to allow for such a difference. Dynamic firings should be carried out at warhead velocities corresponding to the expected engagement range; the spin rate should match, as far as possible, the spin rate at this range, and the obliquity of the target must not be such as to impair fuse functioning.

b. All rounds shall be fired with the components normally found in front of the shaped charge cone (eg fuze, seeker, etc) or their equivalent in material density and spacing. If a warhead would be spun at the expected engagement range it should be spun at the same rate in static firings, unless it can be shown that there is no significant difference between the spun and unspun penetration at the stand-off distance used.

c. It is recommended that, in addition to any trials that may be fired against targets defined in STANAG 4089, the penetration capability of shaped charges should be measured against a semi-infinite target and with the projectile at several different stand-off distances from the surface of the target. For dynamic firings a burster plate will be necessary to achieve this. It must be sufficiently robust to ensure correct warhead initiation, but of such thickness and density that it does not significantly interfere with the warhead's performance. In addition, it is desirable that the fuze delay time be measured in any such dynamic firing, in order to establish the actual stand-off.

d. The semi-infinite target consists of a series of armour plates of quality specified in STANAG 4089 stacked face-to-face to a sufficient total thickness to ensure that the jet will not produce any disturbance (such as deformation, discolouration etc) on the back of the last plate. It is attacked at zero degrees.

e. When a shaped charge projectile is fired against one of the targets defined in STANAG 4089, it is possible:

to arrange the target at a preferred angle and measure the remaining penetration into a stack of armour plates arranged behind the target.

or

to arrange the target at a required angle and determine that the round either does or does not defeat the target.

14. The results of test firings of shaped charges shall always be reported as the mean of the results of at least 3, and preferably at least 5, rounds fired under the same test conditions. The results of the individual rounds in the series should also be reported:

a. The minimum results to be reported from a test firing are given in Annex C.

b. Additionally, it is desirable to report the mean diameter of the jet hole at regular intervals along its length.

c. A shaped charge round that is normally fired from a gun shall be rejected for excessive yaw if the measured yaw is more than 2 degrees, except when it is fired with full service charge.

d. A guided weapon shaped charge shall not be rejected for excessive yaw, since yaw can be a result of demands induced by the guidance system, but the actual yaw shall be measured and recorded.

e. A shaped charge firing shall only be considered fair if there is at least 75 mm between the edge of the hole created by that firing and the edge of the plate or of a lifting hole in the plate or the edge of the visible disturbed area surrounding the hole created by a previous firing (see Figure 2). This criterion applies on both faces of all plates in the target.

## PART III: POINTS APPLICABLE TO BOTH KE PROJECTILE AND SHAPED CHARGE TESTS

### 15. Definition of a Complete Perforation

A round shall be considered to have achieved a complete perforation if it produces at least one perforation, through which light can be seen, in a witness plate placed 300 mm behind and parallel to the back of the rear plate of the target array. The witness plate is to be:

a. Aluminium sheet to specification US 2024 T3 (or equivalent), 0.45 mm to 0.55 mm thick, for calibres up to and including 40 mm.

b. Mild steel plate 1.5 mm to 1.7 mm thick, for calibres above 40 mm.

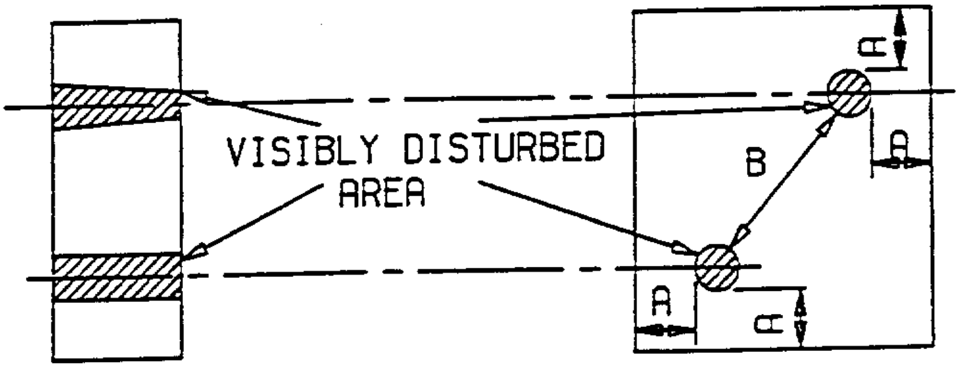
16. The angle of obliquity quoted in all trial instructions and reports shall be that previously defined for NATO purposes, ie the angle between the trajectory of the projectile and an imaginary line perpendicular to the surface of the target array through the point of impact of the projectile.

17. All angles shall be measured with an error of not more than ± 3 mils (± 1 mil desirable), and shall be measured at the expected point of impact of the projectile or jet.

18. Annex F contains notes on firings at targets representing modern armour containing brittle materials.

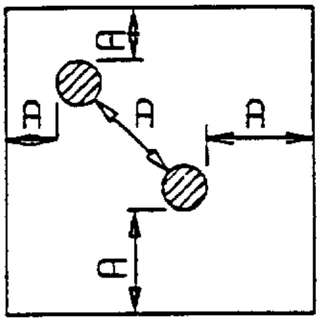
## IMPLEMENTATION OF THE AGREEMENT

19. This STANAG is implemented when a nation has issued the necessary instructions to the establishments concerned putting the procedures detailed in this agreement into effect.




A≥ 2 DIAMETERS OF THE PROJECTILE IN FLIGHT
B≥ ONE DIAMETER OF THE PROJECTILE IN FLIGHT

**Figure 1**




A≥ 75 mm

**Figure 2**

ANNEX A to

STANAG 4164
(Edition 2)

FIRING PROCEDURE - LANGLIE METHOD

AIM

1. a. The aim is to obtain an angle of obliquity (or a striking velocity) at which armour plate with defined characteristics will be penetrated with 50% probability by a KE round, fired at a specified striking velocity (or angle of attack).

b. For simplicity this Annex describes the measurement of θ50. To establish V50, the velocity at which there is a 50% chance of penetration at a specific angle of obliquity, the same method may be used provided the upper and lower values of velocity are assigned accordingly.

INFORMATION REQUIRED BY OFFICER IN CHARGE OF FIRINGS

2. The following information is required, for each type of round involved in the firings, by the officer in charge of the firings:

a. The constant mean velocity at which all rounds of a particular type will be fired. For firings comparing the performance of two types of ammunition, the mean velocities selected should normally correspond to those achieved at the same range in full charge firings.

b. Details of which armour plates have been matched for any particular test. This information is required as it is most unlikely that comparative firings involving more than one type of round can be carried out on one plate, and with the larger calibres it will often be necessary to use more than one plate to determine θ50 for a single type of round.

c. An upper angle of obliquity ($\theta_U$) at which the probability of obtaining a complete perforation with a particular type of round is highly unlikely.

d. A lower angle of obliquity ($\theta_L$) at which the probability of obtaining a complete perforation with a particular type of round is highly likely.

(NOTE: For early development tests where the penetration data are limited a wide gate ($\theta_L$ - $\theta_U$) is recommended. For tests where data are available a smaller gate is recommended.)

e. The constant (reduced) range at which all targets will be set up for a particular type of round.

f. Definition of a fair hit in terms of acceptable yaw, striking velocity and distance of the point of strike from the locations of previous strikes.

TRIAL PROCEDURE

3. Decisions on the firing conditions for each round are based solely on previous fair hits. The purpose of the following rules is to obtain a spread of rounds across the range of angles in which there is uncertainty whether a particular round will, or will not, obtain a complete perforation.

4. Plate Angle for First Round

The first round is fired at an angle mid-way between the upper and lower angles of obliquity defined in Sub-Paragraphs 2c and 2d above.

ie $$\theta_1 = \frac{\theta_U + \theta_L}{2}$$

5. Plate Angle for Second Round

a. If the first round is a complete perforation, then the plate angle for the second round is:

$$\theta_2 = \frac{\theta_1 + \theta_U}{2}$$

b. If the first round is a partial penetration, then the plate angle for the second round is:

$$\theta_2 = \frac{\theta_L + \theta_1}{2}$$

6. Plate Angle for Third Round

a. If the first two rounds give a reversal (1 complete perforation, 1 partial penetration), the plate angle for the third round is:

$$\theta_3 = \frac{\theta_1 + \theta_2}{2}$$

b. If the first two rounds are both partial penetrations the plate angle for the third round is:

$$\theta_3 = \frac{\theta_2 + \theta_L}{2}$$

c. If the first two rounds are both complete perforations the plate angle for the third round is:

$$\theta_3 = \frac{\theta_2 + \theta_U}{2}$$

7. If the first three rounds all produce complete perforations or all produce partial penetrations, it shall be permissible to define new values of $\theta_U$ and $\theta_L$ and start the procedure again. In such an event the results of rounds already fired shall be recorded for use in post-trial analysis.

8. Plate Angles for Succeeding Rounds

Succeeding rounds, up to 12 in all, will be fired using the following rules in the order given below:

a. If the last two rounds have given a reversal (1 complete perforation, 1 partial penetration):

(i) Check whether 5 successive reversals have been obtained. If so, sufficient data has been obtained and the trial will be stopped;

(ii) If 5 successive reversals have not been obtained, the plate angle for the next round (nth round) will be:

$$\theta_n = \frac{\theta_{n-1} + \theta_{n-2}}{2}$$

b. If the last two rounds have been either 2 complete perforations or 2 partial penetrations:

(i) Examine the last 4 rounds. If these have given 2 complete perforations and 2 partial penetrations the plate angle for the next round (nth round) will be:

$$\theta_n = \frac{\theta_{n-1} + \theta_{n-4}}{2}$$

(ii) If the last 4 rounds have not given 2 complete perforations and 2 partial penetrations examine (where applicable) the last 6 rounds. If these gave 3 complete perforations and 3 partial penetrations the plate angle for the next round (nth round) will be:

$$\theta_n = \frac{\theta_{n-1} + \theta_{n-6}}{2}$$

(iii) If the last 6 rounds have not given 3 complete perforations and 3 partial penetrations examine (where applicable) the last 8 rounds. If these gave 4 complete perforations and 4 partial penetrations, the plate angle for the next round (nth round) will be:

$$\theta_n = \frac{\theta_{n-1} + \theta_{n-8}}{2}$$

(iv) If the last 8 rounds have not given 4 complete perforations and 4 partial penetrations examine (where applicable) the last 10 rounds. If these gave 5 complete perforations and 5 partial penetrations, the plate angle for the next round (nth round) will be:

$$\theta_n = \frac{\theta_{n-1} + \theta_{n-10}}{2}$$

(v) If the steps in sub-paragraphs (i) to (iv) above have shown that none of the last 4, 6, 8 or 10 rounds, as applicable, contain equal numbers of complete perforations and partial penetrations or insufficient rounds have been fired to allow for the application of any of these rules the plate angle for the next round (nth round) will be as follows:

(A) Where the last round fired was a complete perforation:

$$\theta_n = \frac{\theta_{n-1} + \theta_U}{2}$$

(B) Where the last round fired was a partial penetration:

$$\theta_n = \frac{\theta_{n-1} + \theta_L}{2}$$

COMPLETION OF TRIAL

9. As noted in Paragraph 7 above, the trial will be completed when:

a. Five successive reversals (alternate complete perforation and partial penetration) are obtained; or

b. A total of 12 rounds has been fired.

ANALYSIS OF RESULTS

10. a. If the firings do not produce a zone of mixed results, $\theta_{50}$ will be calculated by averaging the highest angle which has given a complete perforation and the lowest angle which has given a partial penetration.

(NOTE: Failure to produce a zone of mixed results occurs when the highest angle at which a complete perforation occurred is less than the lowest angle at which a partial penetration occurred.)

b. Where the firings have produced a zone of mixed results $\theta_{50}$ will be calculated using the cumulative normal distribution and the principle of maximum likelihood. The calculations can be carried out either by means of a computer programme or manually by using profit analysis. An approximate estimate can also be obtained by graphical techniques.

11. This method assumes that the velocity is kept constant. Where this is not approximately true, errors in the calculations may be introduced. It is therefore recommended that the results are plotted on a graph with axes representing striking velocity and angle of attack, as a check that errors have not been introduced.

FIRING PROCEDURE - UP-AND-DOWN METHOD (BRUCETON METHOD)

AIM

1. a. The aim is to obtain a striking velocity (or an angle of attack) at which a KE round of a specified type will have a 50% probability of defeating a specified armour plate array at a specified obliquity (or striking velocity).

b. For simplicity this Annex describes the measurement of V50. The measurement of θ50 is similar substituting angle for velocity, 75 mils for 50 m/s, 25 mils for 17 m/s, and Δθ for ΔV, where appropriate.

c. The Up-and-Down Method can be used in place of the Langlie Method if there is no great uncertainty about the value of the V50 (or θ50) ballistic limit, and/or there are constraints that warrant firing less rounds than required by the Langlie Method. Properly used, once a complete perforation and a partial penetration have been obtained, all steps thereafter are approximately equal to one standard deviation, which is designated ΔV below. If no good estimate of the standard deviation is known, use 17 m/s for ΔV, or 25 mils for Δθ when obtaining a θ50.

INFORMATION REQUIRED BY OFFICER IN CHARGE OF FIRINGS

2. The following information is required by the officer in charge of the firings, for each type of round involved in the firings:

a. The constant obliquity at which the target array is to be set up for every round in the series.

b. Details of the target array required for the series, including details of which plates have been matched for any particular comparative trial. This is necessary as it is most unlikely that series for more than one round can be completed on one plate.

c. The expected V50, ie the velocity at which the round will have a 50% probability of a complete perforation.

d. Definition of a complete perforation.

e. Definition of a fair hit in terms of acceptable yaw, departure from the specified obliquity and distance of the point of strike from the location of previous strikes, or the edge of the plate.

f. A table or graph of propellant charges versus muzzle velocity.

g. Drag coefficient and ballistic coefficient of the projectile (if available).

TRIAL PROCEDURE

3. For the First Round The propellant charge is to be adjusted to give the prior estimate of V50 (see Paragraph 2c).

4. For the Second Round

a. If the first round was a complete perforation, adjust the charge to give an expected striking velocity 3 ΔV (or 50 m/s if ΔV cannot be estimated) less than the first round.

b. If the first round was a partial penetration, adjust the charge to increase the expected striking velocity by 3 ΔV (or 50 m/s).

5. For Later Rounds

a. If all previous rounds were complete perforations, adjust the charge to reduce the expected striking velocity by 3 ΔV (or 50 m/s).

b. If all previous rounds were partial penetrations, adjust the charge to increase the expected striking velocity by 3 ΔV (or 50 m/s).

c. As soon as at least one complete perforation and one partial penetration have been obtained, adjust the charge to increase the expected striking velocity by ΔV if the last impact was a partial penetration. On the other hand, if the last impact was a complete perforation, adjust the charge downward to decrease the expected striking velocity by ΔV. Continue in this fashion increasing the charge after partial penetrations and decreasing the charge after complete perforations until the conditions of Paragraphs 6a and 6b have been satisfied.

6. Completion of Firings

The trial will be completed when either:

a. There are at least 3 complete perforations and at least 3 partial penetrations within a striking velocity spread of 3 ΔV (or 50 m/s), or

b. 12 rounds have been fired.

CALCULATION OF V50

7. If the 3 highest partial penetrations and the 3 lowest complete perforations cover a spread of less than or equal to 50 m/s, compute the V50 ballistic limit by taking the arithmetic mean of the striking velocities of these 6 rounds.

8. If a large zone of mixed results exists in which the highest partial penetration is more than 50 m/s above the lowest complete perforation, compute the V50 ballistic limit by the method of maximum likelihood.

9. Occasionally, anomalous results occur. In such cases extra rounds should be fired to provide further information.

ANNEX C to
STANAG 4164
(Edition 2)

MINIMUM TRIALS DATA TO BE REPORTED

1. GENERAL

Date of trial

Place of trial

Description of target array - nominal plate thicknesses including witness plate and actual spacing

Actual range in metres

Range in metres simulated by charge adjustment

Distance from velocity measurement point to target

Upper and lower limits of angle/velocity (Langlie Method only)

Limit on yaw

Velocity decrement (m/s/km)

Complete round temperature (°C)

Air temperature (°C)

2. PLATE DATA

For each plate component of a target: Plate identification (maker/plate no/material specification, name or composition) for each plate used

Minimum )
Maximum ) thickness in mm
Mean )

Maximum and minimum hardness (BHN scale or equivalent) (method and load used to be stated)

Impact values at ambient temperature and -40°C (Izod or Charpy Methods may be used)

0.2% yield stress (tsi or $MN/m^2$)

Ultimate tensile strength (tsi or $MN/m^2$)

Elongation % (initial gauge length to be stated)

Reduction of area % (original diameter or cross-section to be stated).

For witness plate: Plate identification (maker/plate no/material specification, name or composition)

Thickness (mm)

Distance behind target plate (mm)

ANNEX C to
STANAG 4164
(Edition 2)

3. RESULTS OF FIRINGS

For each round:

Project identification (when appropriate)

Round serial no

Detail of which individual plates were used to construct target array

Impact velocity

Angle of attack (mils)

For each target plate:

Result
Maximum diameter and minimum diameter of entrance hole (mm)
Maximum diameter and minimum diameter of exit hole (if any) (mm)
Height of any bulge (mm)
Depth, width and length of any scoop (mm)
Depth of penetration if plate is not perforated (mm)

Details of holes in witness plates

Angle of yaw (degrees or mils)

Orientation of yaw relative to slope of plate

Spin rate (as appropriate)

Stand-off (as appropriate, state whether measured from base of cone or from front of projectile).

DESCRIPTION OF TARGET DAMAGE

| | |
|---|---|
| Hole Normal (HN) | A complete hole through the plate of approximately the diameter of the projectile. |
| Hole Small (HS) | A hole through the plate, of smaller diameter than the projectile, through which light can be seen. |
| Cracked Bulge (CB) | A bulge on the back of the plate with at least one distinct crack in it. |
| Smooth Bulge (SB) | A bulge on the back of the plate without cracks. |
| Disc Off (DO) | A complete disc off the back of the plate considerably larger in size than the normal "collar" effect around the hole exit, or a disc off the back of the plate without a perforation. It may be used with HN or HS. |
| Disc Started (DS) | A circular cracking effect and lifting of metal on the back of the plate indicating that a disc is starting to detach itself. The extent of the circumferential crack can be indicated, eg 1/2, 3/4 or clock-code (3-8 o'clock) etc. |
| Scoop (SC) | An indentation produced on the front of the plate which does not result in a complete hole through the plate. It would often accompany an SB, CB or DS. |
| Core Lodged (CL) | An indication that the projectile core is lodged in the scoop, cavity or hole. Used with SC, HN or HS. |
| Plug Out (PO) | A lump of metal of approximately the diameter of the projectile punched from the plate in one piece. |

ANNEX E to

STANAG 4164
(Edition 2)

SUMMARY OF MEASUREMENT TOLERANCES

1. This Annex lists the agreed tolerances on the accuracy to which various measurements should be made at trials establishments or on the firing range.

2. Before comparative trials are fired, measurement tolerances on other variables of interest should be agreed by the nations concerned. In setting such tolerances both practical considerations and the view of the analysts who will conduct post-trial analysis should be considered.

| | |
|---|---|
| Individual target plate thickness (measured at the intended point of impact) | ± 0.1 mm |
| Angle of obliquity (measured at point of contact) | ± 3 mils<br>(± 1 mil desirable) |
| Velocity of round | ± 0.2%<br>(± 0.1% desirable) |
| All distances | ± 1% or ± 1mm whichever is less |
| Yaw angle | ± 0.1 degree |
| Spin rate | ± 5% |

NOTES ON MODERN ARMOUR CONTAINING BRITTLE MATERIALS

INTRODUCTION

1. The factors which determine the efficacy of modern brittle armour are less well understood than those affecting more traditional armour materials. This is true of both manufacture and test. Therefore, when such armour is the target material in an anti armour ammunition perforation test, there is potential for significant experimental error. This could give rise to anomalous or misleading results.

2. AOP 35 sets out the details of the representative test targets in terms of the thickness and sequence of material. However, it does not seek to provide definitive guidance on the exact arrangement of the target array nor does it, in the case of ceramics, precisely define the material. Some latitude in the conduct of the test and selection of material is left to allow nations the freedom of choice to suit local circumstances and material availability.

3. Since the purpose of this STANAG is to standardise test procedures for anti armour ammunition so that performance information from testing can be exchanged on a comparable basis it will be important to provide as much test qualifying data as possible. Set out below are notes on the data to be provided and those features of testing which may cause variability in the results.

CONSIDERATIONS

4. Ceramic. The quasi static properties of a ceramic sample are not a reliable guide to its ballistic protection performance. Significant variations in performance can be noted between batches of the same nominal specification. This variability is also noted in samples of the same specification from different manufacturers. Therefore, if results are to be comparable in any series of national tests they should be conducted with materials from a single batch and samples retained for evaluation and comparison against materials used in any subsequent tests. To allow international evaluation of the results the following minimum data should be recorded for the ceramic element of any test target:

Manufacturer
Batch number
Date of manufacture
Nominal specification (to include $Al_2O_3$%, density and porosity)

For any collaborative project which involves nations individually conducting tests in support of the programme the ceramic element of the target should be obtained from a single source and, ideally, from a single batch.

5. Confinement. When the test target is struck by a projectile the tensile shock reflections within the ceramic element will vary in accordance with the size of the ceramic plate and the impact velocity of the projectile. This variation in shock waves will in turn cause the behaviour, in ballistic protection terms, of the ceramic material to change. This may produce test results which would be unrepresentative of those achieved with a full scale target. To minimise this effect, which is attributable to the test target geometry, the following guidelines should be followed:

a. Velocity. If the impact velocity of the projectile is less than 1600 m/s the test target should ideally be 30 times the projectile diameter across the smallest dimension. If material of this size is not available, closely fitting confinement may be used to mimic a larger target. For impact velocities above 1600 m/s the target may be smaller. At velocities above 1800 m/s the target need only be 15 times the projectile diameter.

b. Target Size. If the target is less than 30 times the projectile diameter across the smallest dimension, it should be confined. This assumes impact within 2 projectile diameters of the target centre.

c. Confinement. The target confinement should consist of a RHA, aluminium alloy etc frame which is of the same thickness as the ceramic material. The gap between the frame and the material should be ≤1 mm and may be filled with either shims or a suitable pourable filler. The width of the frame should be proportional to the size of the ceramic target and be calculated in accordance with the formula below.

$$\frac{(\text{Projectile diameter} \times 30) - \text{Ceramic Width}}{2}$$

Frames calculated to be less than half the projectile diameter in width need not be used as these will result in negligible performance variation.

6. Target Size. Given the cost and commonly available sizes of ceramic materials there is a requirement to keep test targets as small as is practicable. There are 3 key factors to consider when determining any particular test target size; projectile diameter, dispersion and target obliquity. The width of the target will be determined by projectile diameter and dispersion. The height of the target will be the same as the width but will need to be proportionally increased with obliquity. With reference to Figure 1 the following formula should be used for calculating target size:

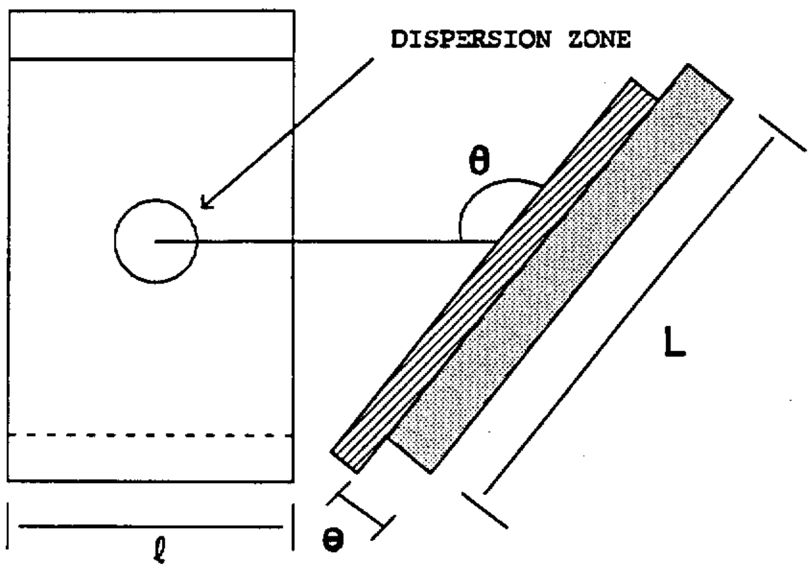



Figure 1

a. Target Width ($\ell$). Assuming the dispersion at target ≤ 2 projectile diameters:

(1). For impact velocities of less than 1600 m/s:

$\ell$ = projectile diameter x 30

(2). For impact velocities greater than 1800 m/s:

$\ell$ = projectile diameter x 15

(3). For impact velocities between 1600 and 1800 m/s:

$\ell$ = projectile diameter x ( 30 - (r x 0.075) )

Where

r = impact velocity - 1600

b. Dispersion Zone. If the dispersion is greater than 2 projectile diameters then dimension $\ell$ must be increased by:
dispersion at target - 2 projectile diameters

No distinction needs to be made between static and dynamic tests except for the dispersion in the dynamic case as above.

c. Target Height (L). For vertical targets the target height (L) will equal the target width ($\ell$). For targets where there is obliquity ($\theta$) the target height (L) should be calculated as follows:

$$L = \left( \frac{\ell}{\cos\theta} \right) + e \tan\theta$$

7. Material Thickness. Due to property variations caused by the manufacturing process, and stress wave interactions in layered structures, the performance of a ceramic target will depend upon the thickness and number of tiles in the system and upon the nature of the layer interface. For this reason, it is important that data be recorded regarding the target layers.

8. Axial Compression. Given the multi element nature of modern armours it will be usual to clamp the target. The axial compression applied should be recorded. As a minimum, the number, configuration, size and thread pitch of the clamping bolts should be recorded, together with the tightening torques.

9. Air Gaps. Ideally there should be no air gaps between elements of the target and surfaces should be machined to fit. However, this is costly and often impractical. Guidance is given in AOP 35 on the maximum air gap allowable between any 2 elements and methods for ameliorating the effect. Since this is another source of variation the methodology used should be recorded.

10. Temperature. Consideration needs to be given to any temperature differential which may exist between the target fabrication facility and the test site. This is particulary important if the fabrication site is either heated or air conditioned or there is a significant time lag between target fabrication and use. Due to the differing coefficients of linear expansion of materials in a multi element target the prescribed set up of the target may be altered.

SUMMARY

11. To allow test results to be accurately assessed the following information should be provided with the test results:

a. Dimensions of all layers.

b. Surface finish (surface ground or as fired).

c. Interface gap thickness.

d. Nature of interface (air gap, epoxy filled etc).

e. Target configuration with dimensions, angles and axial compression (if applicable).

f. Dimensions of penetrator.

g. The manufacturer, type number and manufacturing specification of all materials used. For the ceramic element, at a minimum, the $Al_2O_3$%, density and porosity should be recorded.

h. Temperature during test and temperature during target preparation.

j. Humidity (especially if hygroscopic elements such as GFRP are present).

k. Point of strike with respect to centre of target.

l. Yaw at strike.

m. Yawing rate at strike.