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11 pages

DISCUSSIONS TO SHAPED CHARGE JET TESTS AFTER MIL STD 2105 B

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ABSTRACT

In contrast to the fragment impact test the shaped charge jet impact test No. 5.2.6 of MIL STD 2105 B is very conservative. The detailed description for the shaped charges, which should be used, is already modified from the first edition of the MIL STD 2105 B. The 50 mm Rockeye warhead, fired at 147 mm stand-off, is not internationally to everybody available and represents not the real threat by modern shaped charge systems. On one hand it exist a very large number of shoulder launched projectiles with about 300 mm to 400 mm perforation capabilities. But the missile warheads have mostly 100 mm to 150 mm diameters with perforation potentials of 800 mm to 1.200 mm and jet tip velocities over 9 mm/µs. After the perforation of 100 mm RHA or less the residual jet tip velocities are over 8 mm/µs with large jet diameters. Further missile WH are nearly 100 % using now tandem shaped charges, where the jet of the precursor charge can sensitise propellant and high explosive charges, where the later arriving main jets can start now violent reactions. The initiation criteria for shaped charge jets as function of jet velocities, diameter, material, acceptor charge configurations, covered or not, unconfined and confined etc. will be shortly described. Finally it will be tried to give recommendations for different levels of shaped charge threats.

BACKGROUND

The ammunitions should be less sensitive against different threats, to avoid per example the damage of mass or sympathetic donations at storage magazines (Fig. 1). To get national and international standard test procedures, the MIL-STD-2105A was created first on the 09.09.1982 and the second draft on the 09.01.1990. To the old standard tests in MIL-STD-810 B, seven additional threat tests were added, which includes also tests with shaped charge jet impacts and shape charge spall fragment impacts (Fig. 3). They differentiate between 6 reaction levels, which are verbal described in paper form (Fig. 4). With regards to the fragment formations and blast pressure this text is visualised by the author (Fig. 5).

SHAPED CHARGE TESTS

In the first edition the shaped charge tests were described in § 5.1.10 by threats either of M42/M46 grenades or the 81 mm precision shaped charge, which represents a HEAT attack. The M42/M46 grenades should be fired in the built in stand-off and the 81 mm SC in 147 mm distance (Fig. 6). Surprisingly is, that not the in extremely large quantities produced M42/M46 grenades or bomblets should be used as the standard version (Fig. 7), but a special type with a trumpet liner (Fig. 8) with very special requirements for the liner material (Fig. 9). In the very short distance the liner texture has a minor influence on the jet characteristics.

I have found two sketches for the 81 mm precision shaped charge in the open literature (Fig. 10 and Fig. 11). Also in this case a very precise liner material was required, which has as well no influence on the jet characteristics in the required two calibre stand-off (Fig. 12).

The test procedure was reworked and in my latest edition of the 12th January 1984 (Fig. 13) is described in § 5.2.6, that now the Rockeye shaped charge warhead with 50 mm diameter should be used at 147 mm standoff (Fig. 14). This can be an USA national standard but not an international standard, because this cluster ammunition is not world-wide available.

For the spall fragment impact tests the 80 mm precision shaped charge is left (Fig. 15), where the same limitations exist for this shaped charge type, as described before.

JET INITIATION PHENOMENA

A rough rule of thumb for the initiation threshold of high explosive charge is the Held $v_j^2 \cdot d_j$ criteria, where v_j is the jet impact velocity and d_j the jet diameter (Fig. 17). The high explosive charges behave much more sensitive, if the charges have an air gap between a casing or a cover plate and the charge (Fig. 18). They reacts faster with less build up distances as the pictures of a rotating mirror cameras with 1 million frames/sec show (Fig. 19). The charges behave much less sensitive, if the air gaps are beneath 1 mm and they are more or less constant sensitive, if the air gap is larger than 5 mm (Fig. 20). If the casing or the cover plate is thicker than 6 mm, then the charge reacts less sensitive (Fig. 21). The build up distances Δs, measured delayed times Δt or initiation times t_i as a function of jet velocity for a composition B charge type are presented in Fig. 22, or as a function of the $v_j^2 \cdot d_j$ in Fig. 23. The following observation is very surprising. If the jet is beneath the initiation threshold of an acceptor charge in contact to a barrier and then follows an air gap, the charge is initiated after the air gap. The detonation wave also runs again backwards and detonates the already by the jet perforated charge section (Fig. 24). The different threshold values of high explosive charges, arranged in direct contact or in an air gap distance, explains the author by a pre-compression of the bulging cover material, if the charge is in contact to the case. The cover material move before the jet exits (Fig. 25). On the high explosive charge are first arriving shock waves. The longitudinal sound velocities in steel are 5,9 mm/µs fast. Before the jet arrives, the surface between barrier and high explosives starts to move and pre-compress the charge and squeeze out the hot spots (Fig. 26). The pressure is in this case rising from a low value up to the Bernoulli stagnation pressure over a time scale of few microseconds as a ramp wave. If the jet is directly impacting or after an air gap the produced shock wave is rising spontaneously to a 5 times higher value, but over one magnitude less duration (Fig. 27). The high explosives react much more sensitive under this second load condition.

The MIL-STD-2125 B requires firing of shape charges through the centre of a rocket motor if the energetic material contains a cavity (Fig. 28). It was in this case also documented, that higher violent reaction levels occur. The explanation is a bit different then the expelled propellant material from the inner surface impacts as a powder on the other side with high velocities, where it starts to react much more easily.

SHAPED CHARGE THREAT

A big threat for military and civilians terrorist attacks are the shoulder launched HEAT rounds. World-wide most distributed and produced seems to be the RPG 7 (Fig. 29). But it exists in every country similar systems mostly with better performances as M72 in USA, LAW 80 in UK, Panzerfaust in Germany etc. Also this shoulder launched weapon systems have now tandem shaped charges (Fig. 30). But in the worldwide distributed anti tank missile systems with larger warheads between 100 mm and 150 mm diameter and which are ranging in the penetration between 800 mm and 1.200 mm (Fig. 31). The first warhead generation has one shaped charge. In the next generation a leading shaped charge is installed in front, to defeat especially reactive armour systems. The numbers are remarkably world-wide less, but the threat by the faster and thicker jets are enormous increased.

RECOMMENDATION

Some time ago on a meeting in Shrivenham, a Lady from USA says that she had done an extremely large gap test against a propellant charge and has got no detonation. Therefore she had not to do any shaped charge tests. I think tandem shaped charge impact tests, where the precursor charge can sensitise remarkably the reaction behaviour of energetic materials, cannot be compared with shock load tests. To reduce the costs, I would recommend the following test procedure. Start with a small shaped charge. If no violent reaction happens continue with a bigger shaped charges and finally with a tandem shaped charge, as examples: start with an M42/M46 shaped charge in the building stand-off. If no violent reaction happens, then take the RPG 7 or similar type. If also this showed no violent reaction, a 100 mm or 150 mm mono shaped charge with jet tip velocities of at least of 9 mm/µs and in a stand-off of 300 mm (2 CD) would be good realistic test vehicles. If this was also OK then I would recommend to use a tandem shaped charge test set-up. For this an existing tandem shaped charge can be used. Eastern countries are typically using 64 mm leading shaped charges, which can be arranged in typically 2 CD´s stand-off to the test item and the main shaped charge in 900 mm or 6 CD stand-off (Fig. 32).

CONCLUSION

No type of high explosive charge is found up to now, which is not violent reacting against larger shaped charge warheads. On the other hand, the initiation process is not at all well understood. To find out how the initiation with violent reactions can be reduced, more fundamental tests of the interaction behaviour of shaped charge jets with high explosive charges under different configurations should be conducted under different diagnostic techniques. A better understanding means it can be better worked on the taylorring of the high explosive behaviour against single and tandem shaped charge jet loads.

Mass-or Sympathetic Detonation of an Ammunition Storage Place at Kuwait 1991

Fig. 1

MIL-STD-2105 A (NAVY) 19. Jan. 1990

NOTE: This draft, dated 19 January 1990, prepared by the Naval Sea Systems Command (OS), has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL. (Project SAFT-0024)

INCH-POUND
MIL-STD-2105A (NAVY)

SUPERSEDING
DOD-STD-2105 (NAVY)
9 September 1982

MILITARY STANDARD

HAZARD ASSESSMENT TESTS
FOR NON-NUCLEAR MUNITIONS

AMSC AREA SAFT

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Fig. 2

Item Number and Test Sequence

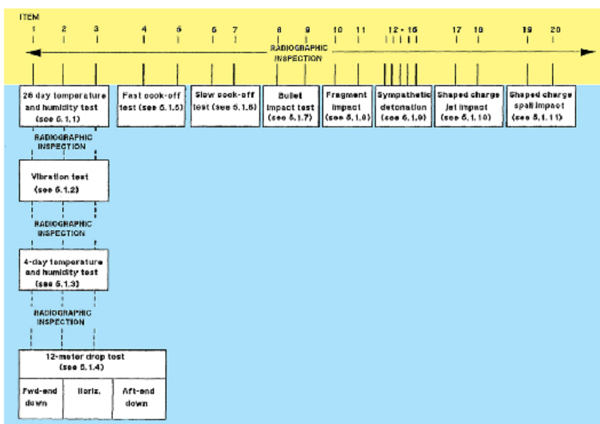

Fig. 3

MIL-STD-2105 A (NAVY)

Explosive reaction levels.

a. Detonation Reaction (Type I). The most violent type of explosive event. A supersonic decomposition reaction propagates through the energetic material to produce an intense shock in the surrounding medium,e.g., air or water, and very rapid plastic deformation of metallic cases followed by extensive fragmentation. All energetic material will be consumed. The effects will include large ground craters for munitions on or close to the ground, holing/plastic flow damage/fragmentation of adjacent metal plates and blast overpressure damage to nearby structures.

b. Partial Detonation Reaction (Type II). The second most violent type of explosive event. Some, but not all of the energetic material reacts as in a detonation. An intense shock is formed; some of the case is broken into small fragments; a ground crater can be produced, adjacent metal plates can be damaged as in a detonation, and there will be blast overpessure damage to nearby structures. A partial detonation can also produce large case fragments as in a violent pressure rupture (brittle fracture). The amount of damage, relative to a full detonation, depends on the portion of material that detonates.

c. Explosion Reaction (Type III). The third most violent type of explosive event. Ignition and rapid burning of the confined energetic material builds up high local pressures leading to violent pressure rupturing of the confining structure. Metal cases are fragmented (brittle fracture) into large pieces that are often thrown long distances. Unreacted and/or burning energetic material is also thrown about. Fire and smoke hazards will exist. Air shock are produced that can cause damage to nearby structures. The blast and high velocity fragments can cause minor ground craters and damage (break-up, tearing, gouging) to adjacent metal plates. Blast pressures are lower than for a detonation.

d. Deflagration Reaction (Type IV). The fourth most violent type of explosive event. Ignition and burning of the confined energetic materials leads to nonviolent pressure release as a result of a low strength case or venting through case closures (leading port/fuze wells, etc.). The case might rupture but does not fragment; closure covers might be expelled, and unburned or burning energetic material might be thrown about and spread the fire. Pressure venting can propel an unsecured test item, causing an additional hazard. No blast or significant fragmentation damage to the surroundings; only heat and smoke damage from the burning energetic material.

e. Burning Reaction (Type V). The least violent type of explosive event. The energetic material ignites and burns, non-propulsively. The case may open, melt or weaken sufficiently to rupture nonviolently, allowing mild release of combustion gases. Debris stays mainly within the area of the fire. This debris is not expected to cause total wounds to personnel or be a hazardous fragment beyond 50 feet.

f. Propulsion (Type VI). A reaction whereby adequate force is produced to impart flight to the test item in its least restrained configuration as determined by the life cycle analysis.

Fig. 4

Explosive Reaction Levels

MIL-STD-2105 A (NAVY)

M. Held

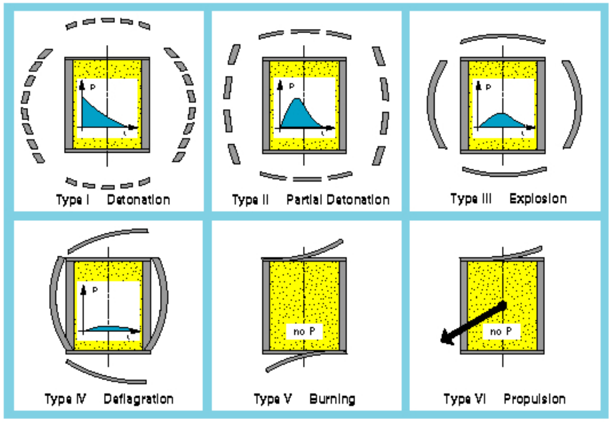

Fig. 5

Shaped Charge Impact Test

5.1.10 MIN-STD-2105 A (NAVY)

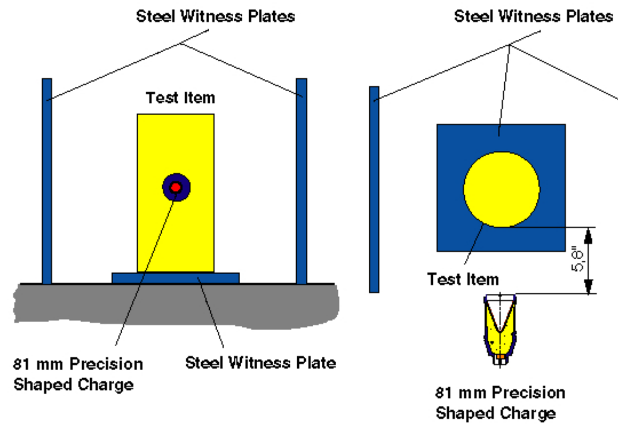

Fig. 6

Grenade M 42 / M 46

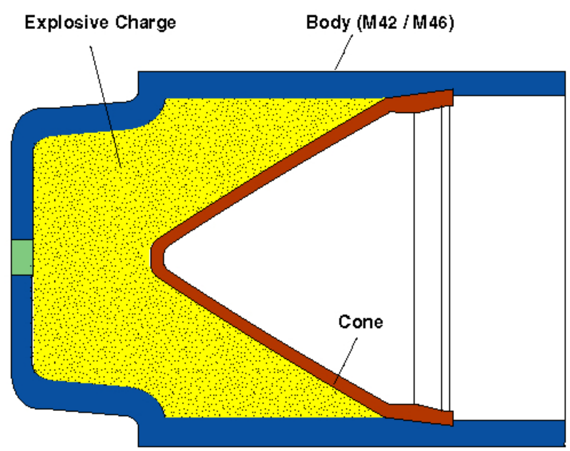

Fig. 7

Grenade M 42 / M 46

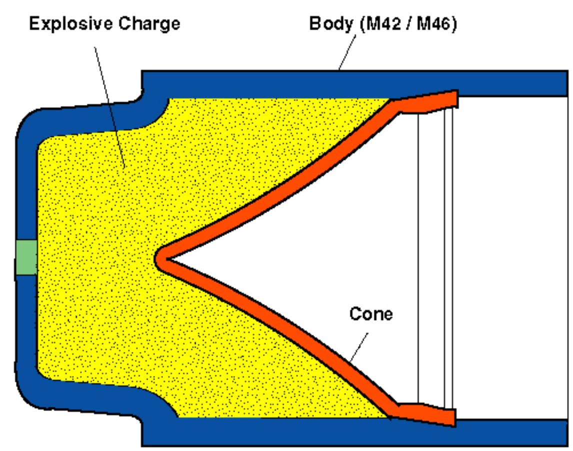

Fig. 8

Shaped Charge Jet Impact Test
5.1.10 MIN-STD-2105 A (NAVY)

The M 42/M46 grenade shall be configured as follows:

Explosive fill:	30 grams of Composition A-5 conforming to MIL-E-14970		
Cone angle:	Trumpet with 3" radius		
Dimensions:	Height of cone	=	1.3 inches
	Outside diameter	=	1.315 inches
	Inside diameter	=	1.237 inches
	Wall thickness	=	0.075 inches
Liner description:	Copper strip, cold-rolled, soft annealed, conforming to QQ-C-576 Electrolytic tough pitch Grain size < ASTM grain size 8 Non-earring quality with suppressed cube texture		
Body:	M 42/M46 body load assembly (without fuze)		

Fig. 9

81 mm Precision Shaped Charge

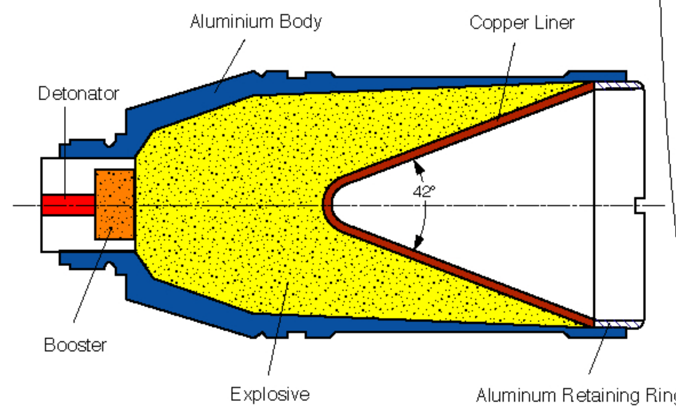

Fig. 10

Standard Shaped Charge

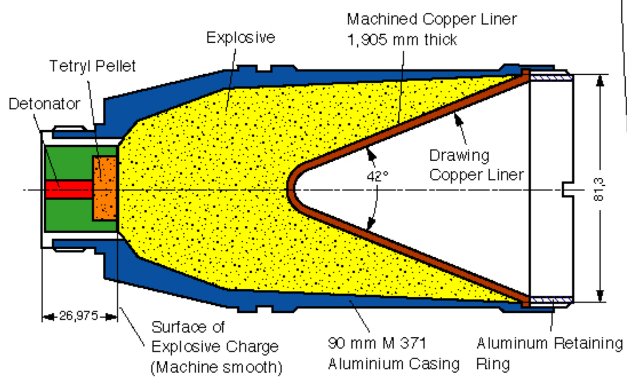

Fig. 11

Shaped Charge Jet Impact Test
5.1.10 MIN-STD-2105 A (NAVY)

The 81 mm precision shaped charge shall be configured as follows:

Explosive fill:	1,8 pounds of Composition B conforming to MIL-C-401		
Cone angle:	42°		
Dimensions:	Height of cone	=	3.7 inches
	Outside diameter	=	3.2 inches
	Inside diameter	=	2.91 inches
	Wall thickness	=	0.075 inches
Liner description:	Oxygen-free copper conforming to ASTM B152 with a temper of OS025 Grain size < 50 microns after stress relief No shear forming Deep drawn anneal		
Body:	Standard 90-mm M371E1 recoilles rifle round		

Fig. 12

METRIC

MIL-STD-2105B
12 January 1994
SUPERSEDING
MIL-STD-2105A(NAVY)
8 March 1991

MILITARY STANDARD

HAZARD ASSESSMENT TESTS
FOR NON-NUCLEAR MUNITIONS

AMSC N6037 AREA SAFT

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Fig. 13

Shaped Charge Impact Test
5.1.10 MIN-STD-2105 A (NAVY)

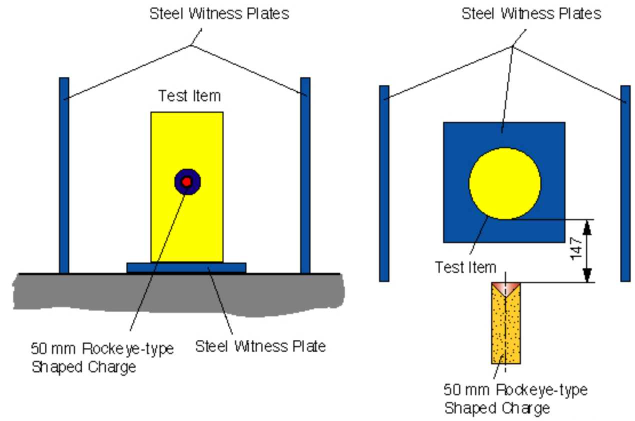
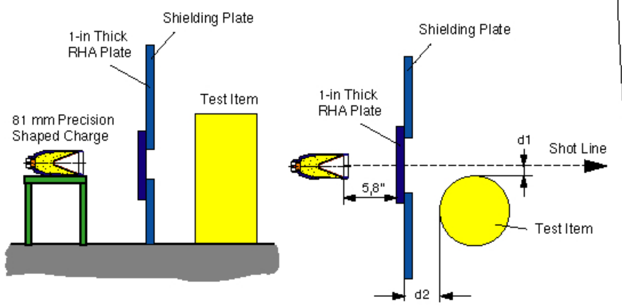


Fig. 14

Spall Impact Test
5.1.11 MIN-STD-2105 A (NAVY)



Minimum of
- 4 Spall Fragments / 10 in^2 in presented area (up to 40 Fragments total)

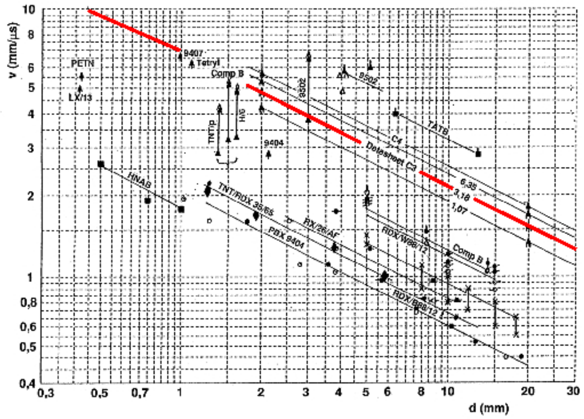
Fig. 15

Problems with SC Tests

- **Availability**
- **SC - Diameter**
- **Liner material**
- **What is the real threat against what type of munitions**

Fig. 16

v² d - Criterion



Threshold or impact velocity as a function of the diameter of shaped charge jets, projectiles or flyer foils for different high explosive charges.

Fig. 17

Setups for SC Jet Initiation Tests

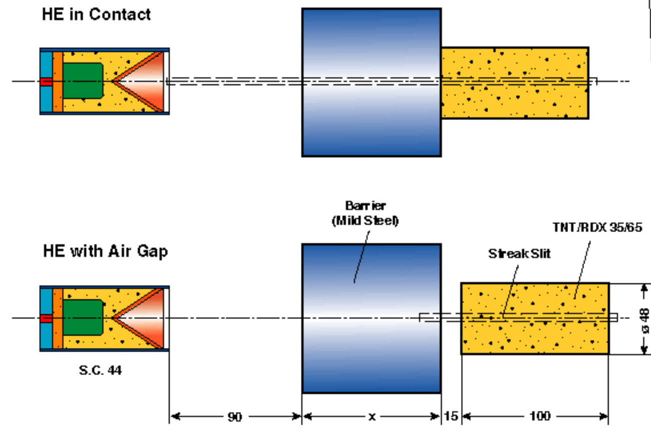


Fig. 18

Buildup Distance with Jet Initiation

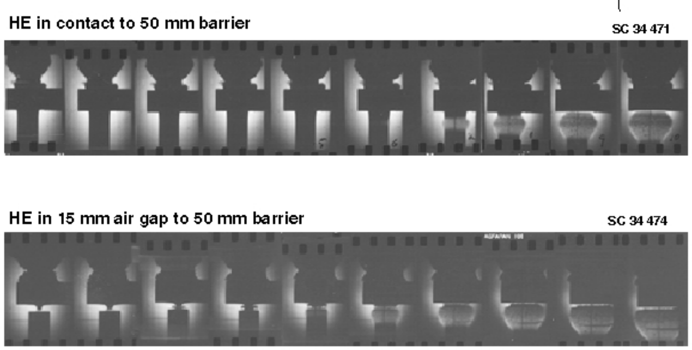


Fig. 19

Δs = f (Width of Air Gap)

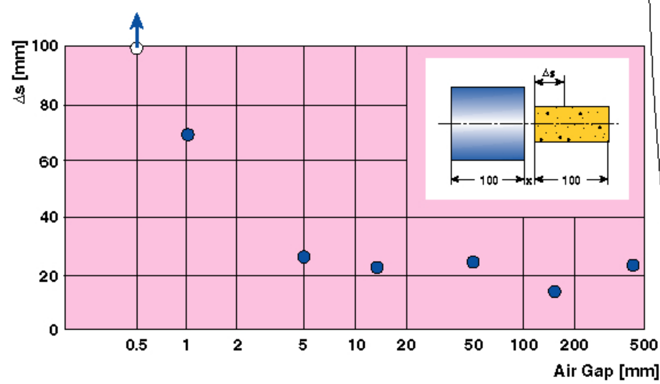


Fig. 20

Spaced Barrier

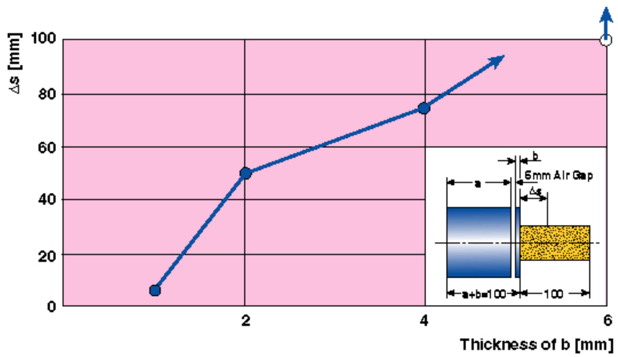


Fig. 21

Δs, Δt, t_i = f (v_j)

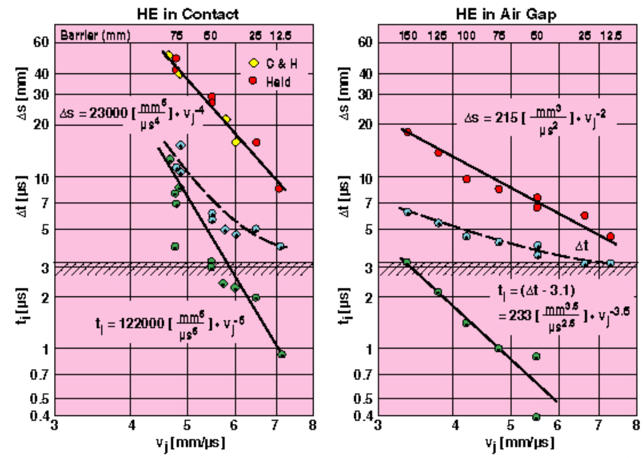


Fig. 22

Δs, Δt, t_i = f ($v_j^2 \cdot d_j$)

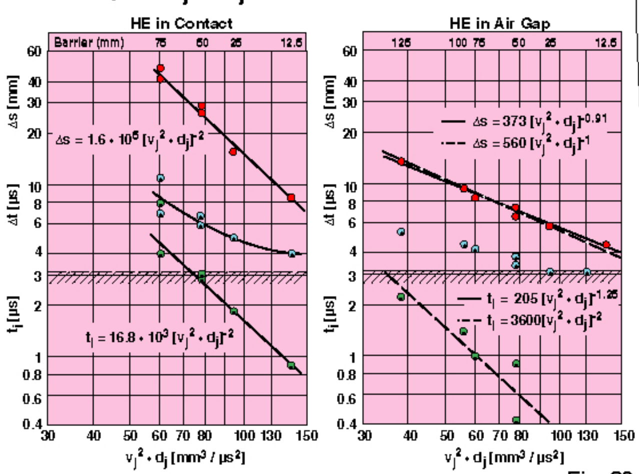


Fig. 23

Jet Initiation of a Split HE - Charge

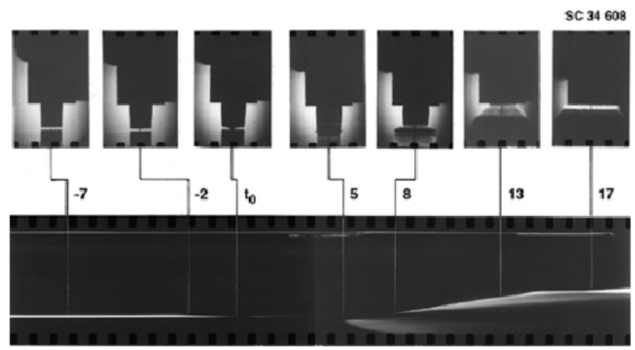


Fig. 24

Jet Load against Plexiglass after 100 mm M.S. Barrier

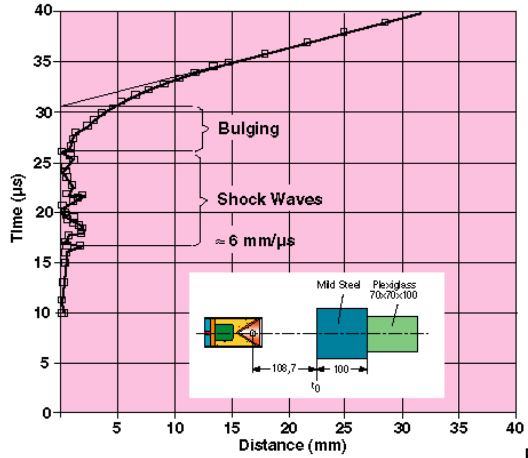


Fig. 25

Time - Distance - Plot

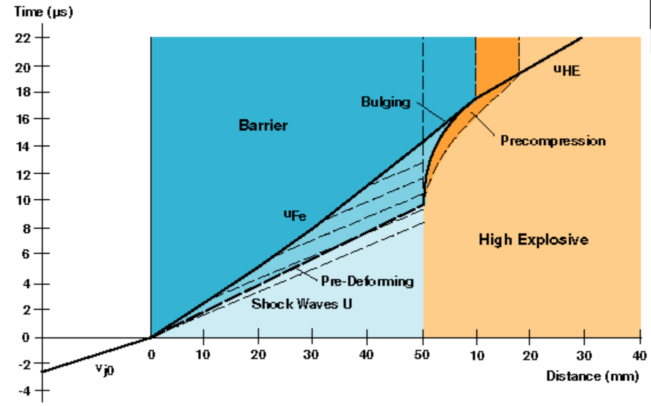


Fig. 26

Different Loads

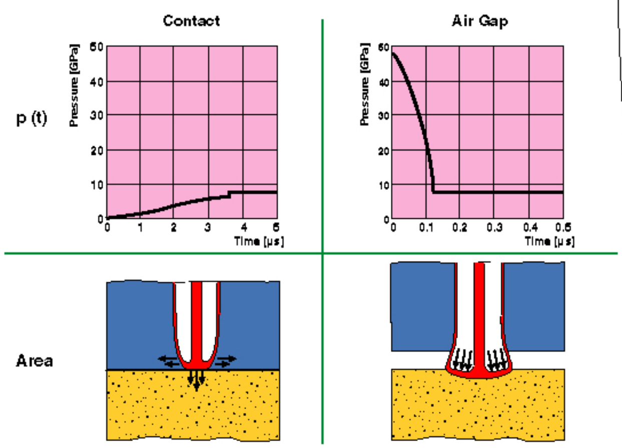
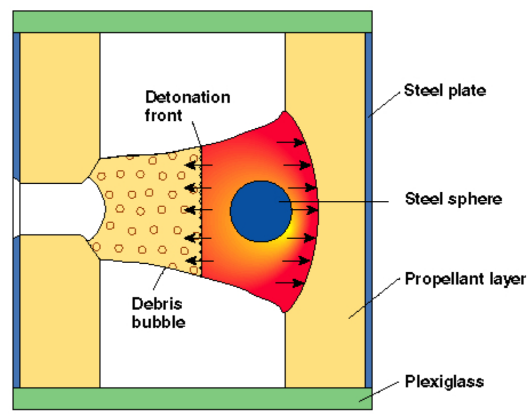


Fig. 27

Delayed Detonation Process



S.A. Finnigan, AGARD CP-511, 1992

Fig. 28

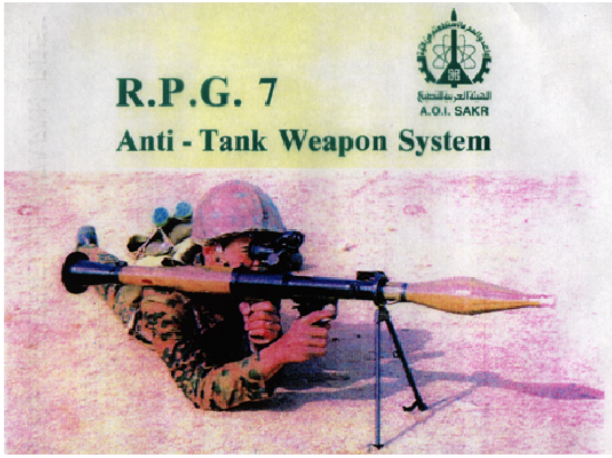


Fig. 29

PART 1 | ЧАСТЬ 1

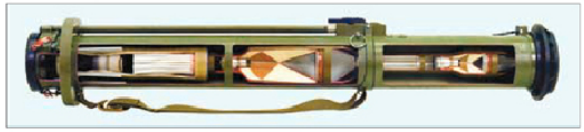
ANTITANK GRENADE LAUNCHERS | ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

RPG-27 ANTITANK ROCKET GRENADE WITH SINGLE-SHOT GRENADE LAUNCHER

The grenade is designed to combat all types of tanks, including those provided with explosive reactive armor, and suppress weapon emplacements and manpower located in buildings and structures.

РЕАКТИВНАЯ ПРОТИВОТАНКОВАЯ ГРАНАТА С ГРАНАТОМЕТОМ ОДНОРАЗОВОГО ПРИМЕНЕНИЯ РПГ-27

Предназначена для борьбы с танками всех типов, в том числе оснащенными динамической защитой, подавления огневых точек и живой силы в зданиях и сооружениях.



Basic Characteristics

Warhead	tandem
Caliber, mm	105
Weight, kg	8
Accurate firing range, m	200
Penetration, m:	
homogeneous armor behind ERA	at least 0.6
reinforced concrete and brick	at least 1.5
log and dirt	at least 3.7

Основные характеристики

Боевая часть	тандемная
Калибр, мм	105
Масса, кг	8
Дальность прицельной стрельбы, м	200
Толщина пробиваемой преграды, м:	
гомогенной брони после преодоления ДЗ	более 0,6
железобетонной и кирпичной	более 1,5
дерево-земляной	более 3,7

Fig. 30

Stand - 0ff Curves Proving Ground Meppen 1985 / Sept. 2000

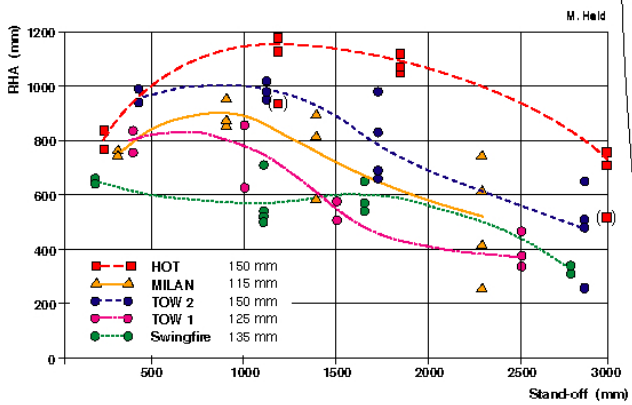


Fig. 31

Test Setup Typical S.C.Dia. 64 x 150

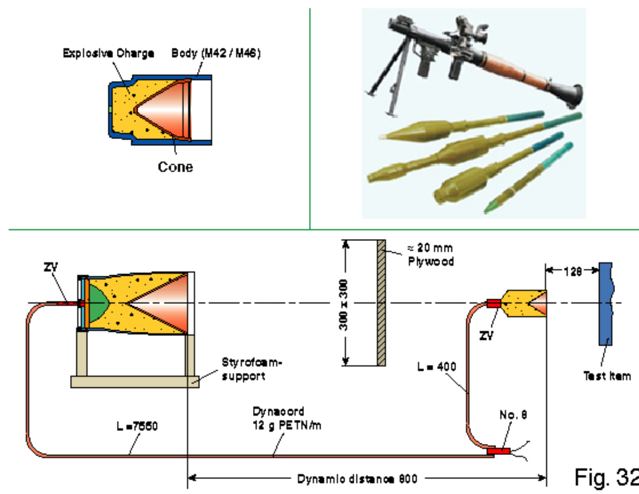


Fig. 32

Discussions to Shaped Charge Jet Tests after MIL STD 2105 B

Prof. Dr. M. Held

EADS TDW

Schrobenhausen, Germany

Overview

Required shaped charge tests

Jet initiation phenomena

Shaped charge threat

Recommendations

MIL-STD-2105 A (NAVY) 19. Jan. 1990

EADS TDW

NOTE: This draft, dated 19 January 1990, prepared by the Naval Sea Systems Command (OS), has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL. (Project SAFT-0024)

INCH-POUND
MIL-STD-2105A (NAVY)

SUPERSEDING
DOD-STD-2105 (NAVY)
9 September 1982

MILITARY STANDARD

HAZARD ASSESSMENT TESTS FOR NON-NUCLEAR MUNITIONS

DEPARTMENT OF DEFENSE · UNITED STATES OF AMERICA

AMSC | AREA SAFT

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Fig. 2

Item Number and Test Sequence

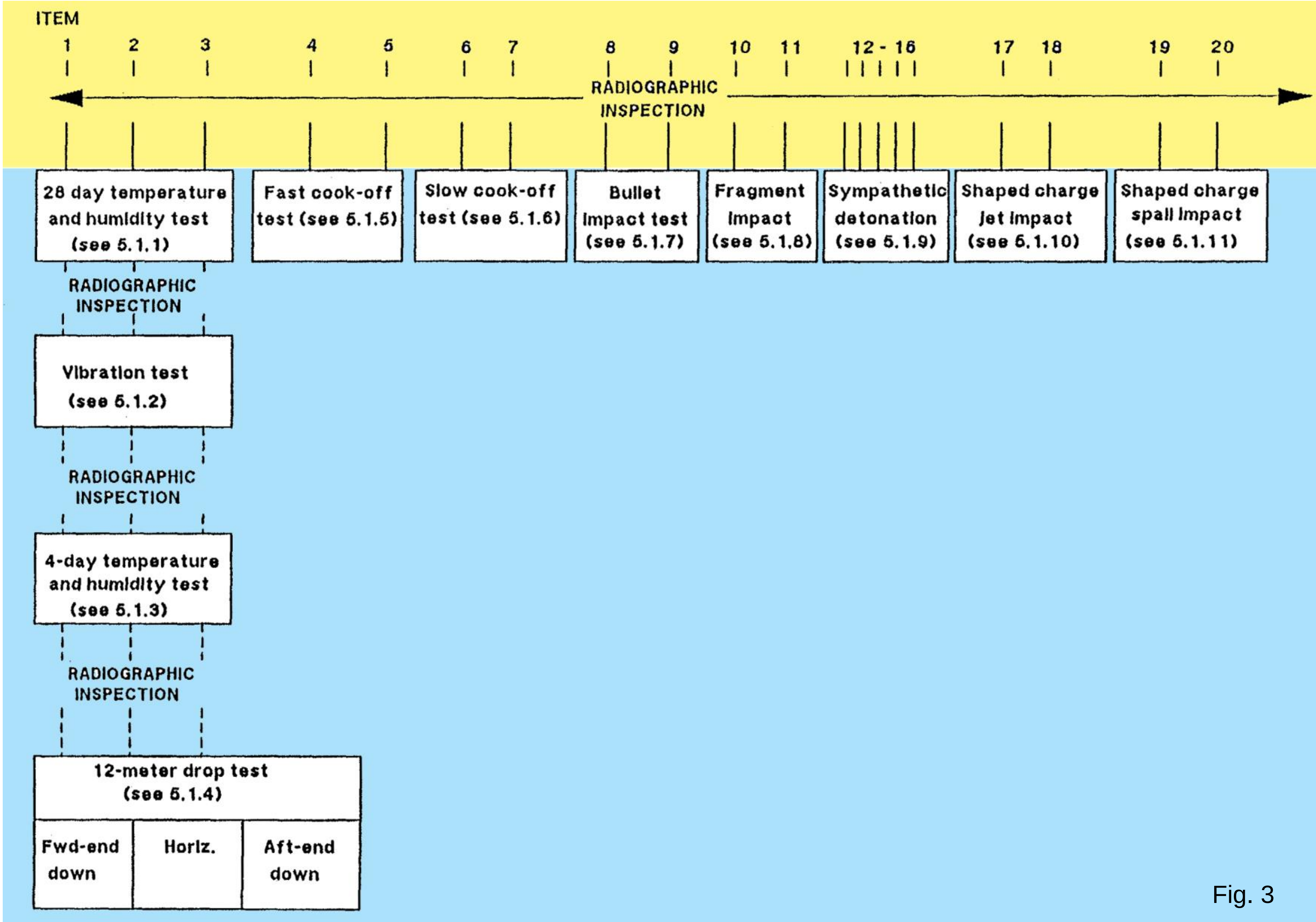


Fig. 3

MIL-STD-2105 A (NAVY)

Explosive reaction levels.

a. Detonation Reaction (Type I). The most violent type of explosive event. A supersonic decomposition reaction propagates through the energetic material to produce an intense shock in the surrounding medium,e.g., air or water, and very rapid plastic deformation of metallic cases followed by extensive fragmentation. All energetic material will be consumed. The effects will include large ground craters for munitions on or close to the ground, holing/plastic flow damage/fragmentation of adjacent metal plates and blast overpressure damage to nearby structures.

b. Partial Detonation Reaction (Type II). The second most violent type of explosive event. Some, but not all of the energetic material reacts as in a detonation. An intense shock is formed; some of the case is broken into small fragments; a ground crater can be produced, adjacent metal plates can be damaged as in a detonation, and there will be blast overpessure damage to nearby structures. A partial detonation can also produce large case fragments as in a violent pressure rupture (brittle fracture). The amount of damage, relative to a full detonation, depends on the portion of material that detonates.

c. Explosion Reaction (Type III). The third most violent type of explosive event. Ignition and rapid burning of the confined energetic material builds up high local pressures leading to violent pressure rupturing of the confining structure. Metal cases arc fragmented (brittle fracture) into large pieces that are often thrown long distances. Unreacted and/or burning energetic material is also thrown about. Fire and smoke hazards will exist. Air shock are produced that can cause damage to nearby structures. The blast and high velocity fragments can cause minor ground craters and damage (break-up, tearing, gouging) to adjacent metal plates. Blast pressures are lower than for a detonation.

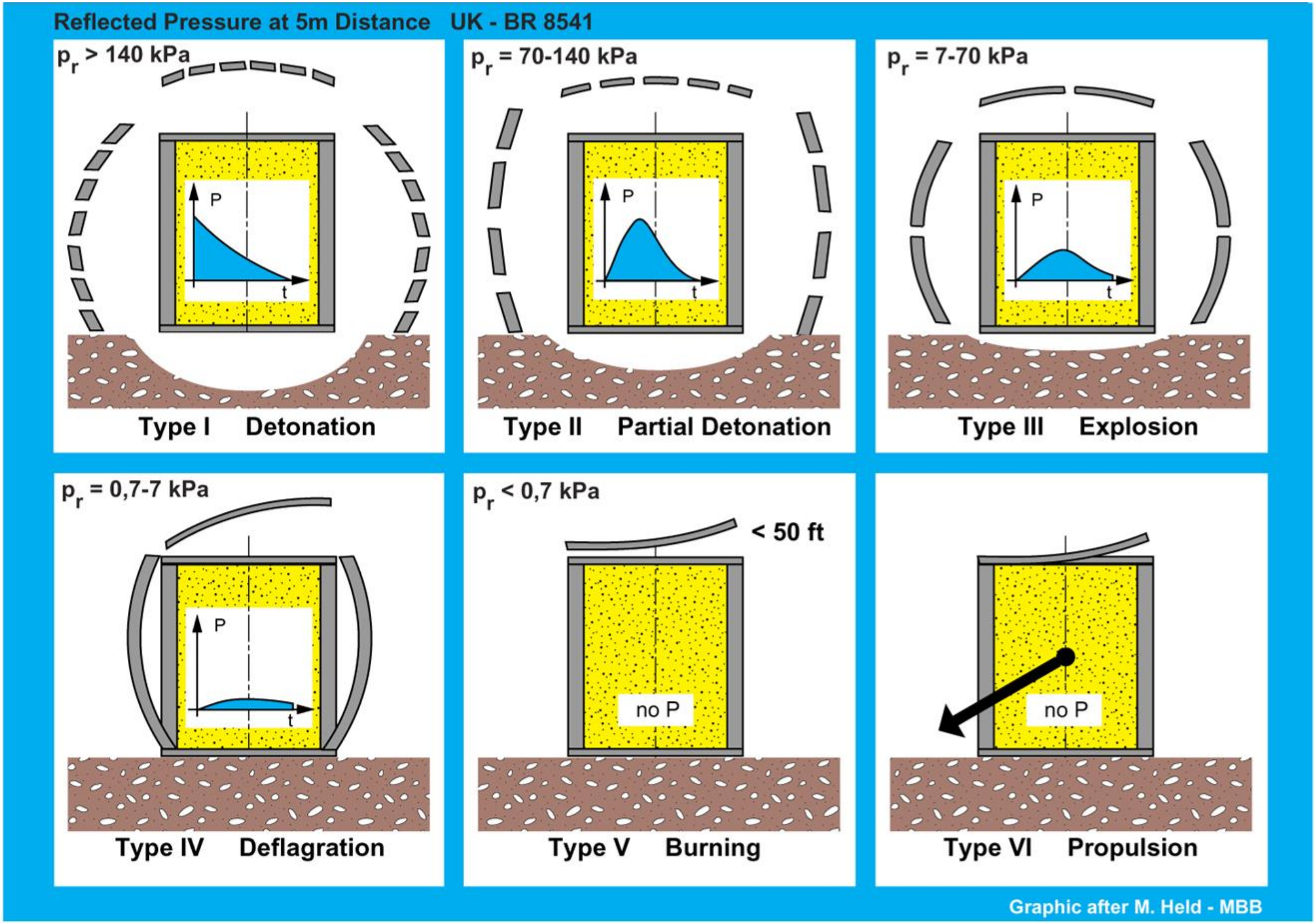
d. Deflagration Reaction (Type IV). The fourth most violent type of explosive event. Ignition and burning of the confined energetic materials leads to nonviolent pressure release as a result of a low strength case or venting through case closures (leading port/fuze wells, etc.). The case might rupture but does not fragment; closure covers might be expelled, and unburned or burning energetic material might be thrown about and spread the fire. Pressure venting can propel an unsecured test item, causing an additional hazard. No blast or significant fragmentation damage to the surroundings; only heat and smoke damage from the burning energetic material.

e. Burning Reaction (Type V). The least violent type of explosive event. The energetic material ignites and burns, non-propulsively. The case may open, melt or weaken sufficiently to rupture nonviolently, allowing mild release of combustion gases. Debris stays mainly within the area of the fire. This debris is not expected to cause fatal wounds to personnel or be a hazardous fragment beyond 50 feet.

f. Propulsion (Type VI). A reaction whereby adequate force is produced to impart flight to the test item in its least restrained configuration as determined by the life cycle analysis.

Fig. 4

Explosive Reactive Levels MIL-STD-2105A (NAVY)



Shaped Charge Impact Test

5.1.10 MIL-STD-2105 A (NAVY)

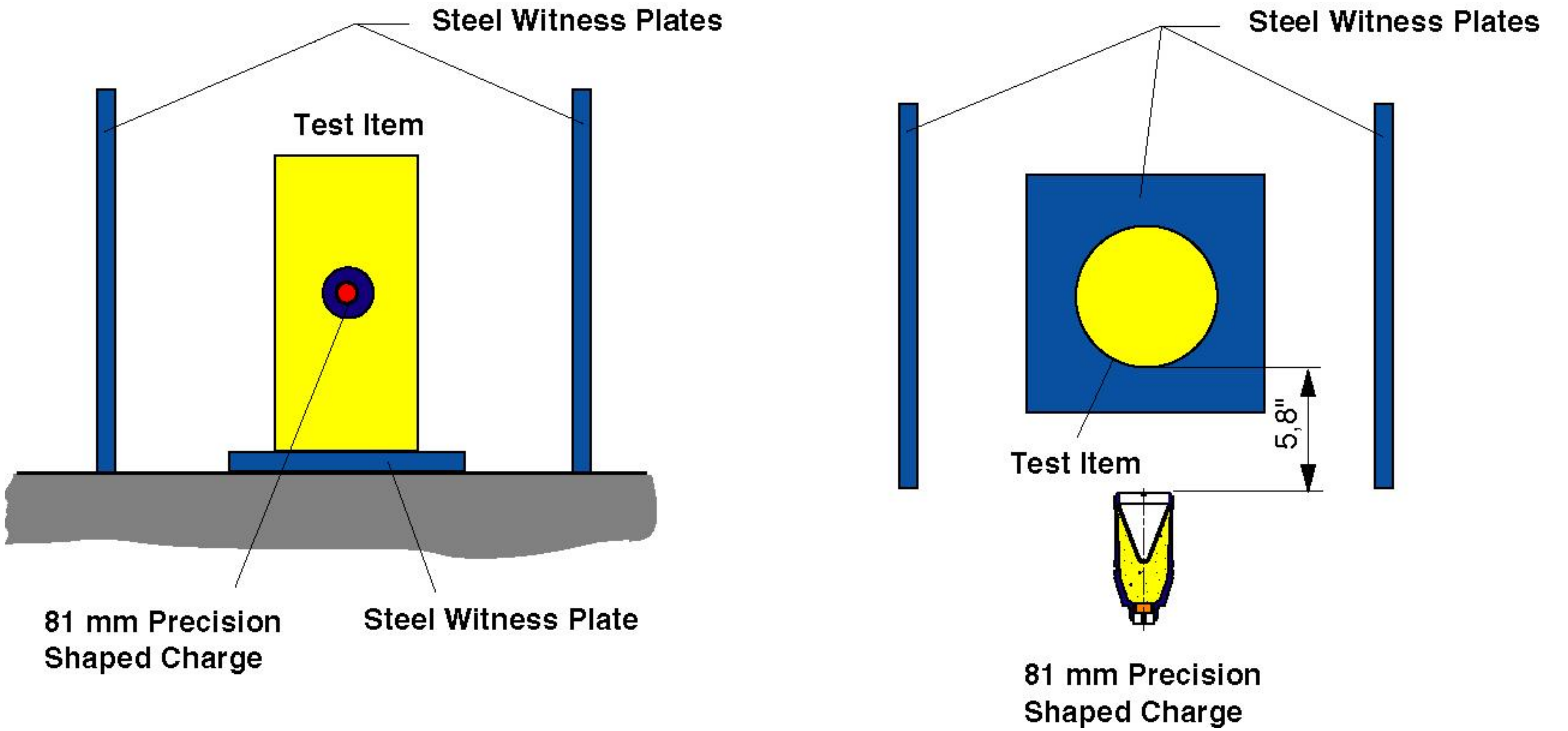


Fig. 6

Grenade M 42 / M 46

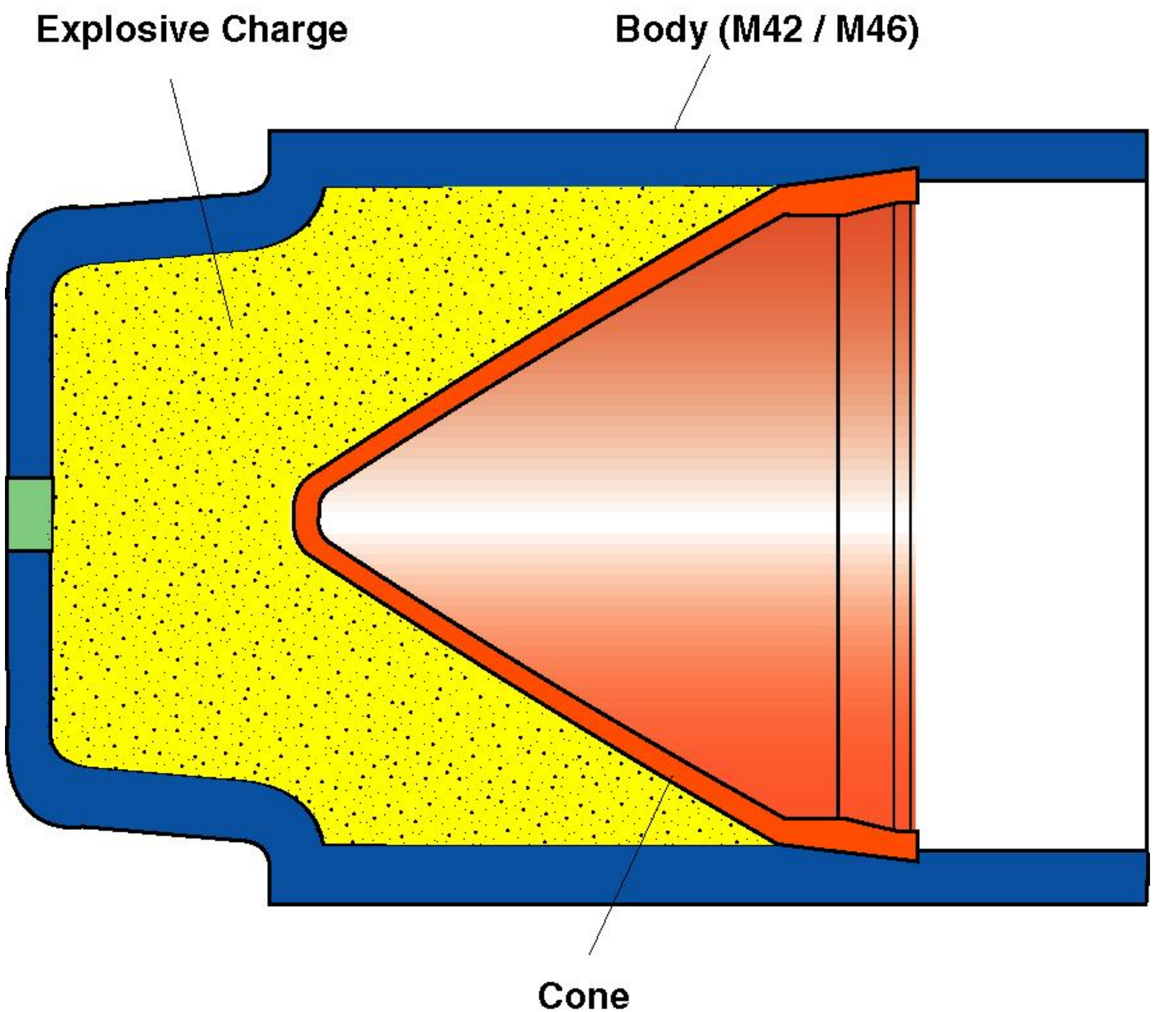


Fig. 7

Grenade M 42 / M 46

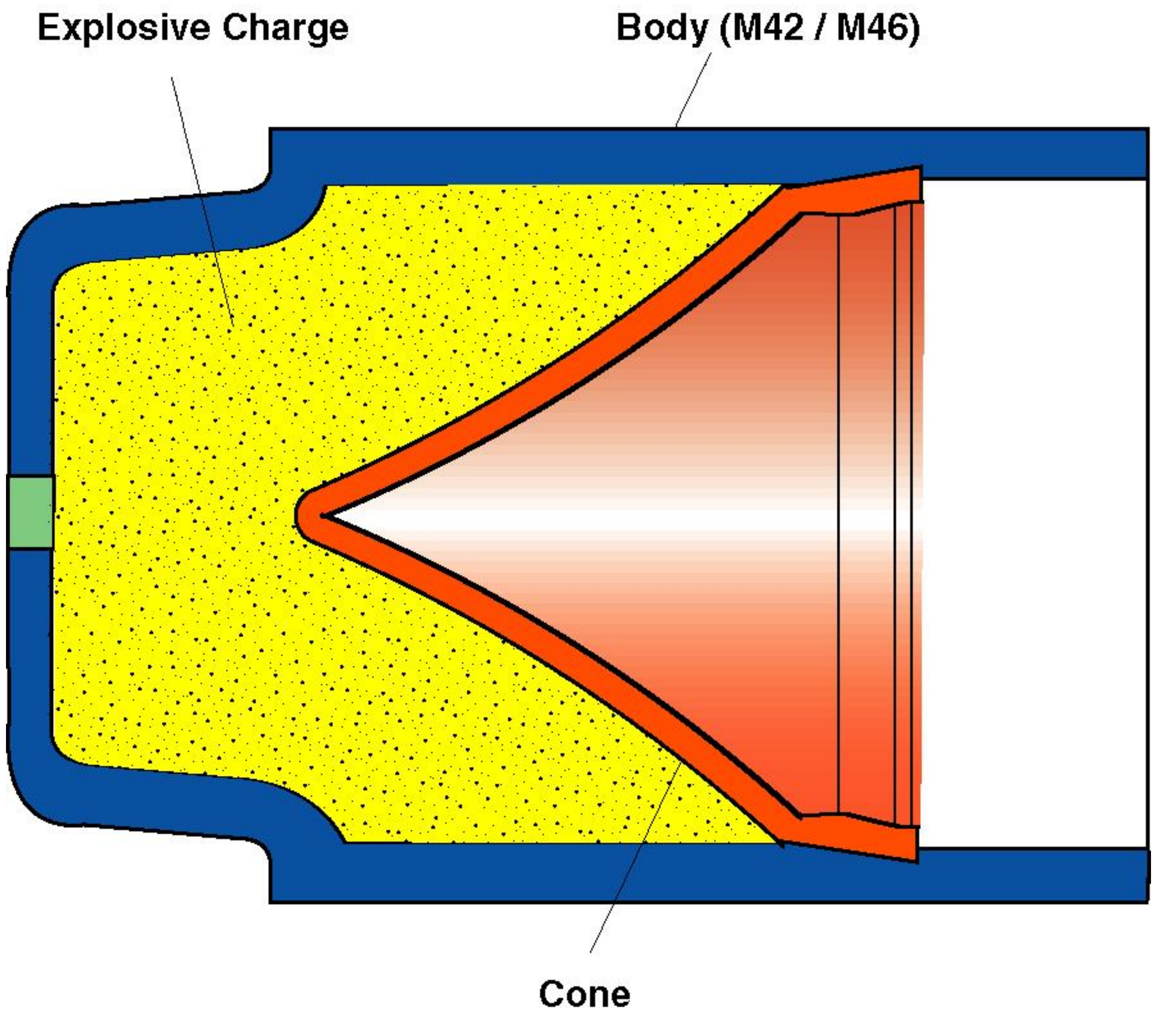


Fig. 8

Shaped Charge Jet Impact Test

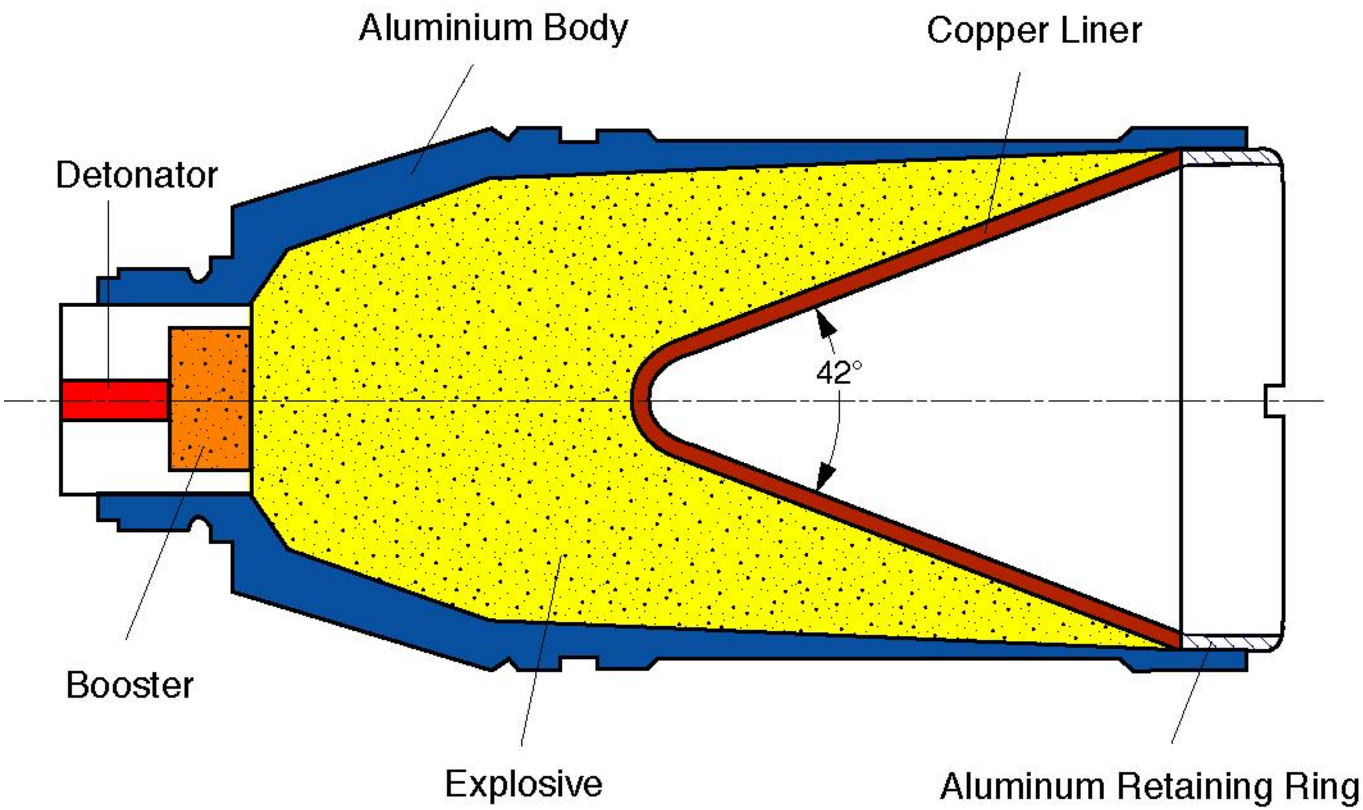
5.1.10 MIL-STD-2105 A (NAVY)

The M 42/M46 grenade shall be configured as follows:

Explosive fill:	**30 grams of Composition A-5 conforming to MIL-E-14970**		
Cone angle:	**Trumpet with 3" radius**		
Dimensions:	**Height of cone**	**=**	**1.3 inches**
	Outside diameter	**=**	**1.315 inches**
	Inside diameter	**=**	**1.237 inches**
	Wall thickness	**=**	**0.075 inches**
Liner description:	**Copper strip, cold-rolled, soft annealed, conforming to QQ-C-576**		
	Electrolytic tough pitch		
	Grain size < ASTM grain size 8		
	Non-earring quality with suppressed cube texture		
Body:	**M 42/M46 body load assembly (without fuze)**		

Fig. 9

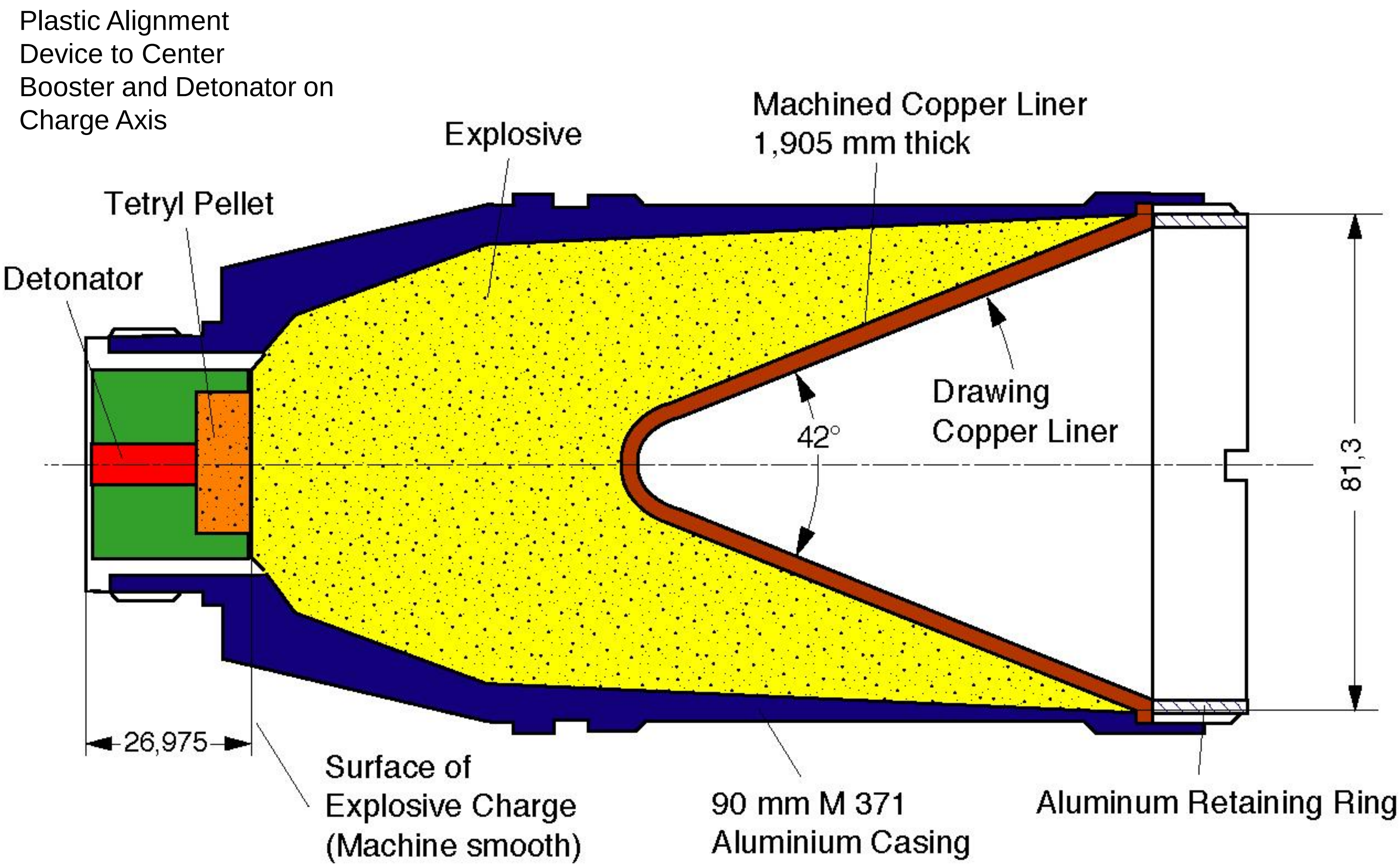
81 mm Precision Shaped Charge



Walters - Fundamental of Shaped Charges 1989

Fig. 10

Standard Shaped Charge



Note:
Liner Thickness not to vary more that .0051mm in any transverse plane and .051mmm in a longitudinal plane

Aseltine (1990)

Fig. 11

Shaped Charge Jet Impact Test

5.1.10 MIL-STD-2105 A (NAVY)

The 81 mm precision shaped charge shall be configured as follows:

Explosive fill:	**1,8 pounds of Composition B conforming to MIL-C-401**		
Cone angle:	**42°**		
Dimensions:	**Height of cone**	**=**	**3.7 inches**
	Outside diameter	**=**	**3.2 inches**
	Inside diameter	**=**	**2.91 inches**
	Wall thickness	**=**	**0.075 inches**
Liner description:	**Oxygen-free copper conforming to ASTM B152 with a temper of OS025** **Grain size < 50 microns after stress relief** **No shear forming** **Deep drawn anneal**		
Body:	**Standard 90-mm M371E1 recoilles rifle round**		

Fig. 12

EADS TDW

METRIC

MIL-STD-2105B
12 January 1994
SUPERSEDING
MIL-STD-2105A(NAVY)
8 March 1991

MILITARY STANDARD

HAZARD ASSESSMENT TESTS FOR NON-NUCLEAR MUNITIONS

DEPARTMENT OF DEFENSE • UNITED STATES OF AMERICA •

AMSC N6037 AREA SAFT

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Fig. 13

Shaped Charge Impact Test

5.1.10 MIL-STD-2105 A (NAVY)

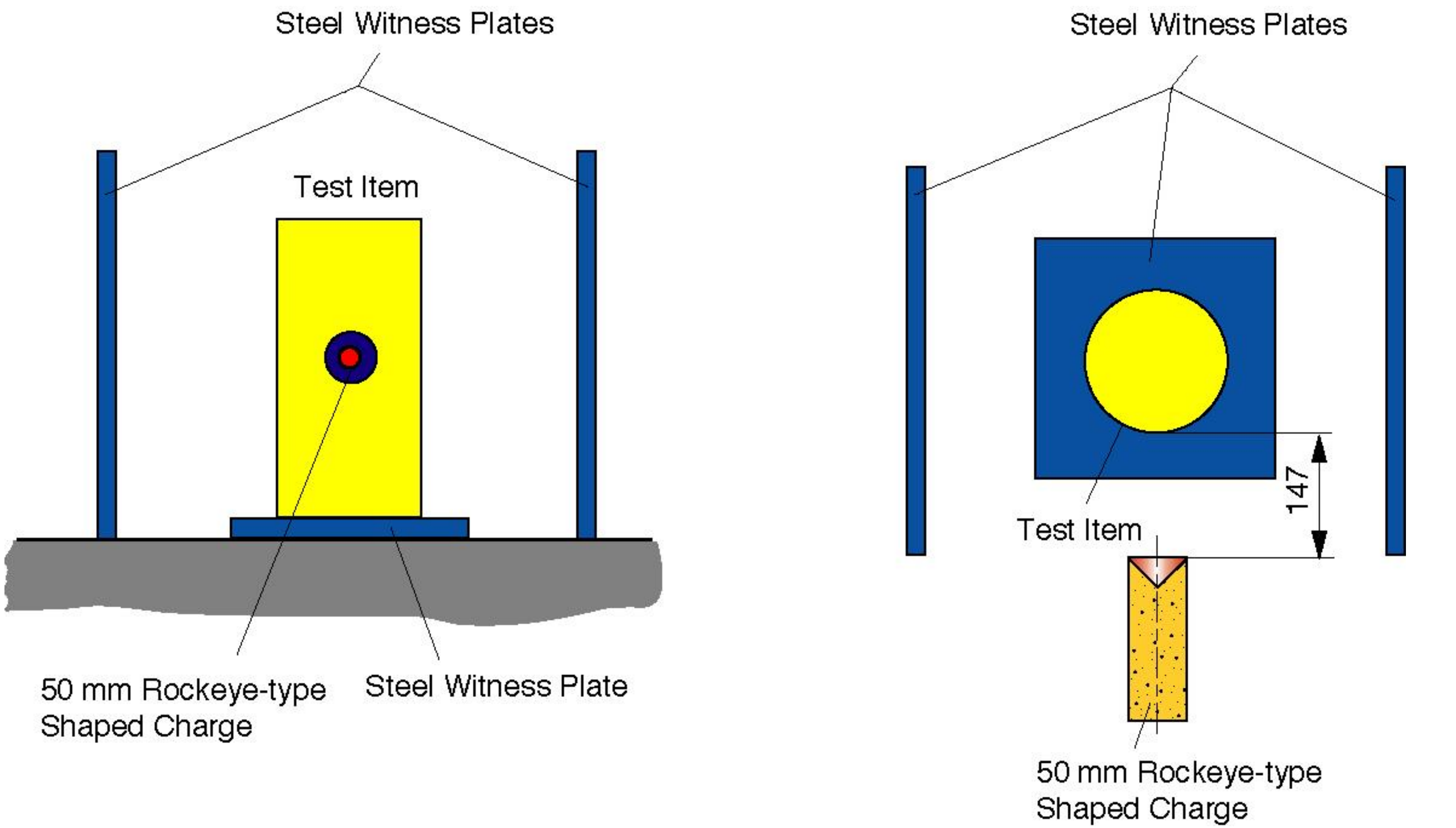


Fig. 14

Spall Impact Test
5.1.11 MIL-STD-2105 A (NAVY)

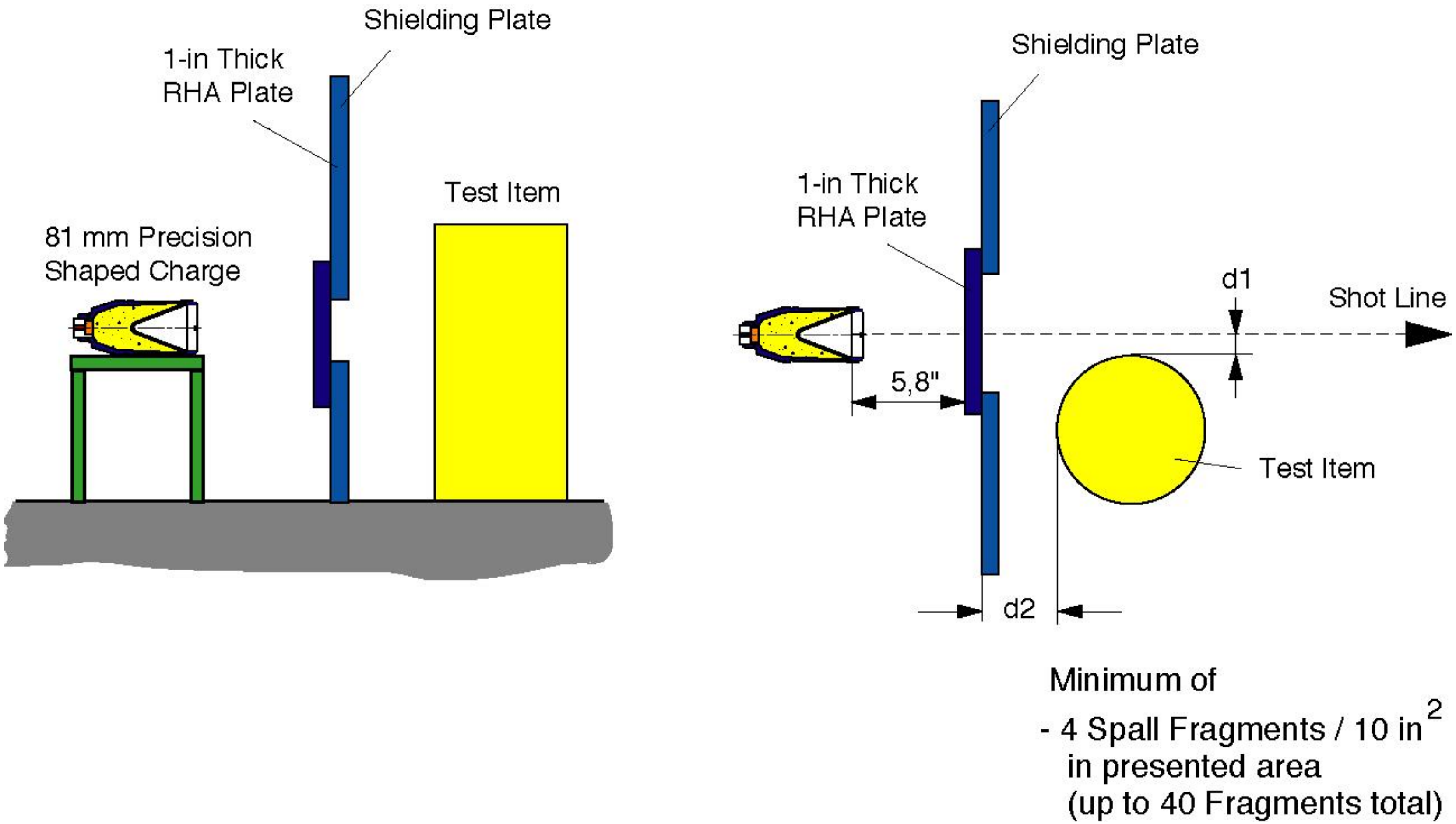


Fig. 15

Problems with SC Tests

- **Availability**
- **SC - Diameter**
- **Liner material**
- **What is the real threat against what type of munitions ?**

Fig. 16

Overview

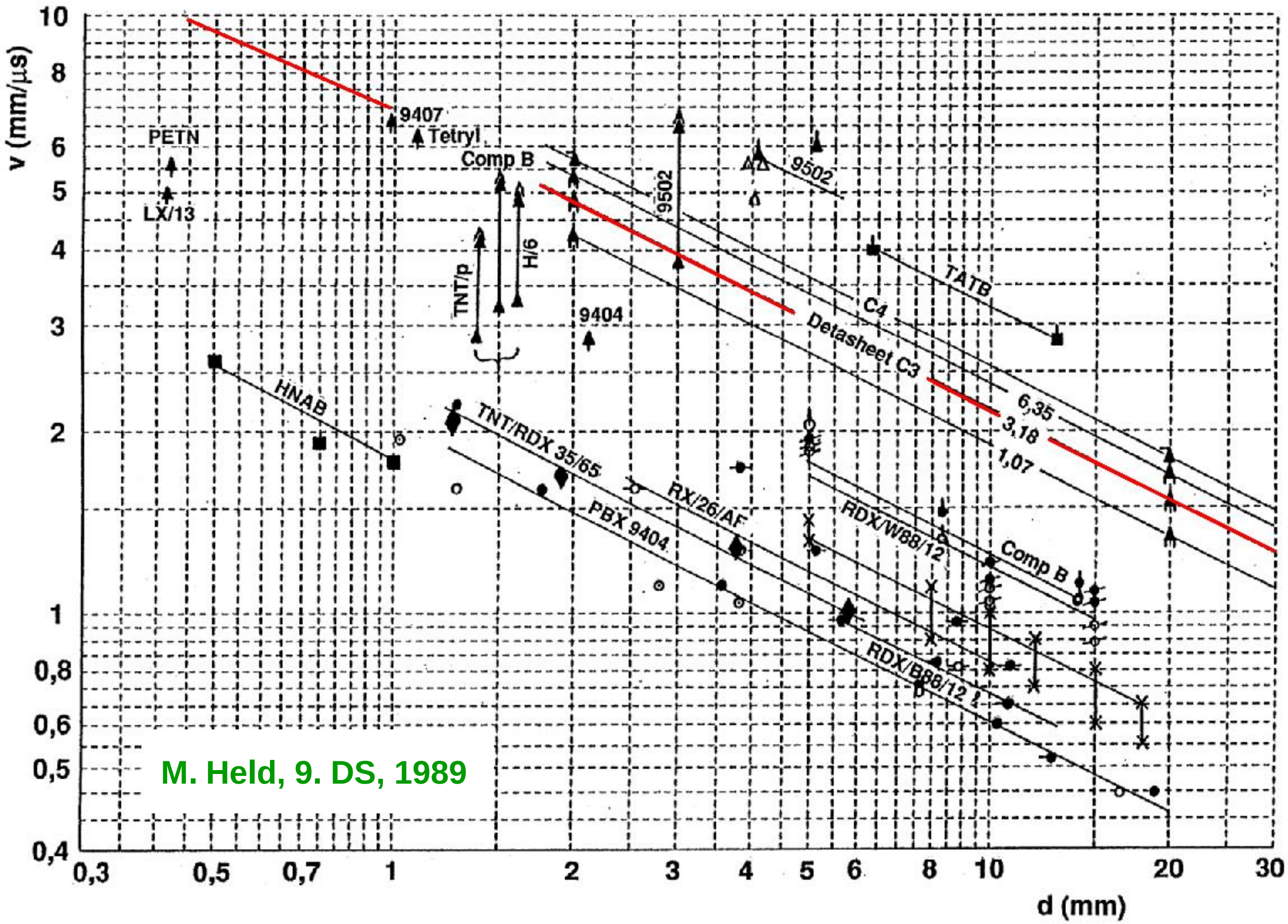
Required shaped charge tests

Jet initiation phenomena

Shaped charge threat

Recommendations

v^2 d - Criterion



Threshold or impact velocity as a function of the diameter of shaped charge jets, projectiles or flyer foils for different high explosive charges.

Fig. 17

Setups for SC Jet Initiation Test

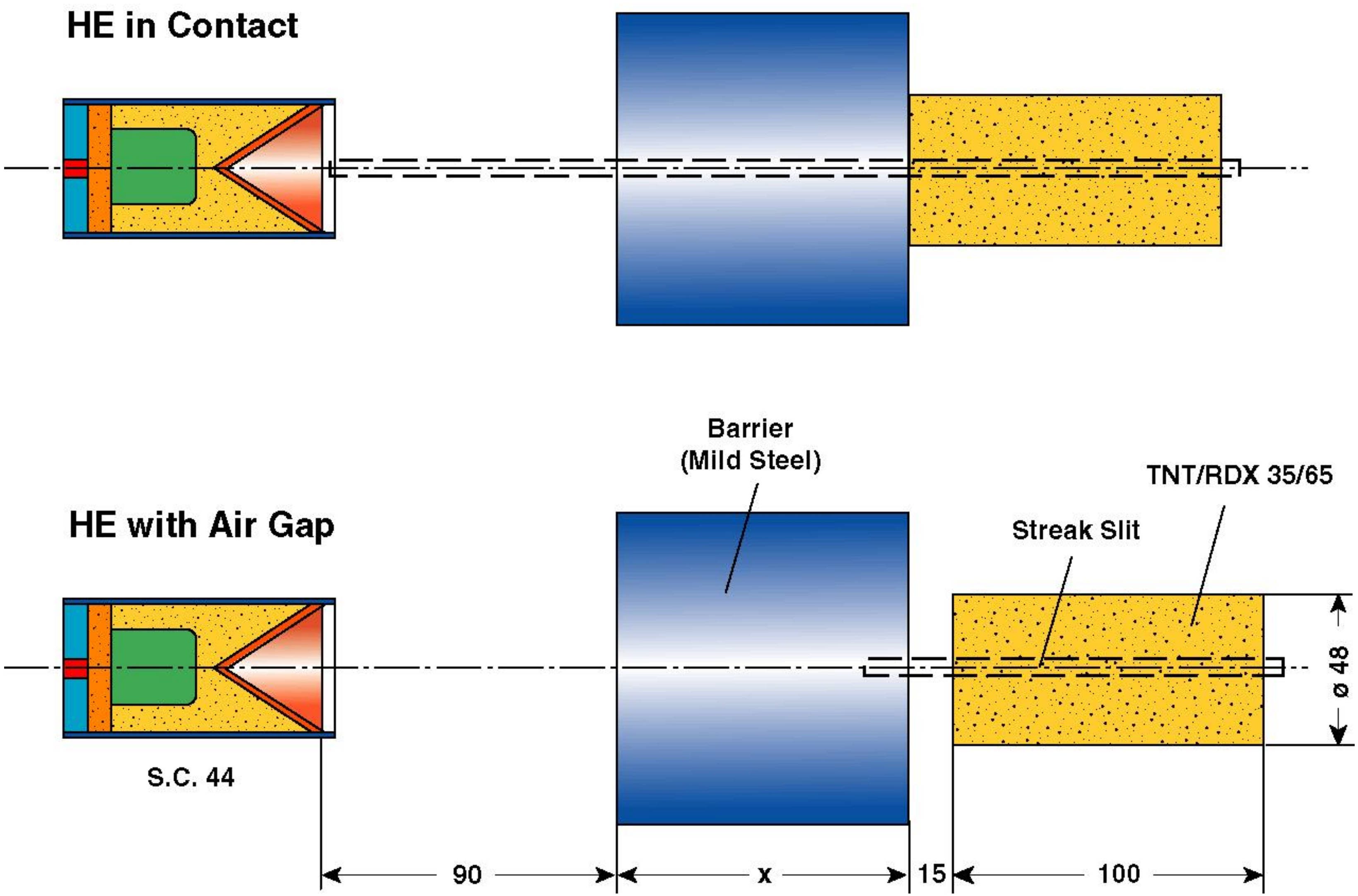
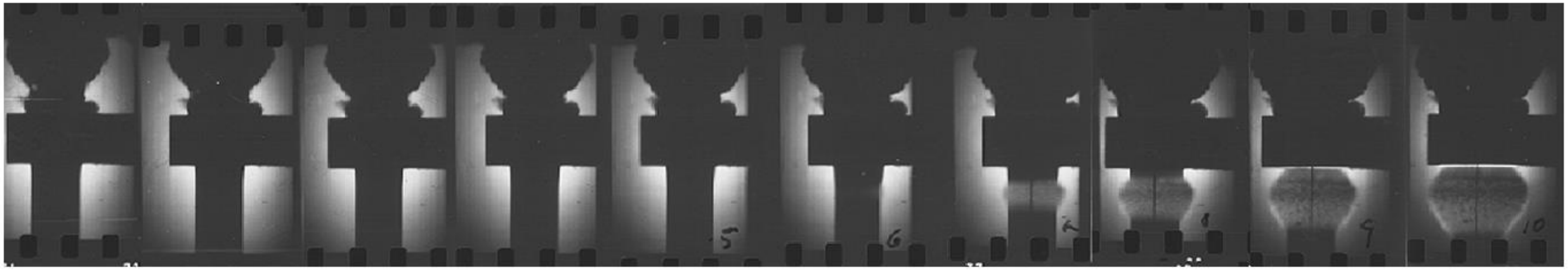


Fig. 18

Buildup Distance with Jet Initiation

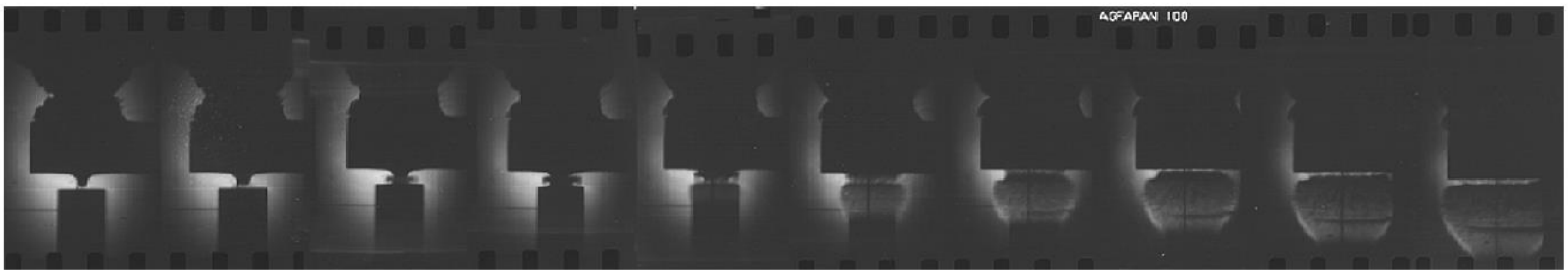
HE in contact to 50 mm barrier Δs = 30 mm   SC 34 471



(a) 0 1 2 3 4 5 6 7 8 9 Δt [µs]

(b) t_i = 6 µs - 3.2 µs = 2.8 µs

HE in 15 mm air gap to 50 mm barrier Δs = 6 mm   SC 34 474



(a) 0 1 2 3 4 5 6 7 8 9 Δt [µs]

(b) t_i = 4 µs - 3.2 µs = 0.8 µs

(a) Δt time from jet impact in µs

(b) Initiation time t_i = Δt - detonation time t_D

t_D = 24 mm / 7.6 mm/µs = 3.2 µs

Fig. 19

$\Delta s = f$ (Width of Air Gap)

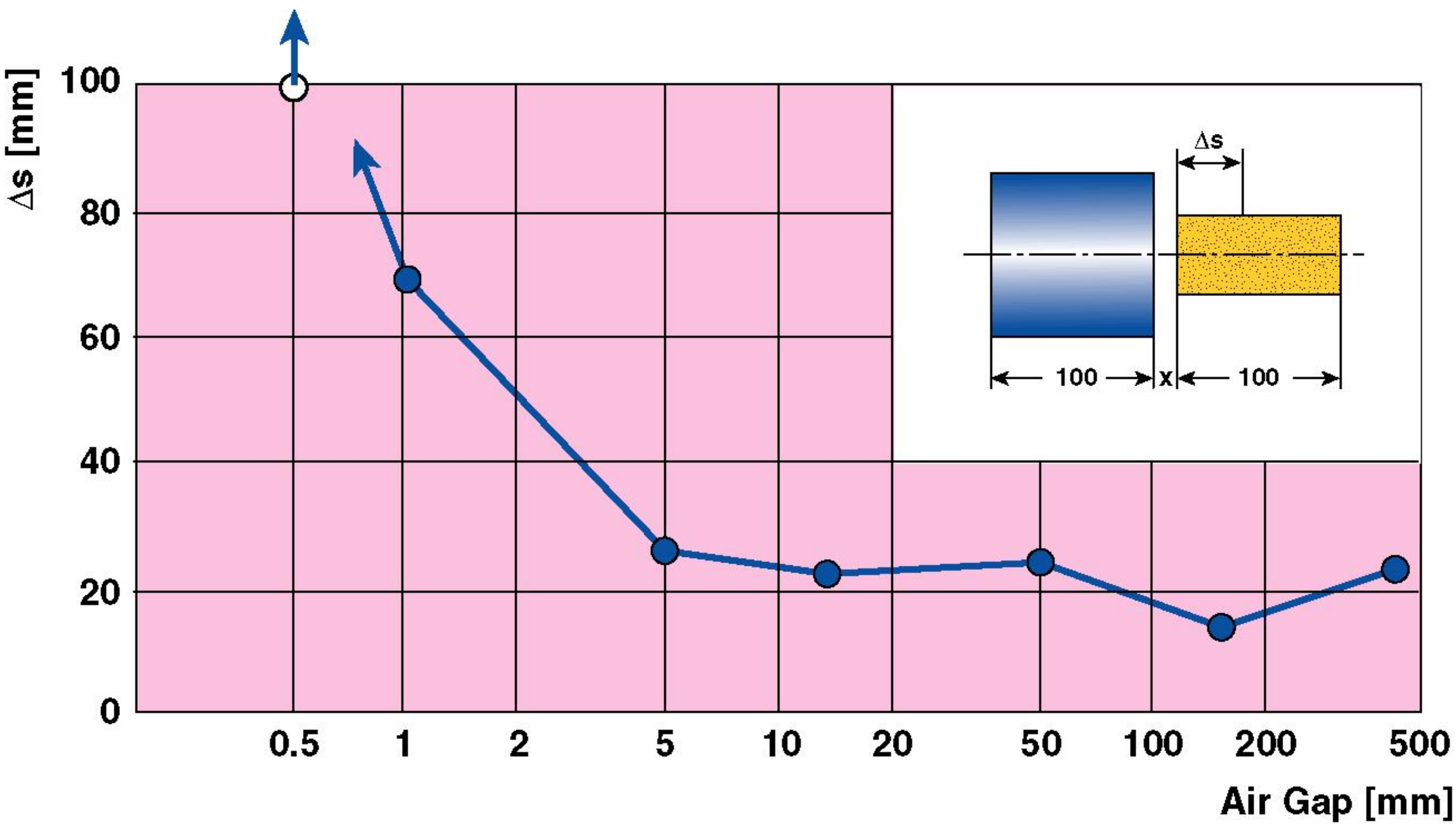


Fig. 20

Spaced Barrier

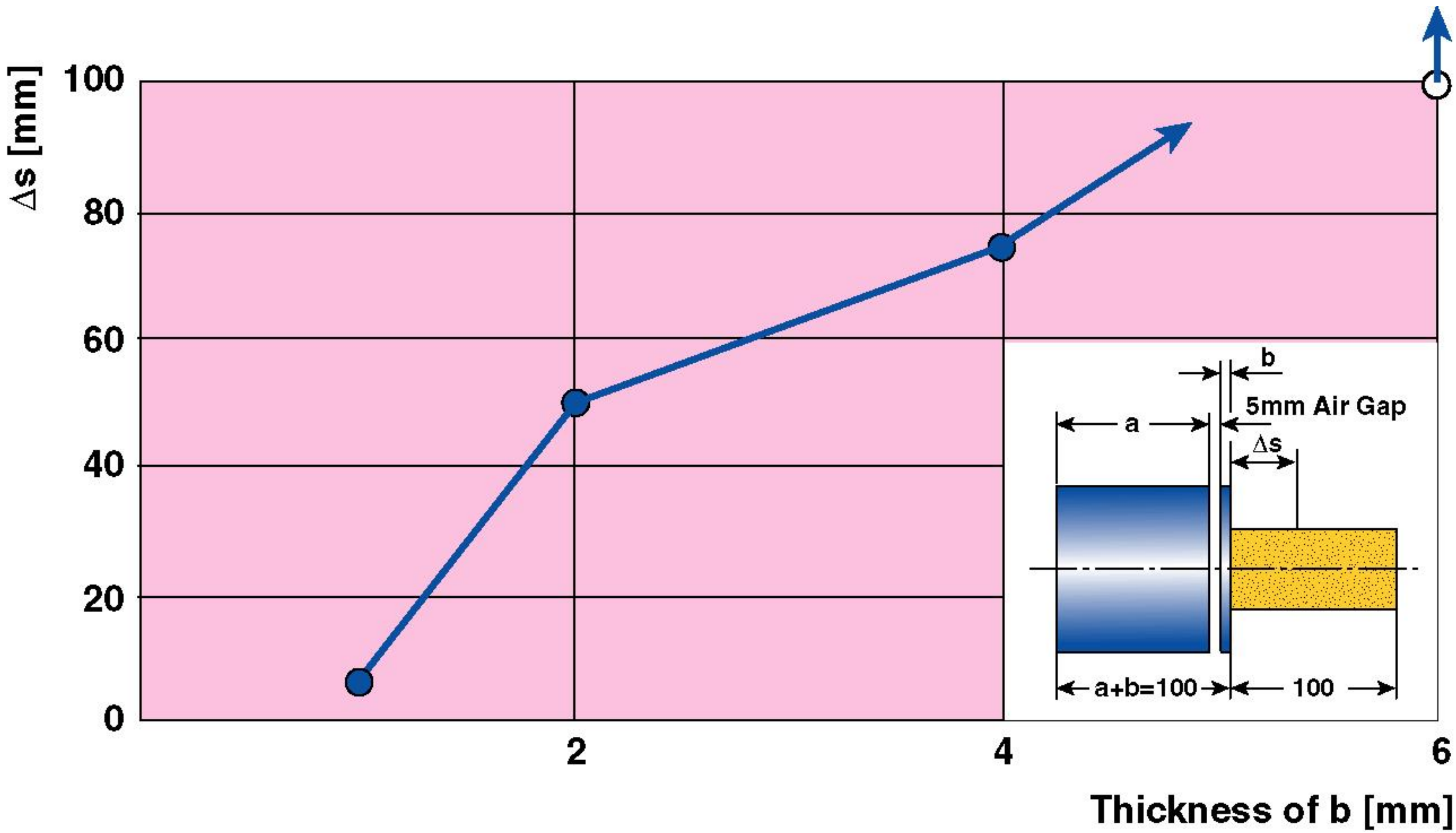


Fig. 21

$\Delta s, \Delta t, t_i = f(v_j)$

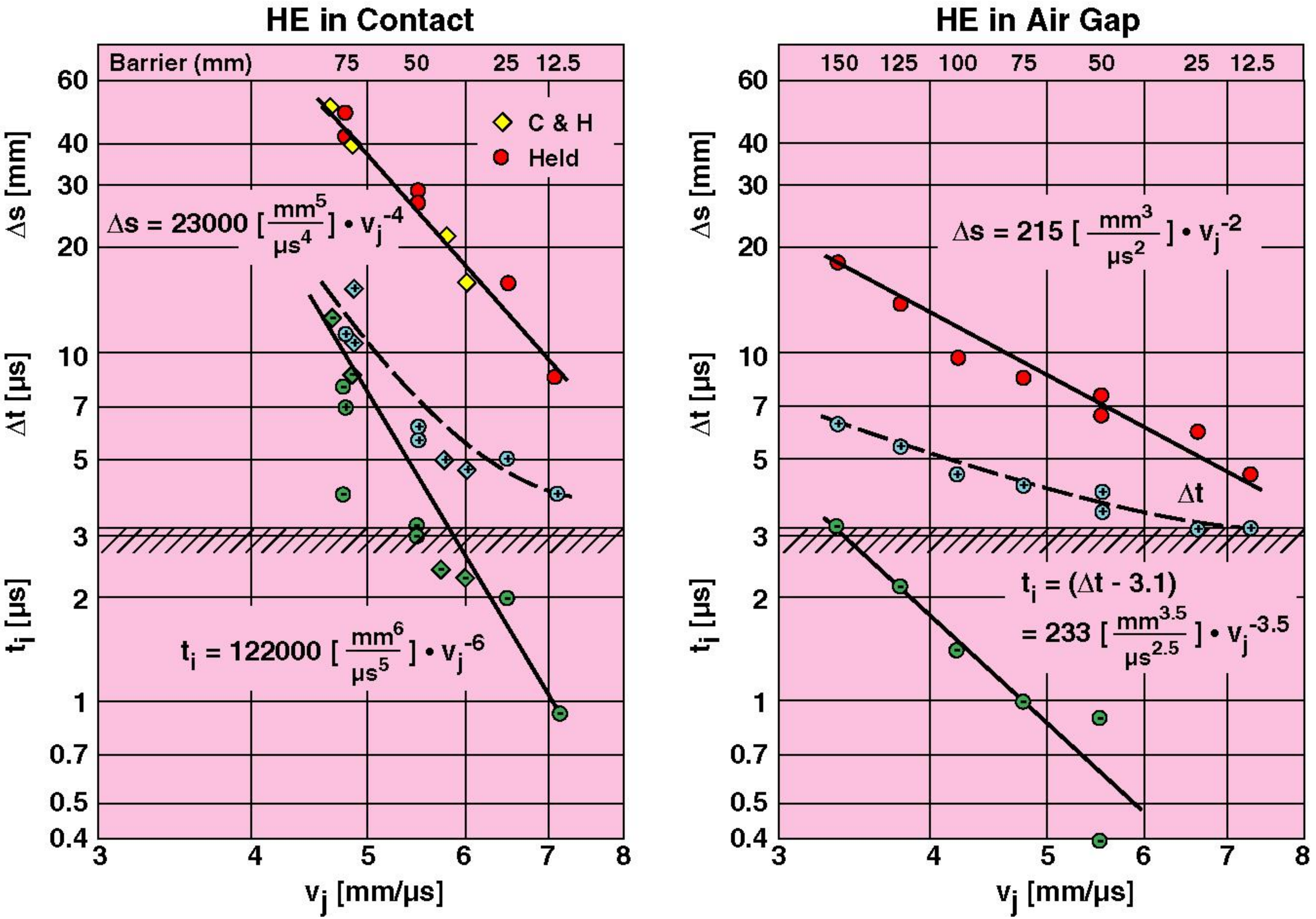


Fig. 22

$\Delta s, \Delta t, t_i = f(v_j^2 \cdot d_j)$

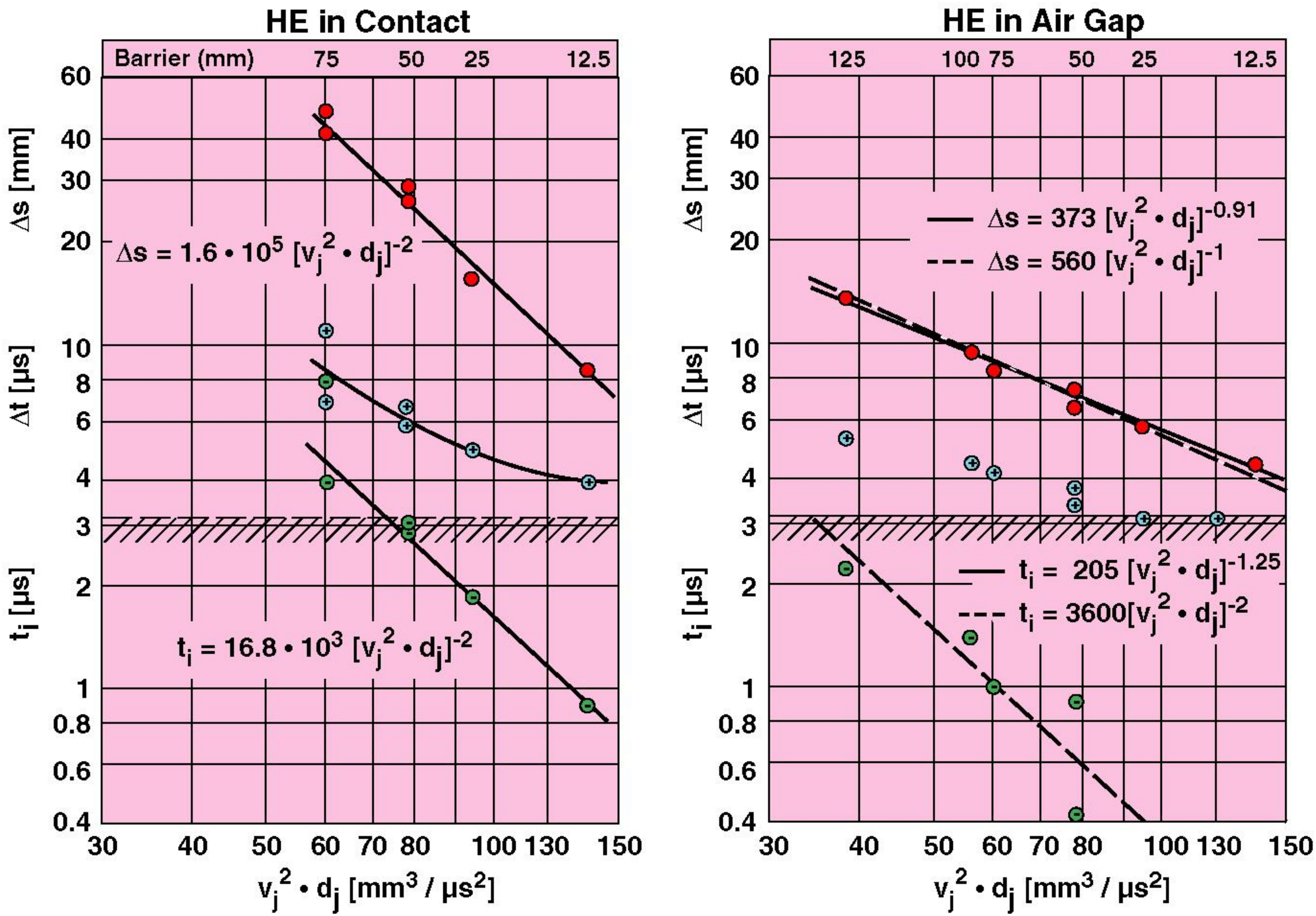


Fig. 23

Jet Initiation of a Split HE - Charge

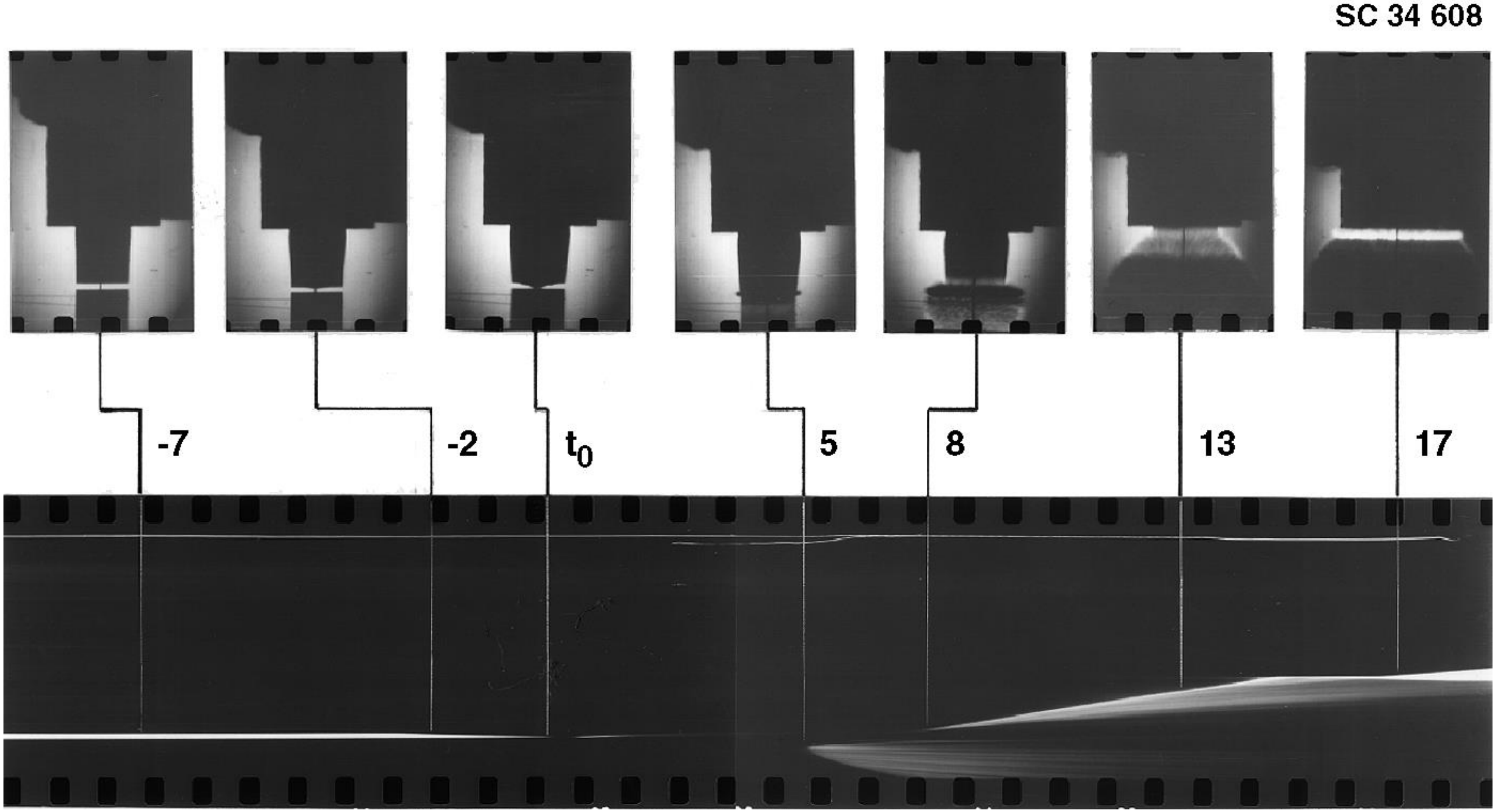


Fig. 24

Jet Load against Plexiglass after 100 mm M.S. Barrier

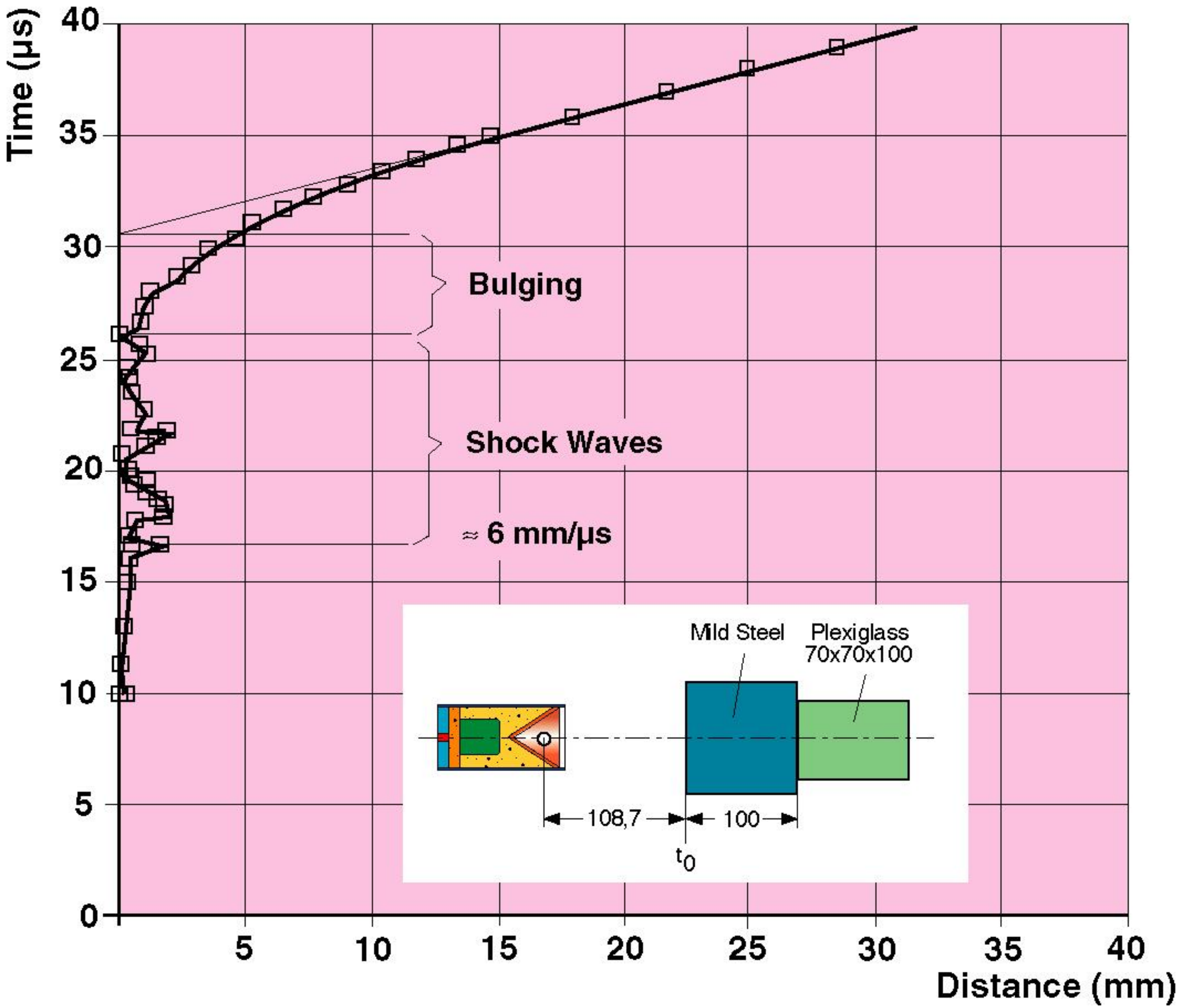


Fig. 25

Time - Distance - Plot

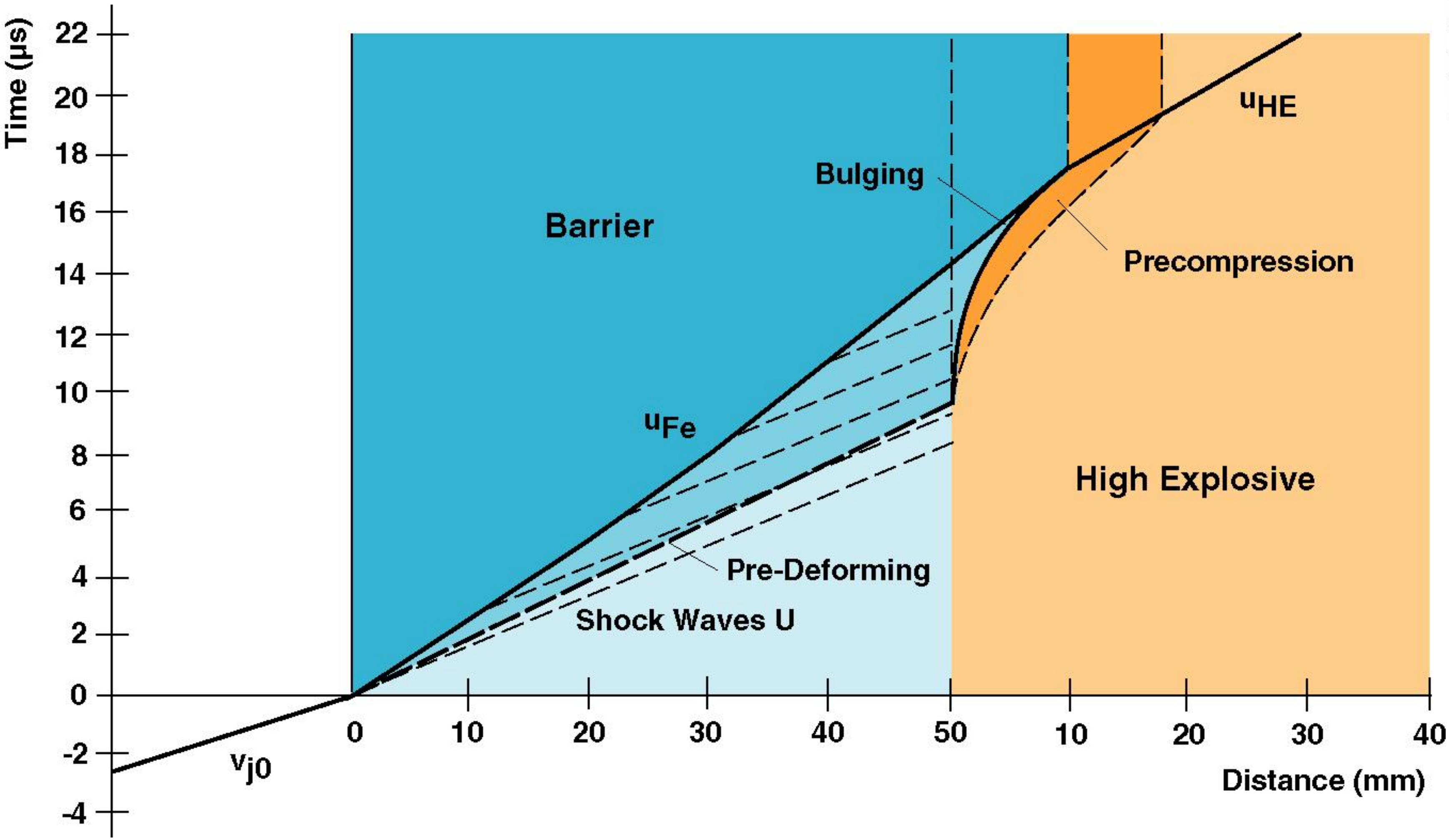


Fig. 26

Different Loads

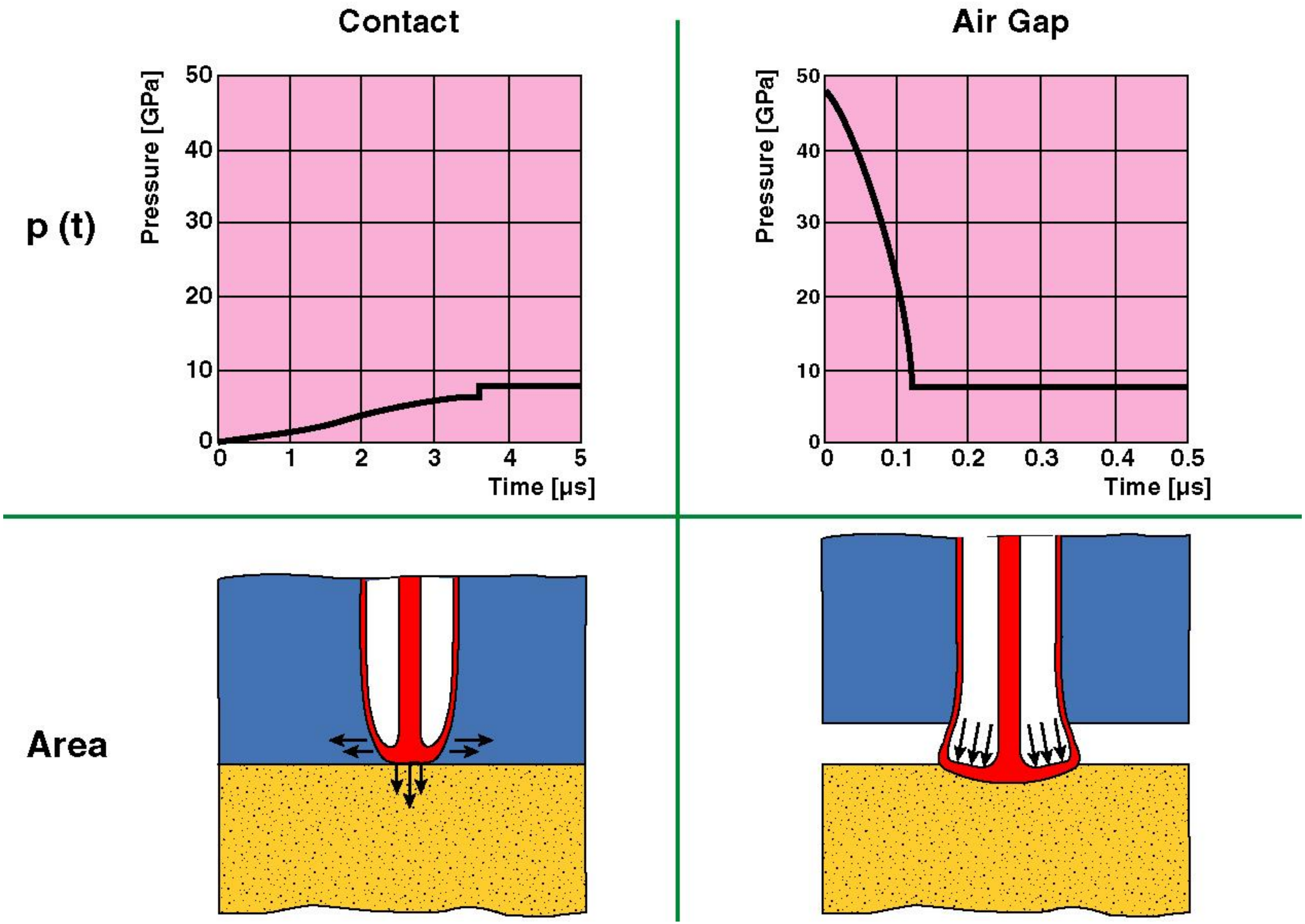
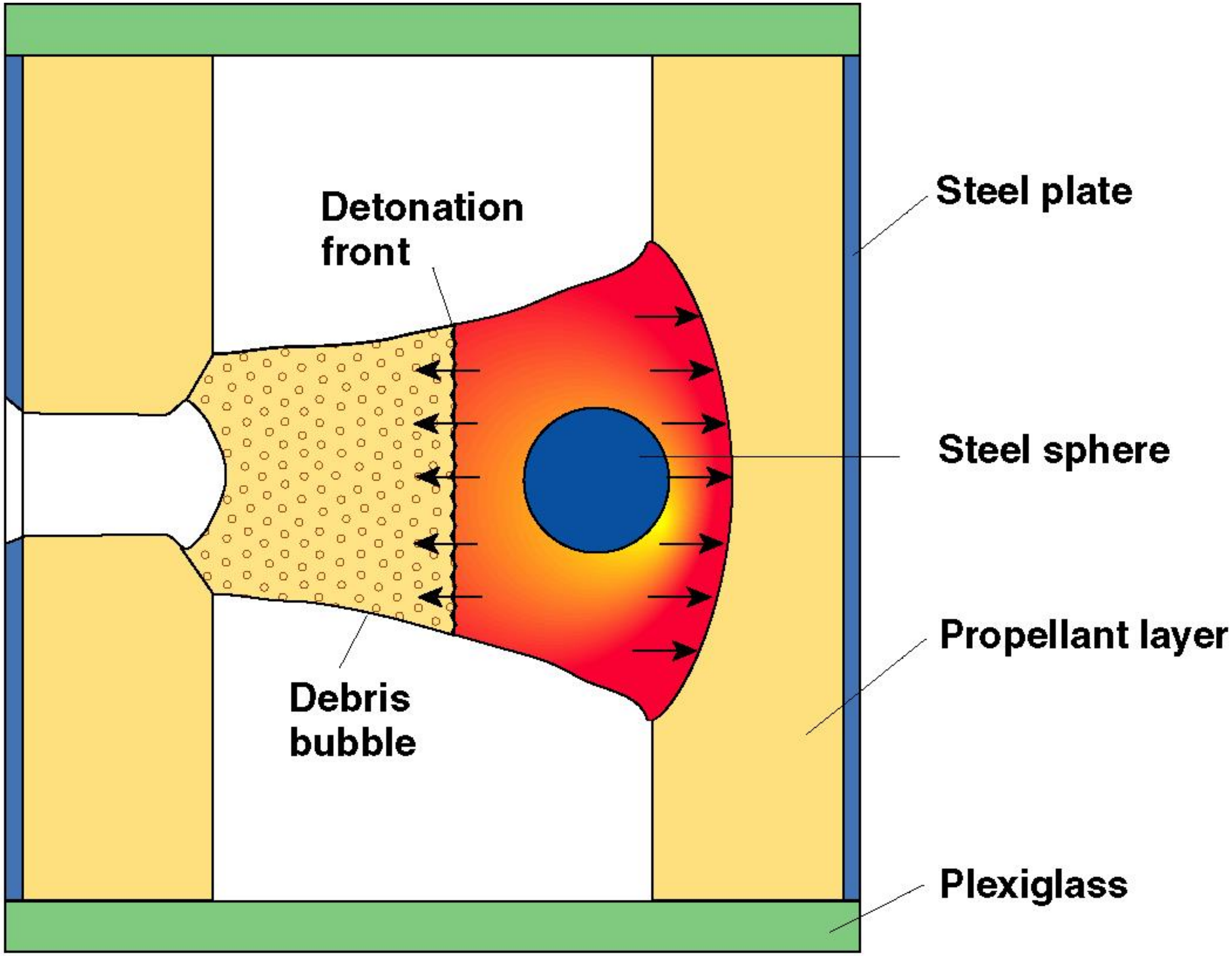


Fig. 27

Delayed Detonation Process



S.A. Finnigan, AGARD CP-511, 1992

Fig. 28

Overview

Required shaped charge tests

Jet initiation phenomena

Shaped charge threat

Recommendations

EADS TDW

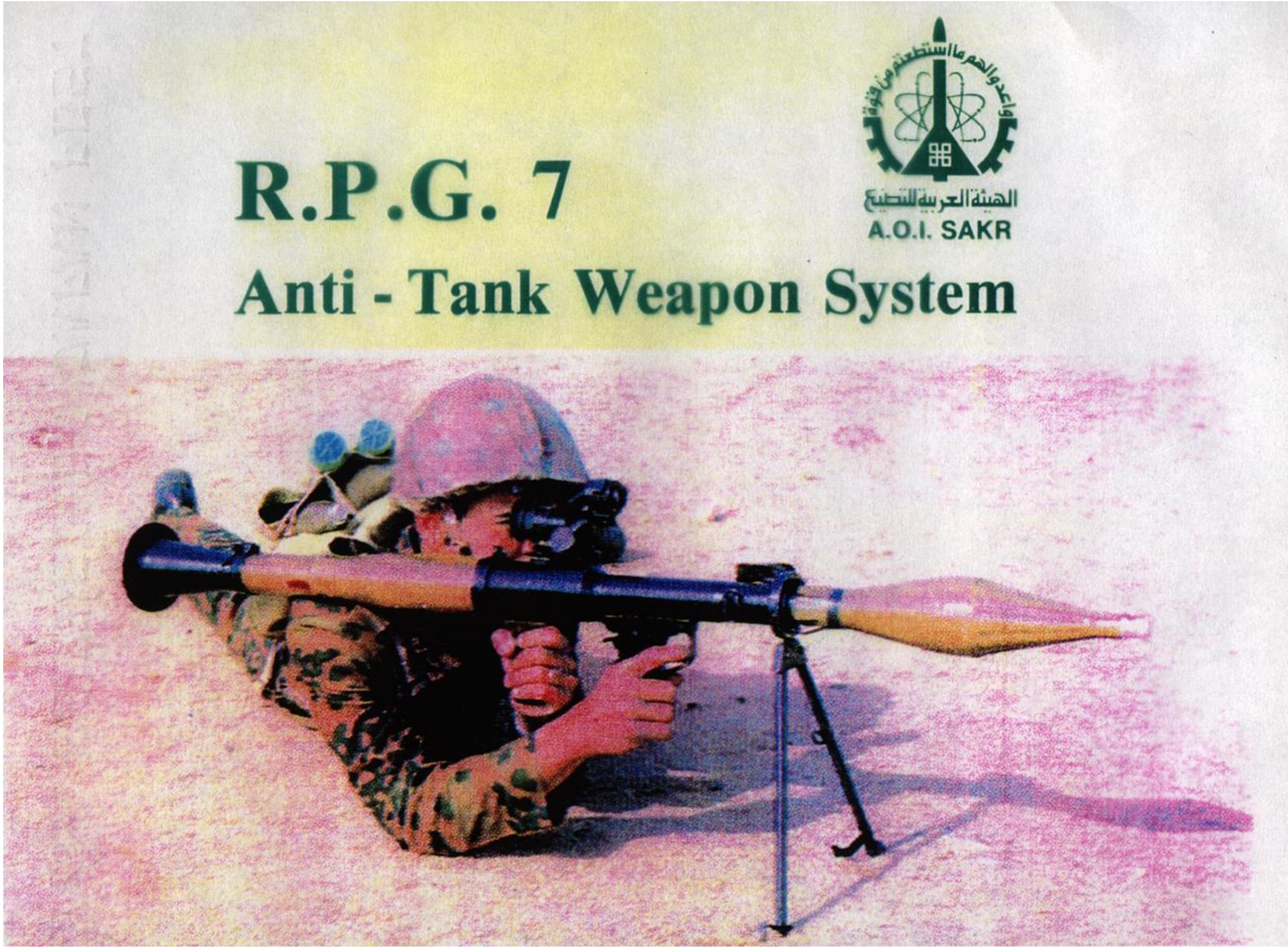


Fig. 29a

PG 7 VL

P = 500 mm

ANTITANK GRENADE LAUNCHERS

ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

PG-7VL ANTITANK ROUND FOR RPG-7 GRENADE LAUNCHER

The round is designed to combat all types of modern tanks and other armor materiel, suppress weapon emplacements and manpower in buildings and structures.

ПРОТИВОТАНКОВЫЙ ВЫСТРЕЛ ПГ-7ВЛ К ГРАНАТОМЕТУ РПГ-7

Предназначен для борьбы с современными танками всех типов и другой бронированной техникой, подавления огневых точек и живой силы в зданиях и сооружениях.

Basic Characteristics

Caliber, mm	93
Weight, kg	2.6
Sighting range, m	300
Penetration, m:	
homogeneous armor	at least 0.5
brick	at least 1.5
reinforced concrete	at least 1.1
log and dirt	at least 2.4

Основные характеристики

Калибр, мм	93
Масса, кг	2,6
Дальность прицельной стрельбы, м	300
Толщина пробиваемой преграды, м:	
гомогенной брони	более 0,5
кирпичной	более 1,5
железобетонной	более 1,1
деревоземляной	более 2,4

Fig. 29b

ANTITANK GRENADE LAUNCHERS — ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

PG - 7 VL

P = 500 mm

PG-7VL ANTITANK ROUND FOR RPG-7 GRENADE LAUNCHER

The round is designed to combat all types of modern tanks and other armor materiel, suppress weapon emplacements and manpower in buildings and structures.

ПРОТИВОТАНКОВЫЙ ВЫСТРЕЛ ПГ-7ВЛ К ГРАНАТОМЕТУ РПГ-7

Предназначен для борьбы с современными танками всех типов и другой бронированной техникой, подавления огневых точек и живой силы в зданиях и сооружениях.

Basic Characteristics

Caliber, mm	93
Weight, kg	2.6
Sighting range, m	300
Penetration, m:	
homogeneous armor	at least 0.5
brick	at least 1.5
reinforced concrete	at least 1.1
log and dirt	at least 2.4

Основные характеристики

Калибр, мм	93
Масса, кг	2,6
Дальность прицельной стрельбы, м	300
Толщина пробиваемой преграды, м:	
гомогенной брони	более 0,5
кирпичной	более 1,5
железобетонной	более 1,1
деревоземляной	более 2,4

PG 7 VR

P behind Era = 600 mm

PG-7VR ANTITANK ROUND FOR RPG-7V1 GRENADE LAUNCHER

The round is designed to combat all types of tanks, including those provided with explosive reactive armor, and suppress manpower located in buildings and structures.

ПРОТИВОТАНКОВЫЙ ВЫСТРЕЛ ПГ-7ВР К ГРАНАТОМЕТУ РПГ-7В1

Предназначен для борьбы с танками всех типов, в том числе оснащенными динамической защитой, подавления живой силы в зданиях и сооружениях.

Basic Characteristics

Warhead	tandem
Caliber, mm	105
Weight, kg	4.5
Accurate firing range, m	200
Penetration, m:	
homogeneous armor behind ERA	at least 0.6
brick	at least 2.0
reinforced concrete	at least 1.5
log and dirt	at least 3.7

Основные характеристики

Боевая часть	тандемная
Калибр, мм	105
Масса, кг	4,5
Дальность прицельной стрельбы, м	200
Толщина пробиваемой преграды, м:	
гомогенной брони после преодоления ДЗ	более 0,6
кирпичной	более 2,0
железобетонной	более 1,5
деревоземляной	более 3,7

RPG 7 V 1

PG - 7 VL
PG - 7 VR
TBG - 7 V
OG - 7 V

RPG-7V1 HAND-HELD ANTITANK GRENADE LAUNCHER WITH PG-7VL, PG-7VR, TBG-7V AND OG-7V ROUNDS

РУЧНОЙ ПРОТИВОТАНКОВЫЙ ГРАНАТОМЕТ РПГ-7В1 С ВЫСТРЕЛАМИ ПГ-7ВЛ, ПГ-7ВР, ТБГ-7В и ОГ-7В

RPG 26

P = 400 mm

PART 1 | ЧАСТЬ 1

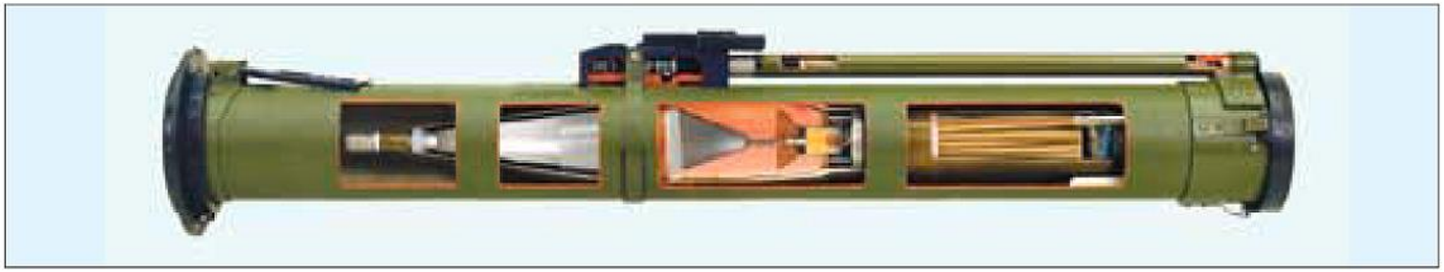
ANTITANK GRENADE LAUNCHERS | ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

RPG-26 ANTITANK ROCKET GRENADE WITH SINGLE-SHOT GRENADE LAUNCHER

The grenade is designed to combat tanks and armored mareriel, suppress weapon emplacements and man-power in buildings and structures.

РЕАКТИВНАЯ ПРОТИВОТАНКОВАЯ ГРАНАТА С ГРАНАТОМЕТОМ ОДНОРАЗОВОГО ПРИМЕНЕНИЯ РПГ-26

Предназначена для борьбы с танками и бронированной техникой, подавления огневых точек и живой силы в зданиях и сооружениях.



Basic Characteristics

Caliber, mm	72.5
Weight, kg	2.9
Accurate firing range, m	250
Penetration, m:	
homogeneous armor	at least 0.4
reinforced concrete	at least 1
brick	at least 1.5
log and dirt	at least 2.4

Основные характеристики

Калибр, мм	72,5
Масса, кг	2,9
Дальность прицельной стрельбы, м	250
Толщина пробиваемой преграды, м:	
гомогенной брони	более 0,4
железобетонной	более 1
кирпичной	более 1,5
деревоземляной	более 2,4

RPG 27

P behind ERA = 600 mm

ANTITANK GRENADE LAUNCHERS

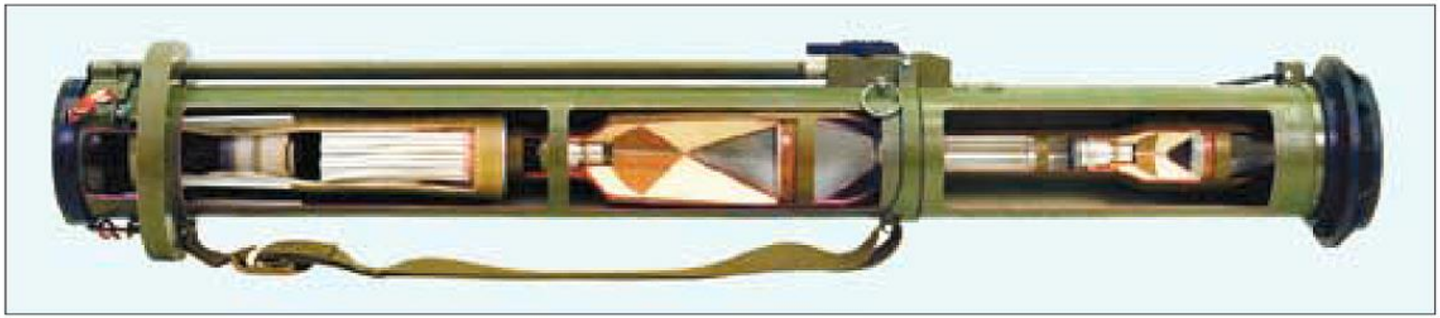
ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

RPG-27 ANTITANK ROCKET GRENADE WITH SINGLE-SHOT GRENADE LAUNCHER

The grenade is designed to combat all types of tanks, including those provided with explosive reactive armor, and suppress weapon emplacements and manpower located in buildings and structures.

РЕАКТИВНАЯ ПРОТИВОТАНКОВАЯ ГРАНАТА С ГРАНАТОМЕТОМ ОДНОРАЗОВОГО ПРИМЕНЕНИЯ РПГ-27

Предназначена для борьбы с танками всех типов, в том числе оснащенными динамической защитой, подавления огневых точек и живой силы в зданиях и сооружениях.



Basic Characteristics

Warhead	tandem
Caliber, mm	105
Weight, kg	8
Accurate firing range, m	200
Penetration, m:	
homogeneous armor behind ERA	at least 0.6
reinforced concrete and brick	at least 1.5
log and dirt	at least 3.7

Основные характеристики

Боевая часть	тандемная
Калибр, мм	105
Масса, кг	8
Дальность прицельной стрельбы, м	200
Толщина пробиваемой преграды, м:	
гомогенной брони после преодоления ДЗ	более 0,6
железобетонной и кирпичной	более 1,5
деревоземляной	более 3,7

Fig. 30

RPG 29 with PG - 29 V P behind ERA = 600 mm

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ANTITANK GRENADE LAUNCHERS — ПРОТИВОТАНКОВЫЕ ГРАНАТОМЕТЫ

RPG-29 HAND-HELD ANTITANK GRENADE LAUNCHER WITH PG-29V ROUND

The grenade launcher is designed to combat all types of tanks, including those provided with explosive reactive armor, and other armored materiel and suppress weapon emplacements and manpower located in buildings and structures.
The grenade launcher can be multiply fired. It is provided with an iron, optical and a night sight.

РУЧНОЙ ПРОТИВОТАНКОВЫЙ ГРАНАТОМЕТ РПГ-29 С ВЫСТРЕЛОМ ПГ-29В

Предназначен для борьбы с танками всех типов, в том числе оснащенными динамической защитой, и другой бронированной техникой, подавления огневых точек и живой силы в зданиях и сооружениях.
Гранатомет многоразового применения. Оснащен механическим, оптическим и ночным прицелами.

Basic Characteristics

Warhead	tandem
Caliber, mm	105
Weight, kg:	
grenade launcher	11.5
round	6.7
Accurate firing range, m	500
Penetration, m:	
homogeneous armor behind ERA	at least 0.6
reinforced concrete and brick	at least 1.5
log and dirt	at least 3.7

Основные характеристики

Боевая часть	тандемный
Калибр, мм	105
Масса, кг:	
гранатомета	11,5
выстрела	6,7
Дальность прицельной стрельбы, м	500
Толщина пробиваемой преграды, м:	
гомогенной брони после преодоления ДЗ	более 0,6
железобетонной и кирпичной	более 1,5
деревоземляной	более 3,7

Stand - off Curves Proving Ground

Meppen 1985 / Sept. 2000

M. Held

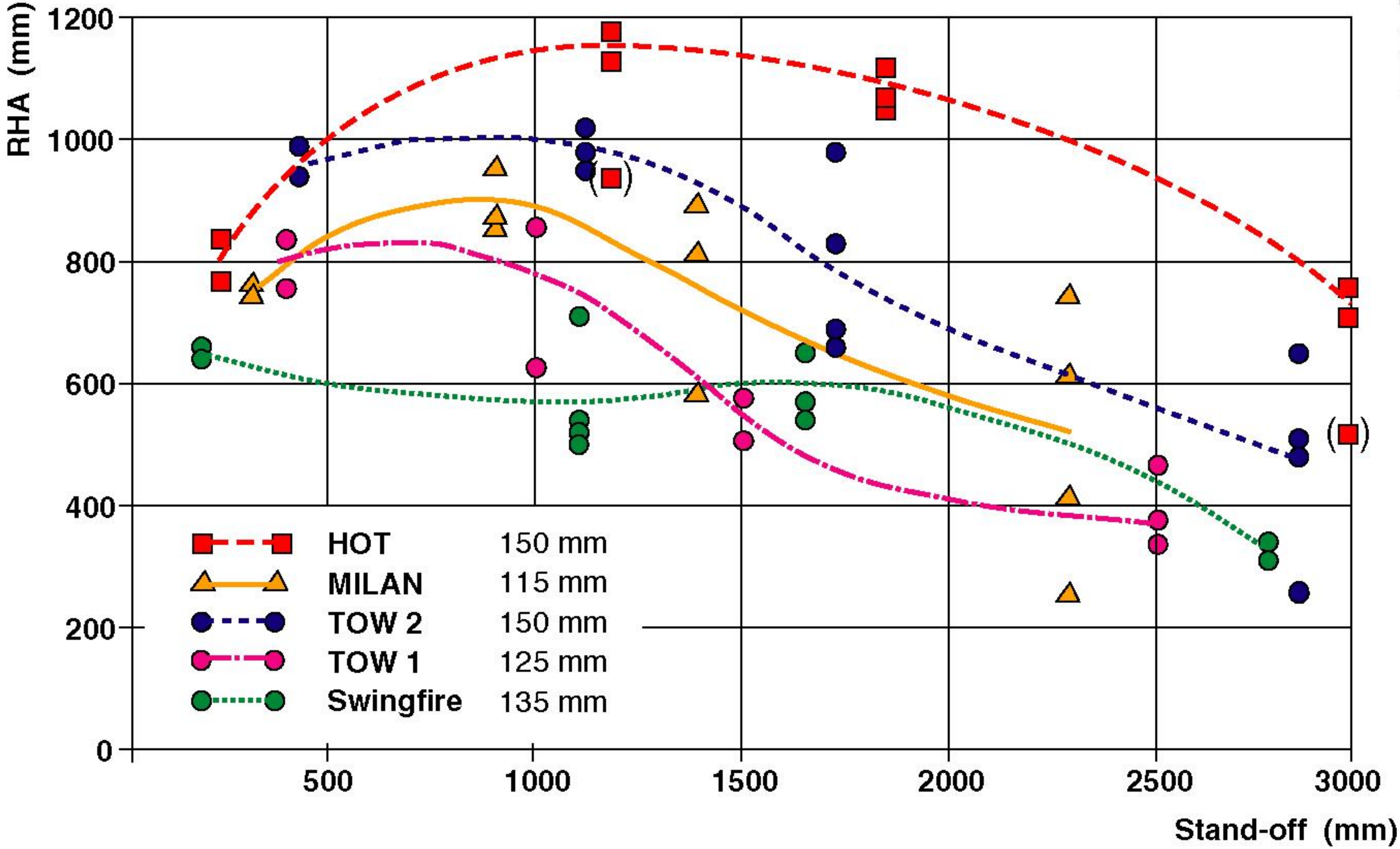


Fig. 31

METRIC

MIL-STD-2105C
14 July 2003
SUPERSEDING
MIL-STD-2105B
12 January 1994

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

HAZARD ASSESSMENT TESTS FOR NON-NUCLEAR MUNITIONS

AMSC N6037 AREA SAFT

EADS TDW

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

NATO STANDARDIZATION AGENCY
(NSA)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: SHAPED CHARGE JET, MUNITIONS TEST PROCEDURE

Promulgated on 15 July 2004

J. MAJ
Brigadier General, POL(A)
Director, NSA

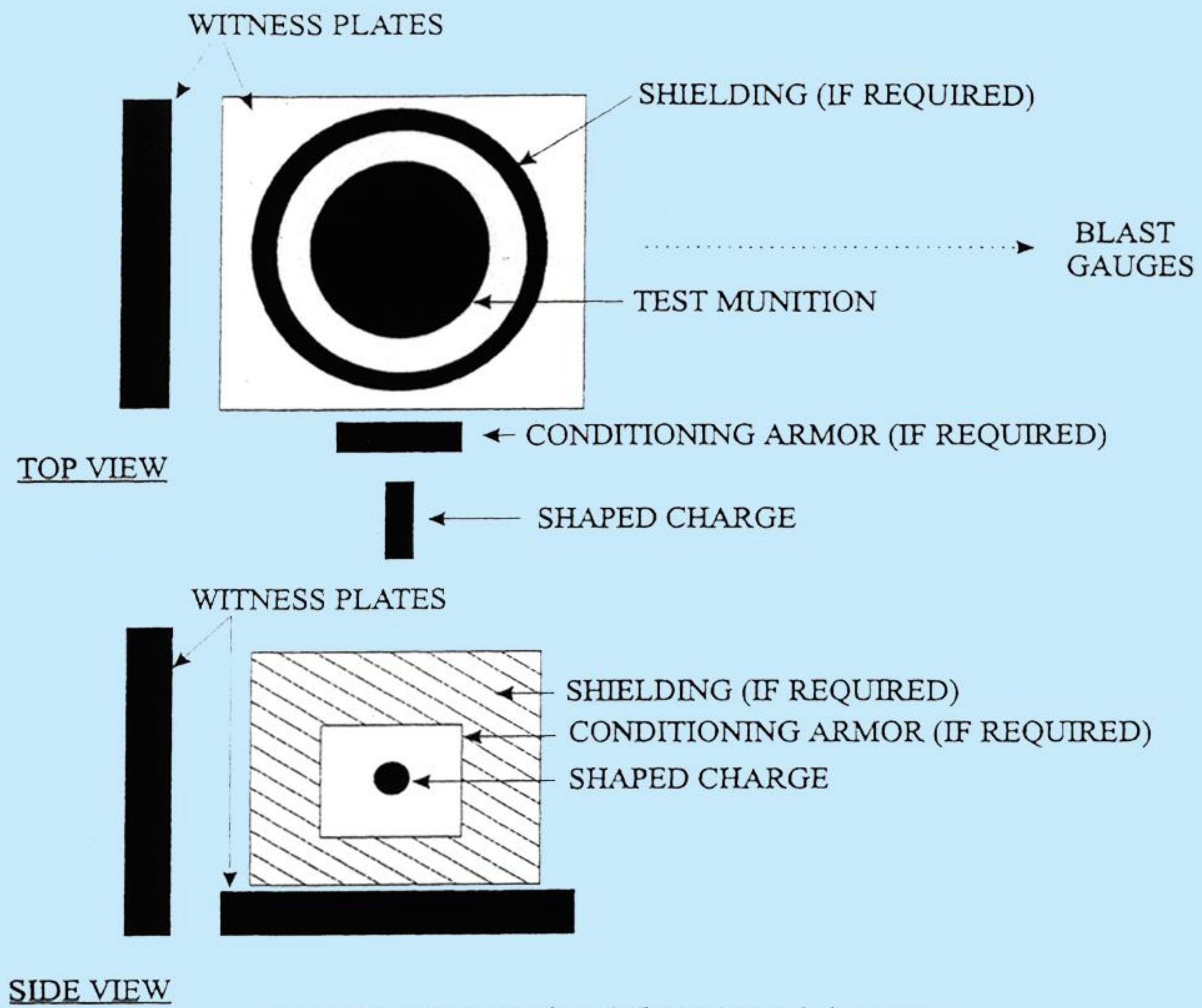


Figure 1. Schematic drawing of a "typical" shaped charge jet impact test.
(Details will vary depending on specific circumstances. The presence of shielding may obviate the usefulness of witness plates.)

Table 1: Standardized V^2d values for a copper jet.

Threat	Representative V^2D ($mm^3/\mu s^2$)
Top Attack Bomblet	200
50mm Rockeye	360
Rocket Propelled Grenade	430
Anti-Tank Guided Missile	800

13. Characterization of the Shaped Charge Jet.

a. Note that two shaped charges which deliver the same V^2d on the outside of a munition or its shielding may deliver VERY different values of V^2d when the jet reaches the energetic material. Consequently, and so all nations may fully understand the test that is conducted, provide a full characterization of the jet if a jet other than the standard 50mm Rockeye is used. Characterization of the jet requires that the following be specified:

- velocity of the leading particle;

  - diameter of the leading particle;
  - average diameter of the jet particles after particulation;
  - breakup time (time from detonation to jet particulation);
  - standoff from shaped charge to munition;
  - position of the virtual origin of the shaped charge jet within the cone;
  - thickness of conditioning armor if any is used;
  - penetration capability.

b. It is presumed that nations will have available characterized shaped charge jets that they can use for this test. Characterization of a shaped charge jet requires separate tests that are not described here.

Overview

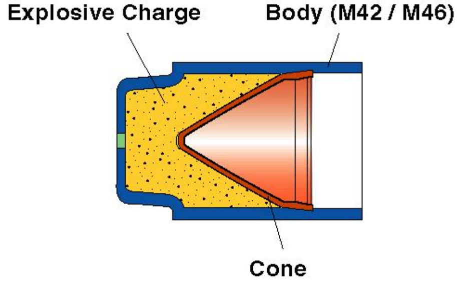
Required shaped charge tests

Jet initiation phenomena

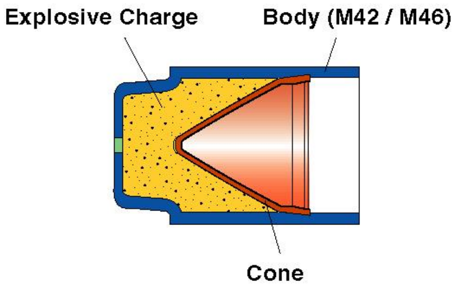
Shaped charge threat

Recommendations

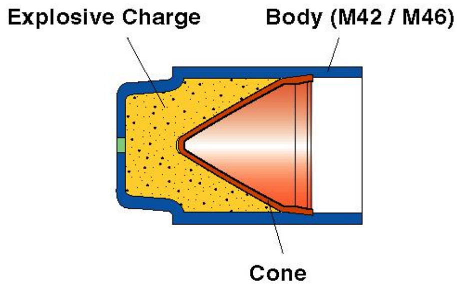
Conclusions Testing Sequence



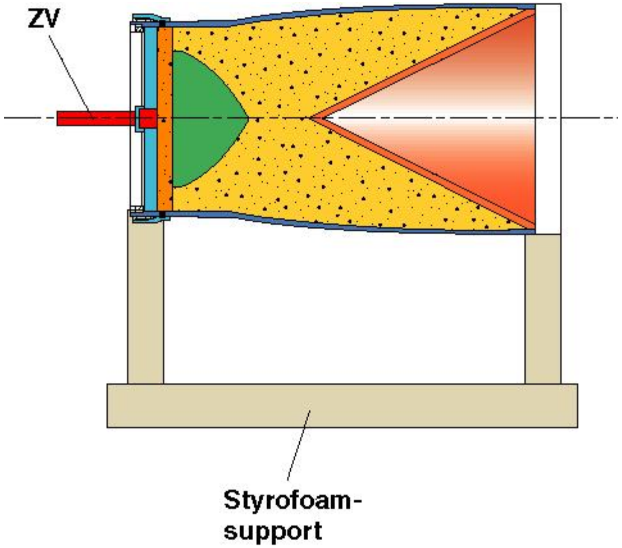
Conclusions Testing Sequence



Conclusions Testing Sequence



Mono Shaped Charges



Tandem Shaped ChargeTest Setup

Typical SC Diameters: 64 mm and 150 mm

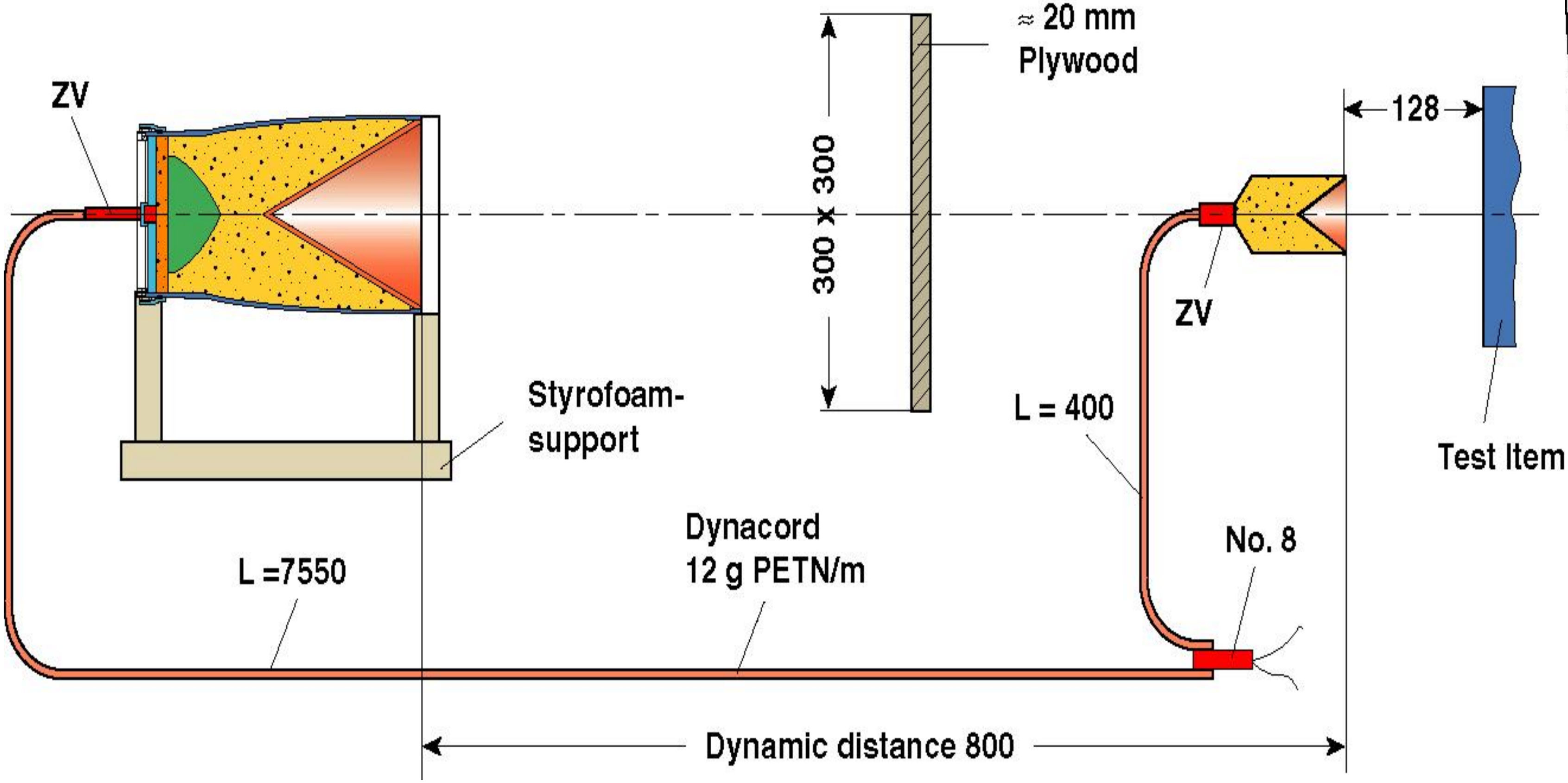
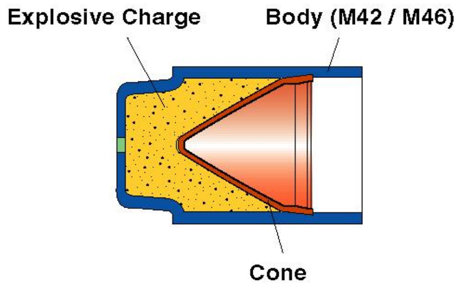


Fig. 32b

Conclusions   Testing Sequence



Mono + Tandem Shaped Charges

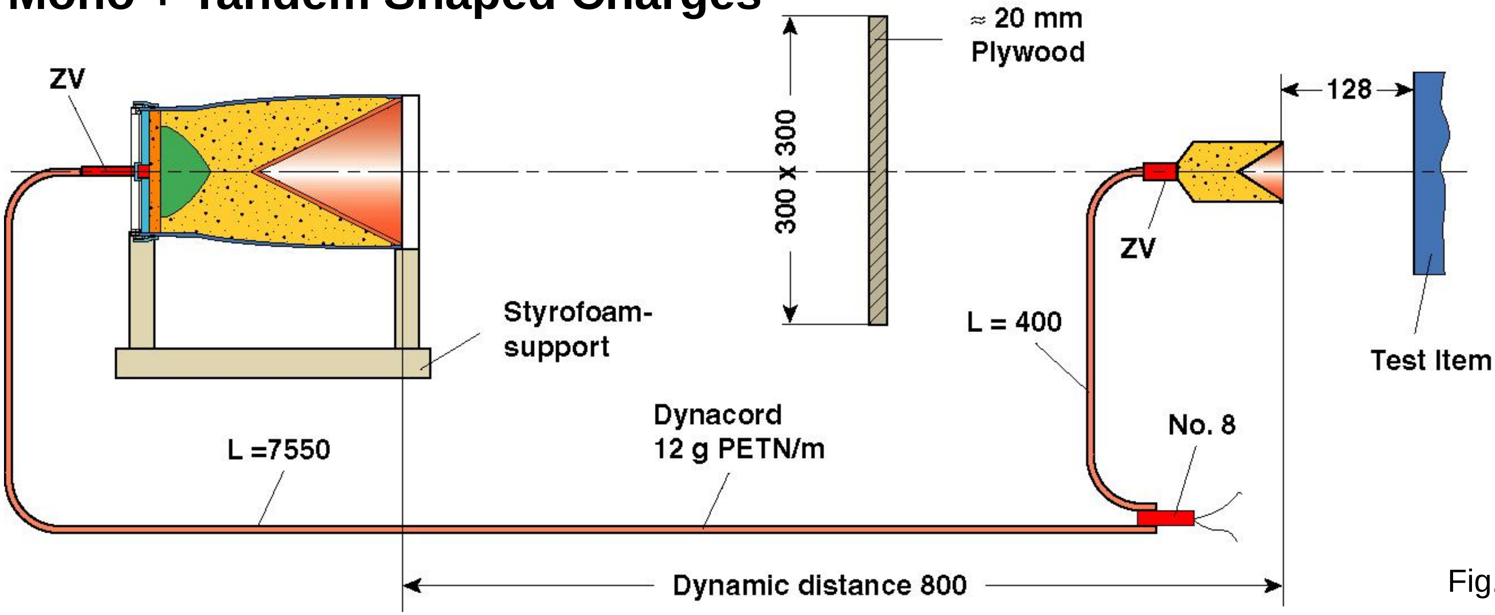


Fig. 32

Mass-or Sympathetic Detonation of an Ammunition Storage Place at Kuwait 1991

Fig. 1

a. **Type I (Detonation Reaction).** The most violent type of explosive event. A supersonic decomposition reaction propagates through the energetic material to produce an intense shock in the surrounding medium, air or water for example, and very rapid plastic deformation of metallic cases, followed by extensive fragmentation. All energetic material will be consumed. The effects will include large ground craters for munitions on or close to the ground, holing/plastic flow damage/fragmentation of adjacent metal plates, and blast overpressure damage to nearby structures.

b. **Type II (Partial Detonation Reaction).** The second most violent type of explosive event. Some, but not all of the energetic material reacts as in a detonation. An intense shock is formed; some of the case is broken into small fragments; a ground crater can be produced, adjacent metal plates can be damaged as in a detonation, and there will be blast overpressure damage to nearby structures. A partial detonation can also produce large case fragments as in a violent pressure rupture (brittle fracture). The amount of damage, relative to a full detonation, depends on the portion of material that detonates.

c. **Type III (Explosion Reaction).** The third most violent type of explosive event. Ignition and rapid burning of the confined energetic material builds up high local pressures leading to violent pressure rupturing of the confining structure. Metal cases are fragmented (brittle fracture) into large pieces that are often thrown long distances. Unreacted and/or burning energetic material is also thrown about. Fire and smoke hazards will exist. Air shocks are produced that can cause damage to nearby structures. The blast and high velocity fragments can cause minor ground craters and damage (breakup, tearing, gouging) to adjacent metal plates. Blast pressures are lower than for a detonation.

d. **Type IV (Deflagration Reaction).** The fourth most violent type of explosive event. Ignition and burning of the confined energetic materials leads to nonviolent pressure release as a result of a low strength case or venting through case closures (loading port/fuze wells, etc.). The case might rupture but does not fragment; closure covers might be expelled, and unburned or burning energetic material might be thrown about and spread the fire. Propulsion might launch an unsecured test item, causing an additional hazard. No blast or significant fragmentation damage to the surroundings; only heat and smoke damage from the burning energetic material.

e. **Type V (Burning Reaction).** The least violent type of explosive event. The energetic material ignites and burns, non-propulsively. The case may open, melt or weaken sufficiently to rupture nonviolently, allowing mild release of combustion gases. Debris stays mainly within the area of the fire. This debris is not expected to cause fatal wounds to personnel or be a hazardous fragment beyond 15 m (49 ft).

Overview

Required shaped charge tests

Jet initiation phenomena

Shaped charge threat

Recommendations