FFI-RAPPORT

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Critical diameter RDX/GAP propellant

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Summary

To type qualify the solid propellant D-07 according to the STANAG 4170 and the accompanying AOP-7, critical diameter has been determined. Two different methods have been applied. First, casted conical test items were tested, and then stepped cylindrical test items.

Four conical charges were casted in polypropylene moulds with large diameter, 30 mm, and small diameter, 3 mm, and length 270 mm. The smallest diameter of these test items varied due to non-optimal filling during casting. Two of the charges were released from the mould while two were in the mould during testing. For all charges, the detonation reaction after initiation at the large end did not terminate before it reached the small end. The smallest diameters of the two confined charges were 3.8 mm and 4 mm. The smallest diameters of the two unconfined test items were 5.8 mm and 9.8 mm.

Cylindrical charges with diameters from 5 mm to 2.3 mm were punched and glued together to stepped test items. They contained four cylindrical charges of different diameters. Three stepped test items were tested, and for all of them the detonation terminated in the cylinder with the second largest diameter (3.6-4.1 mm). Critical diameter was determined to be 3.6-3.8 mm.

Both methods gave the same result, with a critical diameter for the solid propellant D-07 in the range 3.6-3.8 mm. However, the applied methods can give a slightly lower critical diameter than methods applying changes in detonation velocity.

Sammendrag

Kritisk diameter har blitt bestemt for å kvalifisere krutt D-07 i henhold til STANAG 4170, med tilhørende AOP-7. To forskjellige metoder har vært benyttet, først støpte koniske testemner, og deretter testemner av sylindriske ladninger med forskjellige diametere.

Fire koniske ladninger ble støpt i polypropylenkoner med største indre diameter 30 mm, minste diameter 3 mm og lengde 270 mm. To av støpene ble tatt ut av formen før testing, mens to ble testet i formene. Den minste diameteren varierte grunnet ulik fyllingsgrad i formene. I alle testene gikk detonasjonen gjennom hele ladningen og stoppet ikke før hele ladningen var omsatt. For ladningene i støpeformene var de minste diameterne 3,8 mm og 4 mm. For ladningene som var tatt ut av støpeformene, var de minste diameterne 5,8 mm og 9,8 mm.

Sylindriske ladninger med diameter fra 5 mm til 2,3 mm ble stanset ut og limt sammen til testlegemer. De bestod da av fire sylindere med ulike diametere. Tre testlegemer ble testet. For alle tre stoppet detonasjonen i sylinderen med nest størst diameter (3,6-4,1 mm). Dette gir en kritisk diameter på 3,6-3,8 mm for D-07-kruttet.

De oppnådde resultatene er i overensstemmelse med hverandre. De benyttede metodene har den svakheten at de begge kan gi en noe mindre kritisk diameter enn ved å benytte metoder som måler detonasjonshastighetsendringer.

Content

Abbreviations

AOP	Allied Ordnance Publication
BuNENA	Butyl-nitratoethylnitramine
GAP	Glycidyl azide polymer, $(C_3H_5N_3O)_n$
HWC	Hexogen/Wax/Graphite (94.5/4.5/1)
LLM	Lightweight Multirole Missile
RDX	Hexogen/1,3,5-trinitro-1,3,5-triazacyclohexane, $C_3H_6N_6O_6$
STANAG	Standardization Agreement

1 Introduction

The lightweight Multirole Missile (LMM), developed by Thales Land & Air Systems, is a precision lightweight weapon for light platforms to counter the modern and emerging threats of land, sea and air targets. The LMM contains a booster motor with the solid propellant D-07, produced by Nammo Raufoss AS. This is a new minimum smoke propellant, a propellant containing RDX as the main component and a binder of GAP/BuNENA. At the moment the propellant is not type qualified but will soon be it.

To obtain type qualification according to the STANAG 4170 (1) and the accompanying AOP-7 (2), for the solid propellant D-07, a large number of properties have to be characterized. During the development of the composition, most of the required properties were characterized. In reference 3 the majority of mandatory test results were reported. However, critical diameter was not among the tested properties. Determination of critical diameter is a mandatory property necessary to determine to obtain type qualification for solid propellants.

In this report, testing of critical diameter has been performed. The critical diameter has been tested by two different methods. First we applied a method described in reference 4, with casted conical test items. These conical charges had a large diameter of 30 mm and a small diameter of 3 mm with a length of 279 mm. However, since not all of the available test items had the optimal small diameter to obtain an accurate determination, we also used a method applying test items made up of stepped charges of cylinders of different diameters (5). These cylinders were punched with tools having outer diameters of 6, 5, 4 and 3 mm. Stepped test items were produced by gluing together the 4 different cylindrical charges obtained from these tools. The tests we performed were all without any instrumentation except witness plates. Measurements based on detonation velocity can give a slightly larger critical diameter.

2 Experimentally

The mixing of the solid propellant D-07 was performed by Nammo Raufoss A/S. Test items for characterization of the RDX/GAP solid propellant D-07 were casted by Nammo Raufoss. The tested material is all from lot PD-07-005/2016.

For characterization of the critical diameter, 4 conical charges were casted in conical polypropylene moulds with length 270 mm and with an inner large diameter of 30 mm and a small diameter of 3 mm. The X-ray pictures of the charges in the moulds are shown in Figure 2.1.

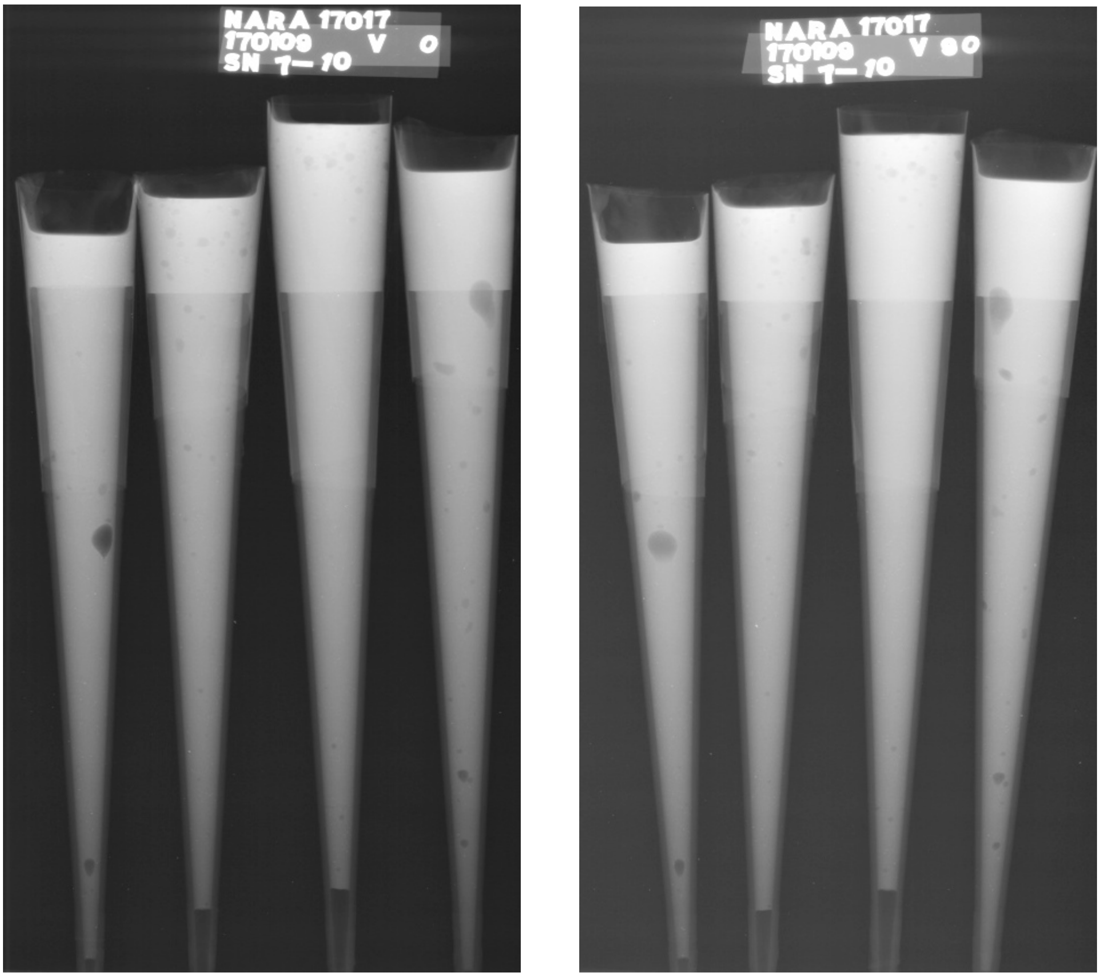

Figure 2.1 X-ray pictures of the conical charges No 7 to No 10, left picture at 0^o, right at 90^o.

All charges contain some bubbles. However, the conical charges No 7 and No 10 contain significantly more and larger bubbles than the conical charges No 8 and No 9. In addition, the X-ray pictures show that the conical charges No 8 and No 9 are not filled in the bottom.

2.1 Conical charges No 8 and No 9

The conical charges No 8 and No 9 were released from the mould without problems. The left picture in Figure 2.2 shows the released charges.

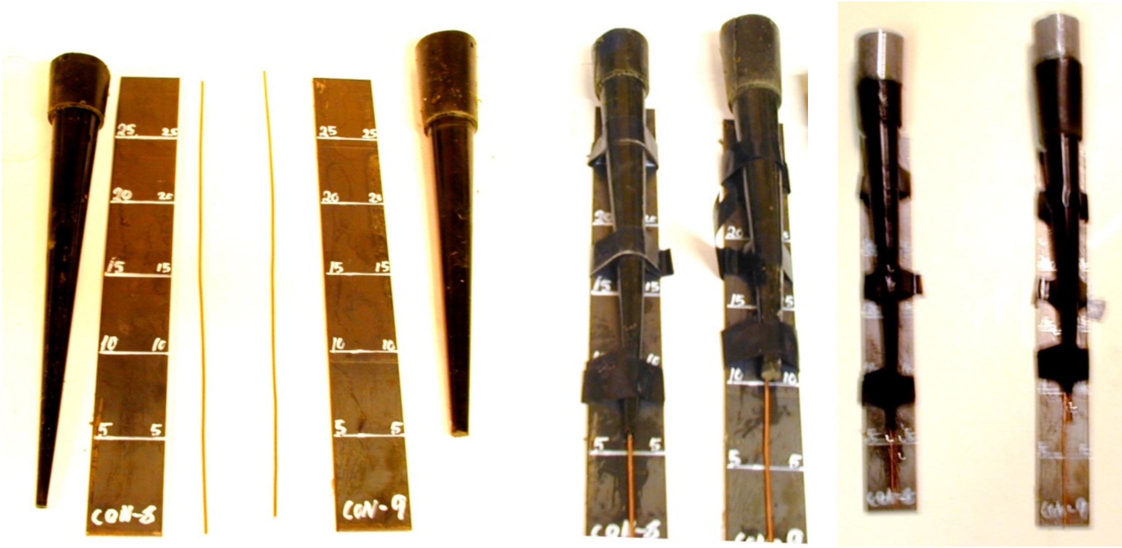

Figure 2.2 Charges No 8 and No 9.

Charge No 8 had a weight of 177.69 g. The length of the cone: 242 mm. Small diameter: 5.8 mm. The dimensions of the overfilling: height 37 mm, top diameter 40 mm, bottom diameter 35.6 mm.

Charge No 9 had a weight of 229.41 g. The length of the cone: 202 mm. Large diameter: 30 mm. Small diameter: 9.8 mm. The dimensions of the overfilling: height 65 mm, top diameter 40 mm, bottom diameter 35.6 mm.

In the middle of Figure 2.2, a picture shows the charges after being placed on the witness plates, with the copper cord between the charge and the witness plate in mild steel (4). The copper cord with diameter 1.5 mm is used to better see the termination of the detonation. The picture to the right shows the two test items after the booster had been added.

2.2 Conical charges No 7 and No 10

It turned out to be difficult to release the two conical charges No7 and No 10 from the moulds. All trials were unsuccessful. We therefore decided to test them in the moulds. The effect of the mould on the critical diameter is unknown. Figure 2.3 shows pictures of the conical charges after these trials, in addition to the test items after they were equipped with the boosters and placed on the witness plates.

Figure 2.3 Conical charges No 7 and No 10 in the mould to the left, to the right after being placed on the witness plates and added boosters.

2.3 Cylindrical charges

Cylindrical charges were punched with diameters as shown in Figure 2.4. The tools applied had outer diameters of 6, 5, 4 and 3 mm. The propellant has high elasticity, and when we punched the cylinders, we had to apply some pressure on the tool to cut out the cylinders. Due to the elastic properties, the obtained cylinders had a smaller diameter in the middle of the cylinder than in the top and bottom. To get straight cylinders, the samples must probably be casted in a mould with the required diameter.

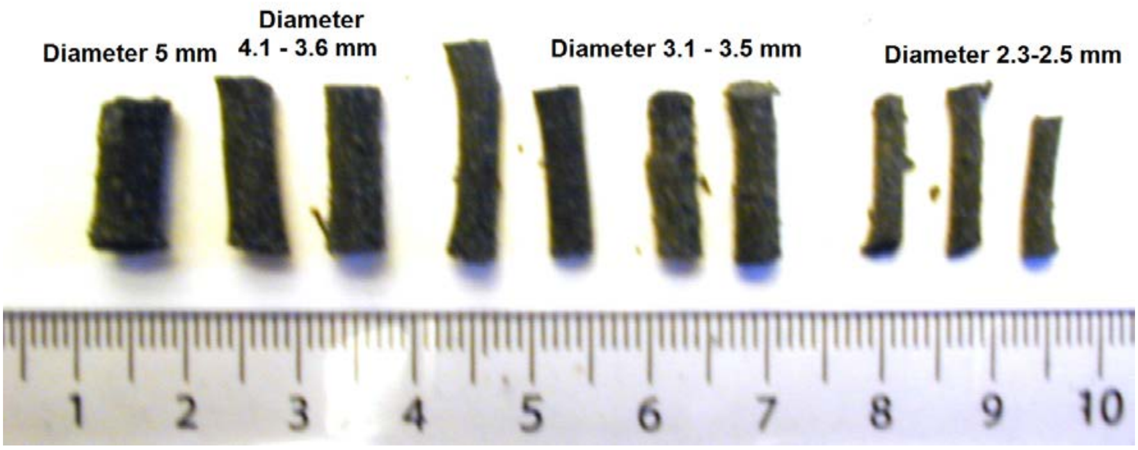

Figure 2.4 Cylindrical charges punched for determination of the critical diameter.

2.4 Initiation

For initiation of both the conical charges and the cylindrical test items we used boosters of HWC. Appendix A gives the control report of the applied composition lot. For the conical charges we used 80 g boosters with diameter 40 mm pressed to a density of 1.61 g/cm^3, for use in the Intermediate Scale Gap test. For the cylindrical test items we used 2 g booster with diameter 8 mm. For all firings a detonator No 8 was used.

3 Results

3.1 Conical charges

3.1.1 Charge No 7

Figure 3.1 shows pictures of the conical charge No 7, with a booster, on the witness plate before testing, the setup for the testing and the recovered witness plate after testing. The charge was in the mould since we did not manage to release it. The detonation continued through the charge, giving a critical diameter of 3.8 mm or less.

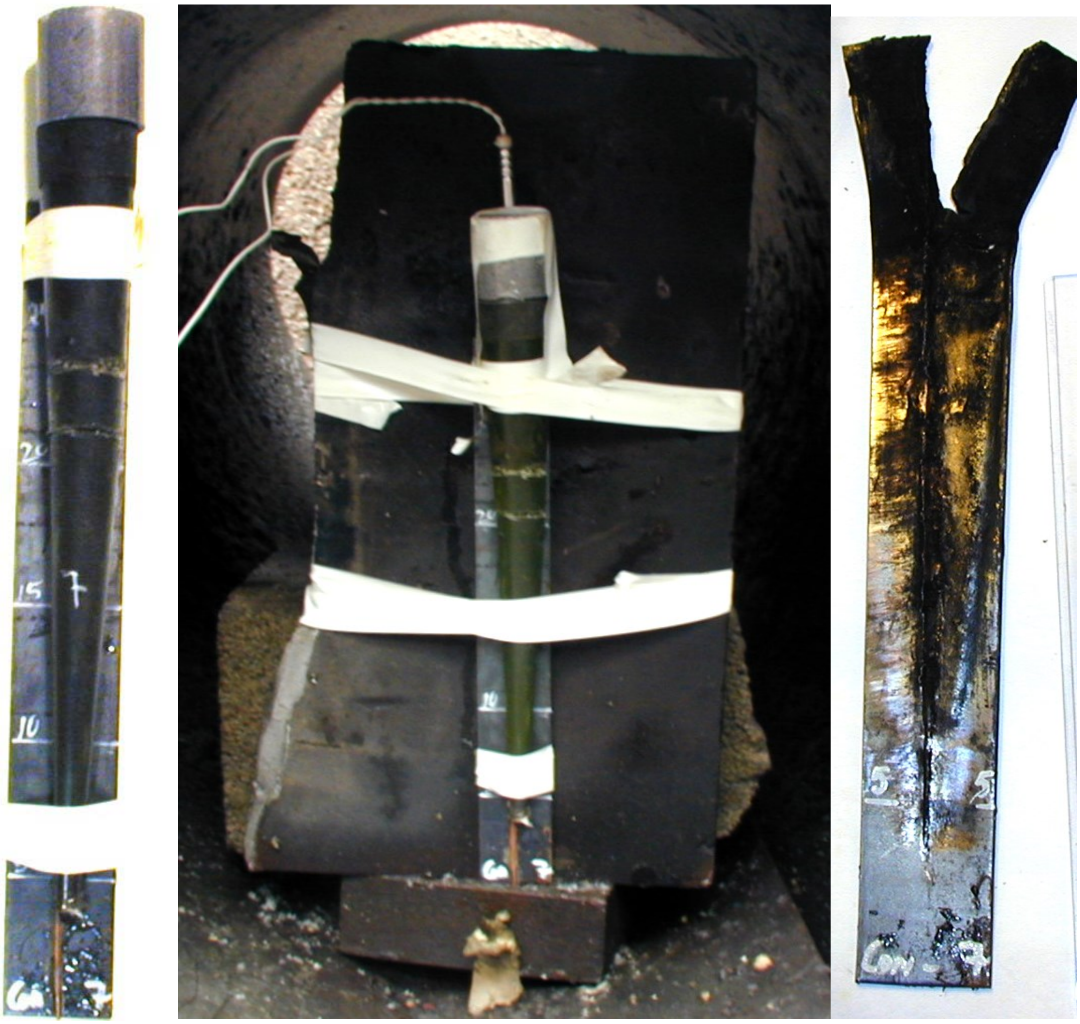

Figure 3.1 Picture of the conical charge No 7 before testing, test setup and witness plate after firing.

3.1.2 Charge No 8

The conical charge No 8 had a small diameter of 5.8 mm. The charge was without mould. Figure 3.2 shows the charge before testing, the setup and the recovered witness plate after testing. The detonation went through the total length of the charge. Since the detonation did not terminate in the charge, this indicates that the critical diameter is smaller than 5.8 mm.

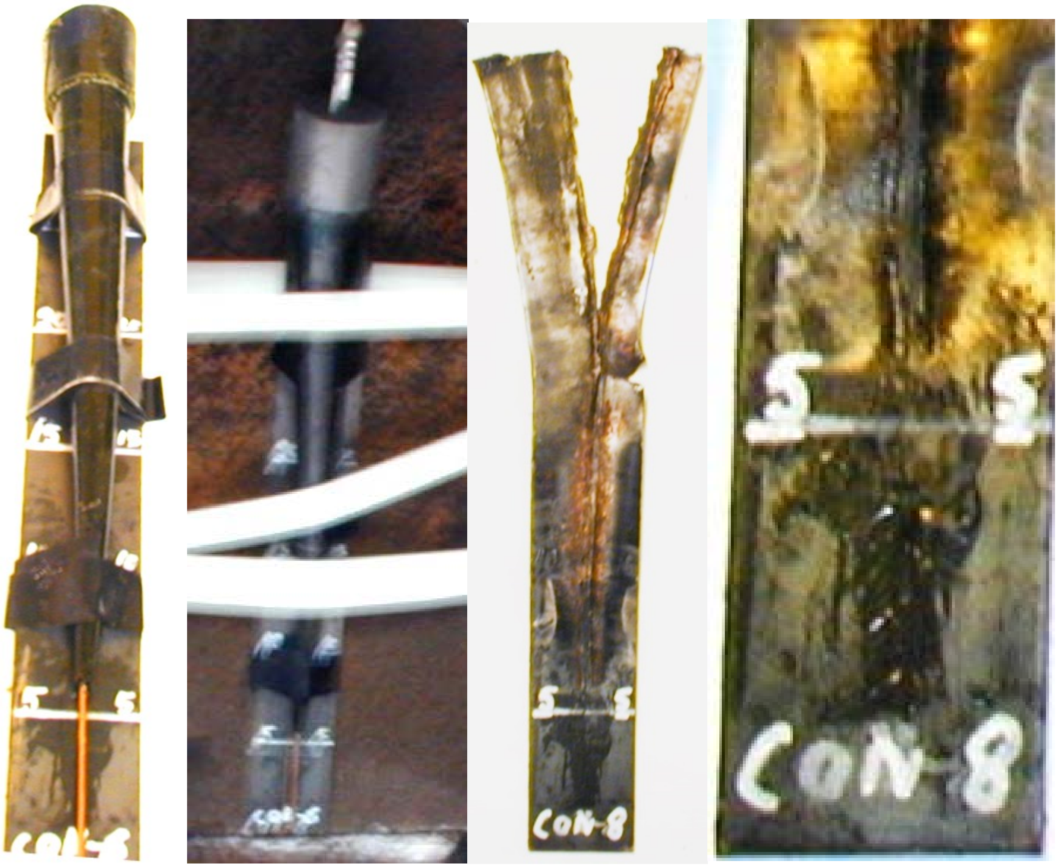

Figure 3.2 Pictures of the conical charge No 8: Before testing, the setup and the witness plate after firing.

3.1.3 Charge No 9

The conical charge No 9 was released from the mould. However it was missing the part of the cone with diameter smaller than 9.8 mm. Figure 3.3 shows pictures of the test item, the setup for testing and the recovered witness plate after firing. The detonation went through the complete charge and did not stop in the charge. Critical diameter is then less than 9.8 mm.

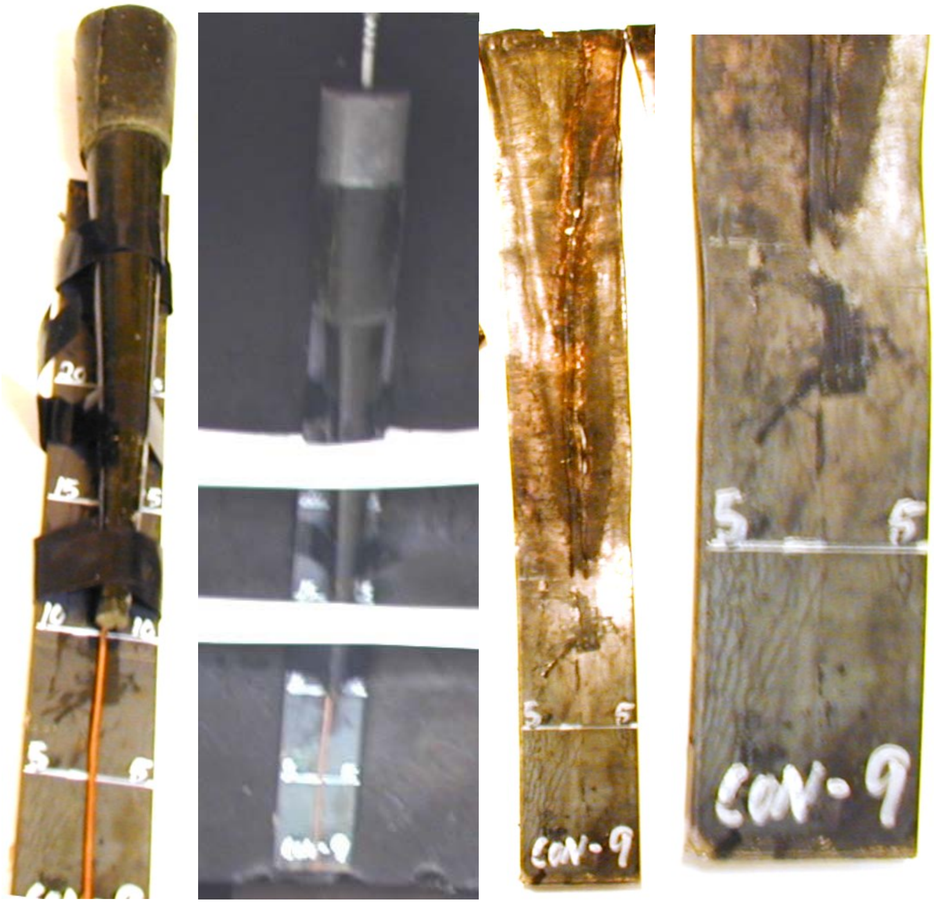

Figure 3.3 Pictures of the conical charge No 9, the setup for the test and the recovered witness plate.

3.1.4 Charge No 10

The last charge to be tested was cast No 10.The cast was impossible to release from the mould. Figure 3.4 shows the charge with booster on the witness plate before testing, the setup and the witness plate after firing. The smallest diameter was 4.0 mm. The detonation did not stop before it reached the end of the charge. This gives a critical diameter of 4.0 mm or less.

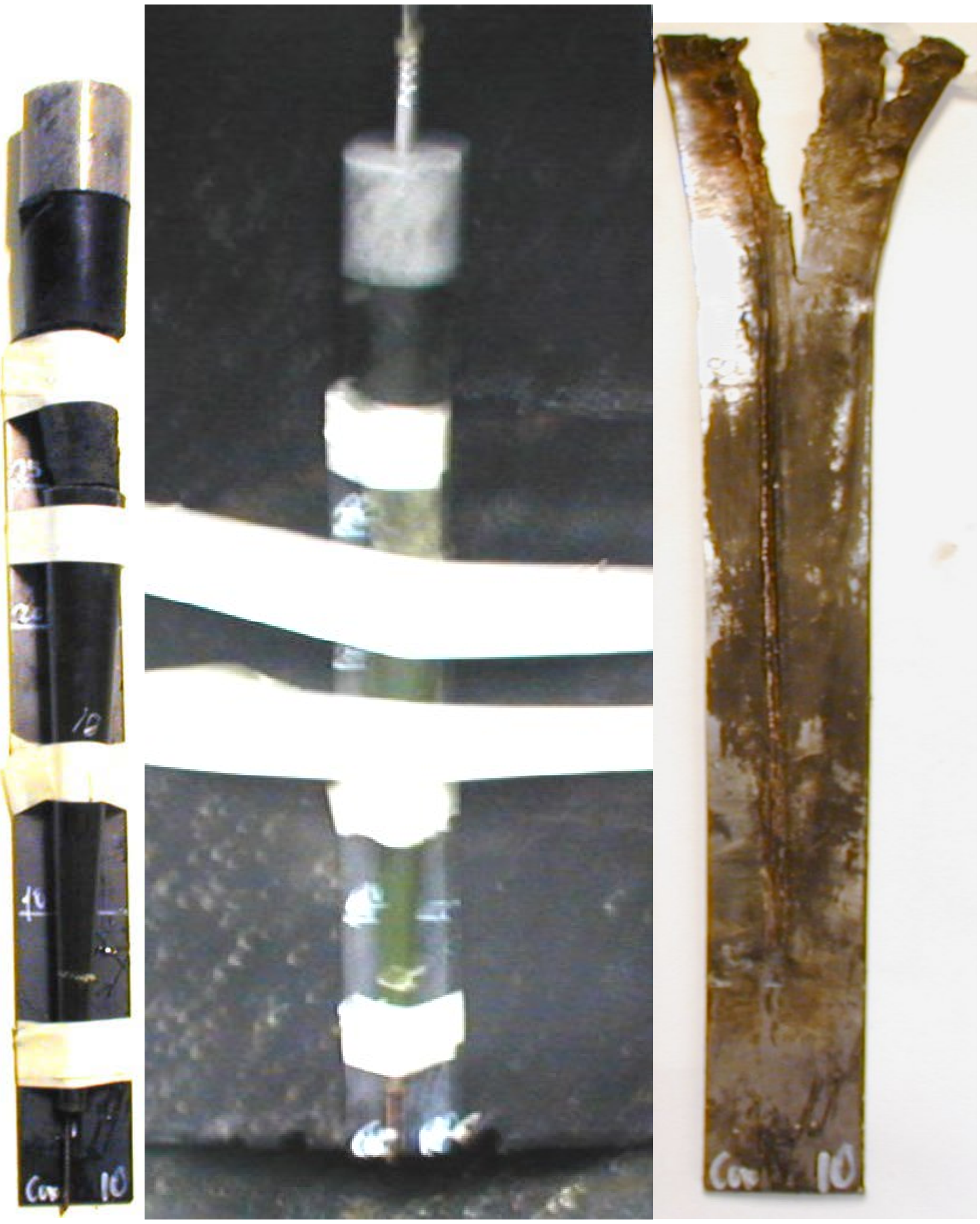

Figure 3.4 Pictures of the conical charge cast No 10 on the witness plate with added booster to the left, the setup for the test and to the right the recovered witness plate.

3.1.5 Comparison conical charges

Figure 3.5 gives a picture of the four witness plates from the firings of the conical charges. None of the tested charges had a termination of the detonation inside the charge. Therefore, from these tests, we could not determine the exact critical diameter for propellant D-07. The only answer the tests gave is that the critical diameter is 4.0 mm or less.

Figure 3.5   Picture of the witness plates from the firings of the 4 conical test items.

3.2   Cylindrical charges

The tested conical charges had too large diameters to get a good or exact determination of the critical diameter. Only two of the conical charges had their smallest diameter in the range of the critical diameter for the solid propellant D-07. We therefore decided to punch some cylindrical charges with small diameters. Four tools with diameters 6, 5, 4 and 3 mm were used to punch cylindrical charges. Stepped test items were produced by gluing together the four cylindrical charges of different diameters that we had available.

3.2.1 Firing No 1

Figure 3.6 shows pictures of the test item, the setup and the witness plate after firing for the first test item. From Figure 3.6 it can be seen that the cylindrical charges have different diameters in the top/bottom and the middle of the charges. The difference is due to the fact that we had to apply some pressure on the piece of propellant that we punched the cylinders from during the punching. Since the solid propellant D-07l was easy to compress during punching (high elasticity), the diameter in the middle of the released cylinder changed. The variation of the diameters for the different cylinders is given in section 2.3. The stepped test item consisting of 4 cylindrical charges glued together and fitted with a HWC booster is shown in the left picture in Figure 3.6.

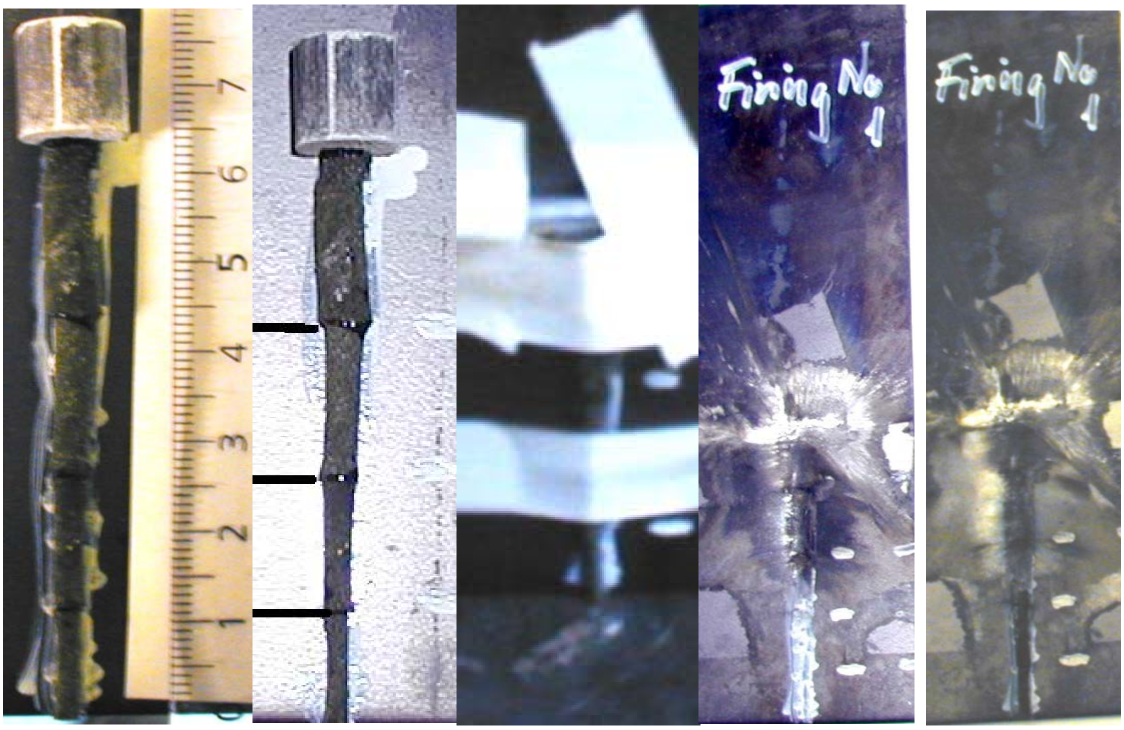

Figure 3.6 Pictures of test item No 1 before firing (to the left), the setup in the centre and to the right the witness plate with and without the recovered part of the test item after firing.

The setup is shown in the central pictures and the witness plate after firing to the right in Figure 3.6. For this firing we recovered a rest of the test item containing two of the cylindrical charges with the smallest diameters and a small piece of the third. From the witness plate we can observe that the reaction terminates in the cylindrical charge with the second largest diameter. The reaction goes through 50% of the length of the cylinder. From these observations the critical diameter is in the range 3.6-3.8 mm.

3.2.2 Firing No 2

Figure 3.7 shows pictures of the test item, the setup and the witness plate after firing for the second test item. The variation of the diameters for the different cylinders is given in section 2.3. The test item consists of 4 cylindrical charges fitted with a HWC booster. Initiation was with detonator No 8. For this firing we did not recover any rest from the test. From the witness plate we can observe that the reaction terminates in the cylindrical charge with the second largest diameter. The reaction goes through 80% of the length of the cylinder. From these observations the critical diameter is in the range 3.6-3.8 mm.

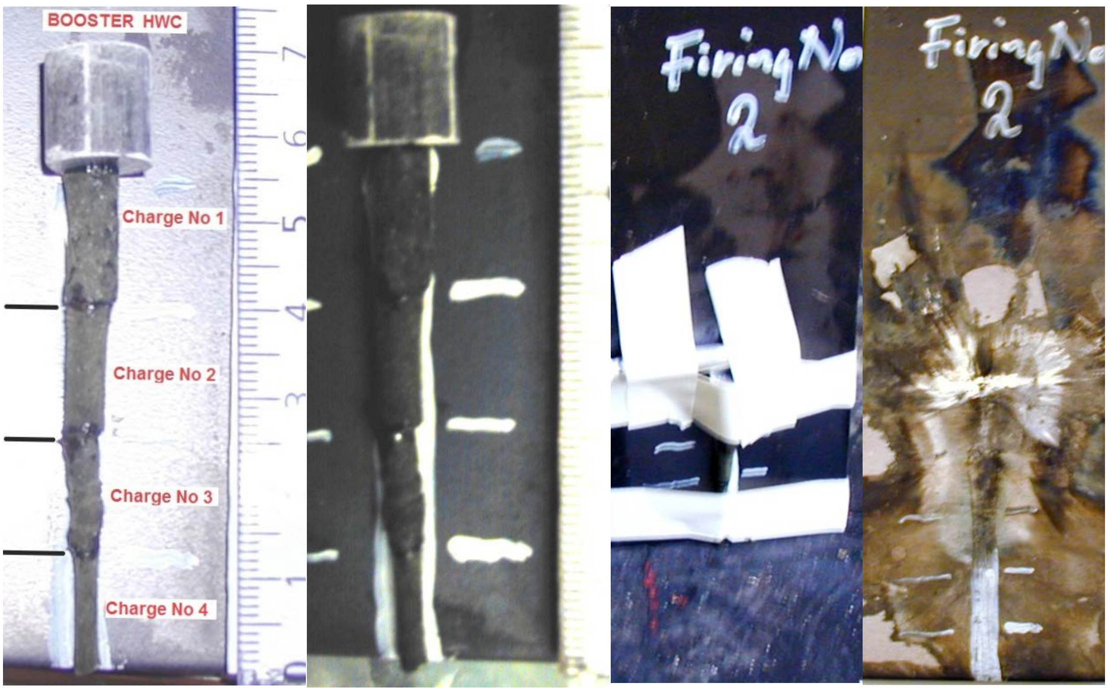

Figure 3.7 Pictures of test item No 2 before firing (to the left), the setup, and to the right the witness plate after firing.

3.2.3 Firing No 3

Figure 3.8 shows pictures of test item No 3, the setup and the witness plate after firing for the third test item. The variation of the diameters for the different cylinders is given in 2.3. The test item consists of 4 cylindrical charges fitted with a HWC booster. Initiation was with detonator No 8. For this firing we recovered a rest of the test containing two of the cylindrical charges with the smallest diameters and a small piece of the third. From the witness plate we can observe that the reaction terminates in the cylindrical charge with the second largest diameter. The reaction goes through 60% of the length of the cylinder. From these observations the critical diameter is in the range 3.6-3.8 mm.

Figure 3.8 Pictures of test item No 3 before firing (to the left), the setup, and to the right the witness plate with and without the recovered part of the test item after firing.

3.2.4 Comparison cylindrical charges

In Figure 3.9 pictures of the witness plates from the three firings are shown. These witness plates show that the reactions terminate in the cylindrical charge No 2, with diameter in the range 3.5-4.1 mm, for all fired test items. For test No 1 and test No 3 the detonation reaction terminated in the middle or after have gone down 50-60% of the length of the charge. For these two test items we recovered more than half of the test items. For firing No 2 the reaction terminated at the end of charge No 2, and we did not recover rests from the test item.

Figure 3.9 Picture of the witness plates from the three firings of cylindrical charges. To the right is a picture of the recovered rests of the test items No 1 and No 3.

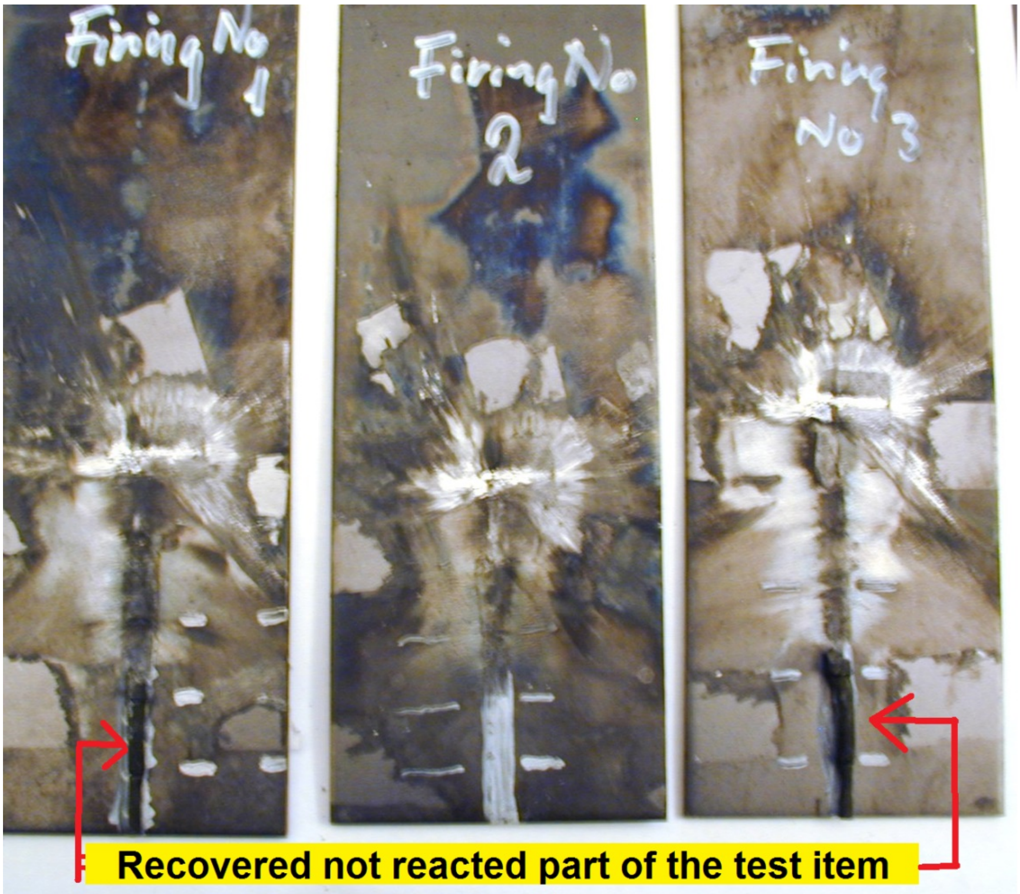

Figure 3.10 Witness plates with recovered rests of test item No 1 and test item No 3.

4 Conclusion

For determination of the critical diameter for the RDX/GAP propellant D-07, four conical charges, with the largest diameter 30 mm and the smallest diameter 3 mm, were casted and tested. None of the tested charges had a termination of the detonation inside the charge. Therefore, from these tests, we could not determine the exact critical diameter for this propellant. Due to filling problems, the smallest diameter of these conical charges varied from 9.8 mm to 3.8 mm.

Four cylindrical charges of different diameters, varying from 5 mm to 2.3 mm, were punched and glued together to form stepped test items. Three stepped test items were tested, and for all of them the detonation terminated in the cylinder with the second largest diameter (3.6-4.1 mm). The critical diameter was determined to fall in the range 3.6 -3.8 mm.

Appendix

A Control report HWC

The control report for the HWC composition used to press boosters for initiation of the different test items is given in Figure-A.1. The applied HWC was manufactured by Chemring Nobel.

KONTROLLRAPPORT B
etter EN 10204 - 3.1

Chemring Nobel

Kjøper/Mottaker	Bestillingsnummer	Rapportnummer
FFI Postboks 25 2007 Kjeller	V/ Gunnar Nevstad Bestillingsdato 16.01.14	045 Kontrolldato 27.01.14
Produsent Dyno Nobel ASA N-3476 Sætre NORWAY	Produksjonsdato 23.01.14	Offentlig oppdragsnummer
Lot nummer DDP14A0068-0002	Mengde 10 kg	
Sprengstofftype **RDX/VOKS/GRAFITT, 94,5/4,5/1**	Leveringsbetingelser/Teknisk underlag For testing	

Analyseresultater for loten

	Sammensetning			Fuktighet og flyktige bestanddeler	Surhet	
	RDX	Voks	Grafitt			
KRAV	94,5 ± 0,5 %	4,5 ± 0,5 %	1,0 ± 0,2 %	≤ 0,1%	≤ 0,02 %	
RESULTAT 03/14	94,4	4,7	0,9	0,0	0,00	0,0

	Uløste partikler på USS No. 60	Vacuum stabilitet	Volumvekt	Kornfordeling %, USS No.		
				> 12	> 18	< 100
KRAV	Ingen	≤ 1,2 ml/g	0,86 - 0,93g/ml	0	≤ 2	≤ 1
RESULTAT 03/14	ingen	0,1	0,89	0	0	1

Kjersti K Berntsen
Kvalitetssjef

Chemring Nobel AS
High Energy Materials
Manager QA

Figure A.1 Control report for the HWC composition used in the applied boosters.

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FFI gjør kunnskap og ideer til et effektivt forsvar.

FFIs VERDIER

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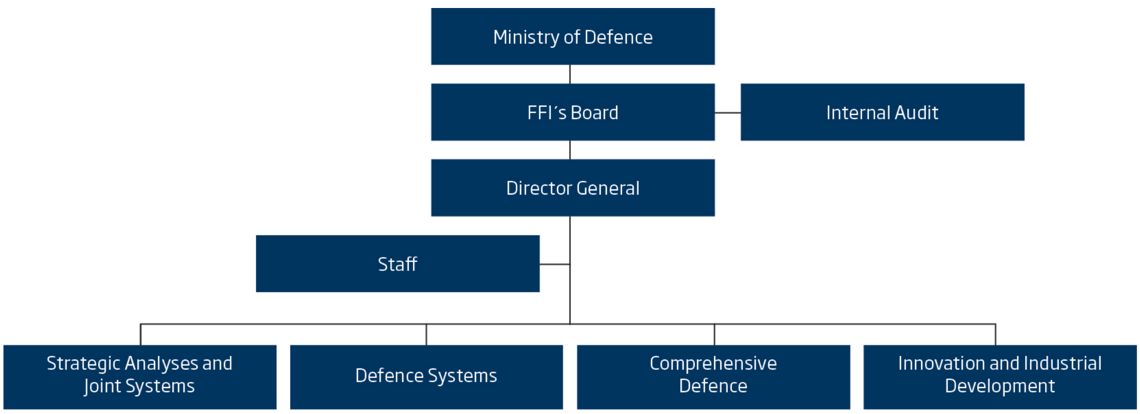

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