FFI RAPPORT

DETERMINATION OF CRITICAL DIAMETER FOR DPX-6

NEVSTAD Gunnar Ove

FFI/RAPPORT-2006/03059

DETERMINATION OF CRITICAL DIAMETER FOR DPX-6

NEVSTAD Gunnar Ove

FFI/RAPPORT-2006/03059

FORSVARETS FORSKNINGSINSTITUTT
Norwegian Defence Research Establishment
P O Box 25, NO-2027 Kjeller, Norway

FORSVARETS FORSKNINGSINSTITUTT (FFI)
Norwegian Defence Research Establishment

P O BOX 25
N0-2027 KJELLER, NORWAY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

REPORT DOCUMENTATION PAGE

1) PUBL/REPORT NUMBER	2) SECURITY CLASSIFICATION	3) NUMBER OF PAGES
FFI/RAPPORT-2006/03059	UNCLASSIFIED	19
1a) PROJECT REFERENCE	**2a) DECLASSIFICATION/DOWNGRADING SCHEDULE**	
FFI-V/873/130	-	

4) TITLE
DETERMINATION OF CRITICAL DIAMETER FOR DPX-6

5) NAMES OF AUTHOR(S) IN FULL (surname first)
NEVSTAD Gunnar Ove

6) DISTRIBUTION STATEMENT
Approved for public release. Distribution unlimited. (Offentlig tilgjengelig)

7) INDEXING TERMS

IN ENGLISH:	IN NORWEGIAN:
a) Pressed PBX	a) Pressbar PBX
b) Density	b) Tetthet
c) Critical Diameter	c) Kritisk diameter
d)	d)
e)	e)

THESAURUS REFERENCE:

8) ABSTRACT

M72 LAW (Light Antiarmour Weapon) has been redesigned with a new warhead for urban warfare. The new warhead is designed for combat of light buildings and therefore needs an explosive filling that is optimized for this purpose. The selected explosive is a pressable composition containing 45 weight percentage aluminium powder. The selected composition DPX-6 is not qualified. A test program in accordance with STANAG 4170 has therefore been effectuated to qualify the composition for use in M72 ASM-RC.

One of the properties the qualification programme required is characterisation of the critical diameter. To determine the critical diameter for DPX-6 pellets of different diameters have been produced by pressing to a density of approximately 98 %TMD. These pellets have then been glued together to charges of approximately 140 mm in length. The charges have been initiated with a detonator No 8 and a RDX/wax booster. From the obtained results the critical diameter for DPX-6 has been determined to 4 mm.

9) DATE	AUTHORIZED BY	POSITION
	This page only	
2006-10-09	Bjarne Haugstad	Director of Research

ISBN 978-82-464-1089-0

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

CONTENTS

DETERMINATION OF CRITICAL DIAMETER FOR DPX-6

1 INTRODUCTION

M72 LAW (Light Antiarmour Weapon) has been redesigned with a new warhead for urban warfare. M72 ASM-RC (Anti-Structure Munition Reduced Caliber) has as the name indicates a new warhead for combat of light buildings. This requires a main charge explosive different from that used in shaped charge warheads. The selected explosive DPX-6 is an aluminized PBX which is press-filled into the warhead. This composition has not been qualified, and to be used in weapons it has to be qualified according to STANAG 4170 (1) and accompanying AOP-7 (2). To qualify an explosive composition a large number of tests have to be carried out. One of these tests is determination of the critical diameter. Critical diameter for the explosive charge is important to know to have a reliable initiation steady state detonation. The charge diameter has to be significantly larger than the critical diameter of the explosive filling.

To determine the critical diameter for our selected explosive filling of DPX-6, a press-filled explosive with high content of aluminium, we have pressed pellets of different diameter and seen if they were possible to initiate and that the detonation did continue through the total length of the charge.

2 EXPERIMENTALLY

All pellets were produced from the same Charge of explosive Ch. 06/05. The control report given by the manufacturer DYNO Nobel ASA is given in Appendix A.

The pellets with the largest diameters were pressed at Nammo Raufoss. Applied pressure force were 2000 kg, 1100 kg and 900 kg for the pellets with diameter of respectively 9.97 mm, 7.16 mm and 6.53 mm. Before the pellets were glued together to obtain a cord of approximately 14 cm they were weighed and measured so that the density could be calculated. Densities calculated from measured dimensions and weights for all pellets are given in Appendix B-D for these three pellet types. ((Appendix B, 9.97 mm), (Appendix C, 7.16 mm), (Appendix D, 6.53 mm)).

Pellets with diameter 5.03 mm were pressed at FFI with a pressure force of 500 kg, piston diameter 5.0 mm and hold time 60 seconds. Density calculated from measured dimensions and weight of these pellets is given in Appendix E.

In addition we did press pellets with diameter 4.11 mm by using a pressure force of 350 kg on 4.0 mm diameter piston with a hold time of 80 seconds. Density calculated from measured dimensions and weight for these pellets is given in Appendix F.

Initiation of the charges was performed with a booster of 12.5 g RDX/Wax (95/5) and a detonator No 8.

3 RESULTS

3.1 Charges with diameter 9.97 mm

Pellets with diameter 9.97 mm pressed by Nammo were measured with respect to height and diameter in addition to weight. These results and calculated density for each pellet are given in Appendix B. Average density of all pellets was found to be 2.045±0.003 g/cm^3. Each charge that was tested contained 8 pellets glued together into one continuous string. Before the charges were placed on the witness plate a 2 mm thick copper wire was glued on the charge and placed against the witness plate. Figure 3.1 shows the test items before testing and how the charges were placed on the witness plates.

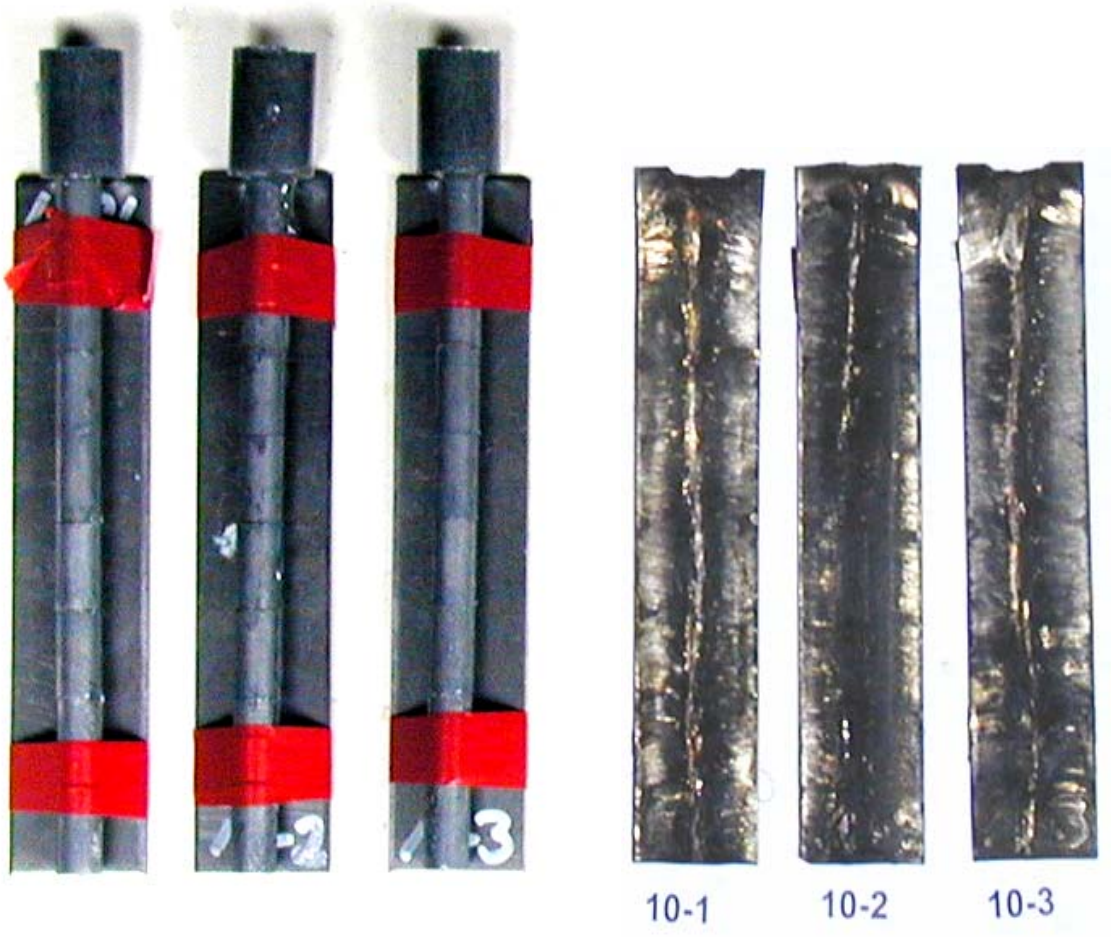

Figure 3.1 Pictures of charges used for testing of critical diameter, charge diameter 9.97 mm. The left picture shows the charges before testing and the right picture shows the witness plates after the charges were initiated.

From the right picture in Figure 3.1 the witness plates show that there has been full detonation in the total length of the charges.

3.2 Charges with diameter 7.16 mm

The next charges to be tested had a diameter of 7.16 mm and contained 9 or 10 pellets glued together. Before the pellets were glued together length and diameter were measured in addition to the weight. These properties and the calculated density for each pellet is given in Appendix C. Average density of all pellets was 2.039±0.013 g/cm^3. In Figure 3.2 is a picture of the charges after they were placed on the witness plates and the booster was glued to the string. Between the charge sting and the witness plate a 2 mm copper wire was placed.

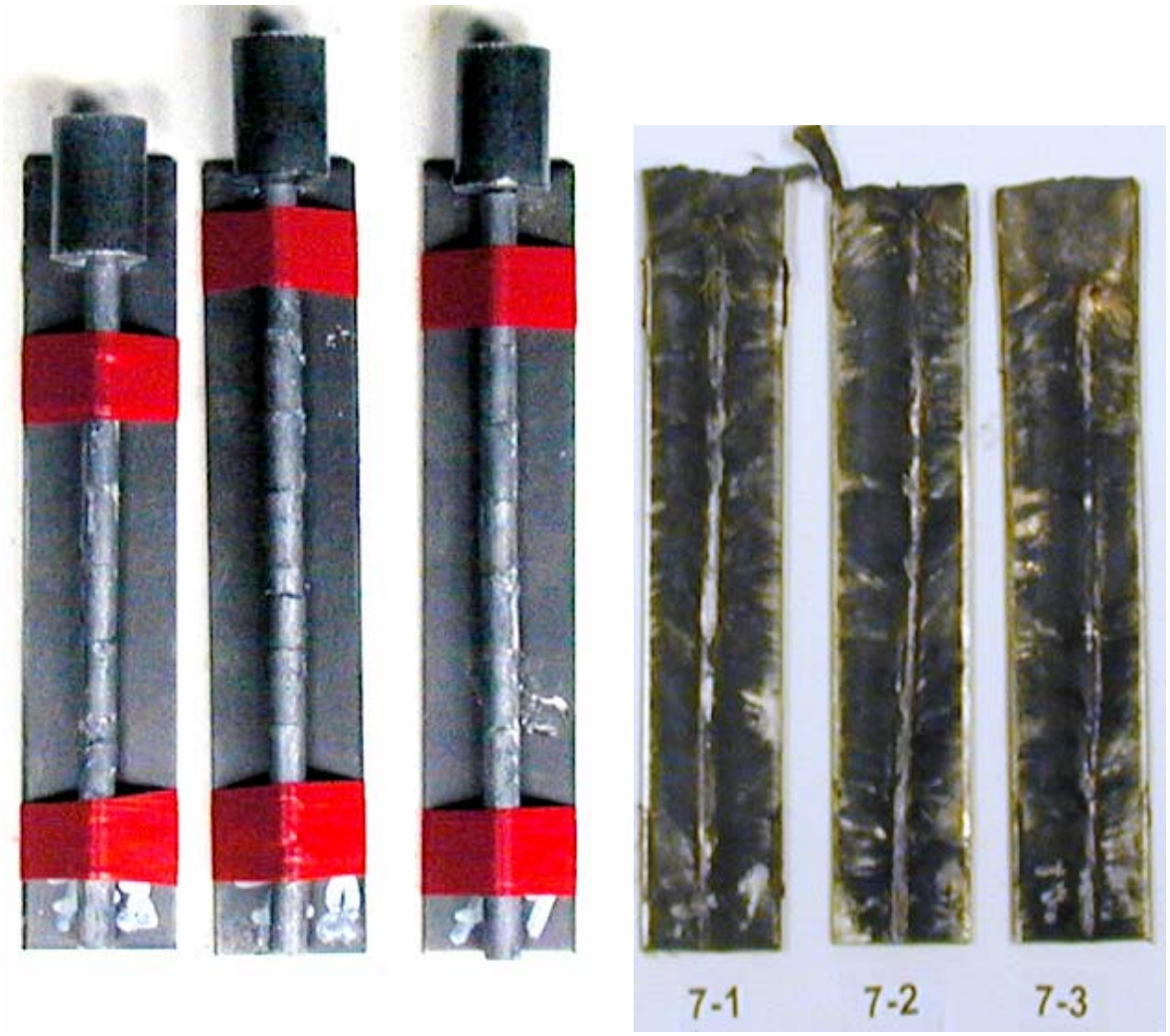

Figure 3.2 Pictures of charges used for testing of critical diameter, charge diameter 7.16 mm. The left picture shows the charges before testing and the right picture shows the witness plates after the charges were initiated.

From the right picture in Figure 3.2, it can clearly be seen that the reaction of the charges have been a full detonation in the total length of the charges. This result indicate that DPX-6 have a critical diameter smaller than 7 mm.

3.3 Charges with diameter 6.53 mm.

The last charges to be tested containing pellets pressed by Nammo had a diameter of 6.53 mm and contained 10 pellets glued together. Before the pellets were glued together length and diameter were measured in addition to the weight. These properties and the calculated density for each pellets is given in Appendix D. Average density of all pellets was 2.060±0.005 g/cm^3.

In Figure 3.3 is a picture of the charges after they were placed on the witness plates and the booster was glued to the string. On the side of the charge sting a 2 mm copper wire was placed. The use of the copper wire give residues of copper on the witness plates in the areas where the charges detonate. In areas where the charge burns there will be no deposition of copper on the witness plate.

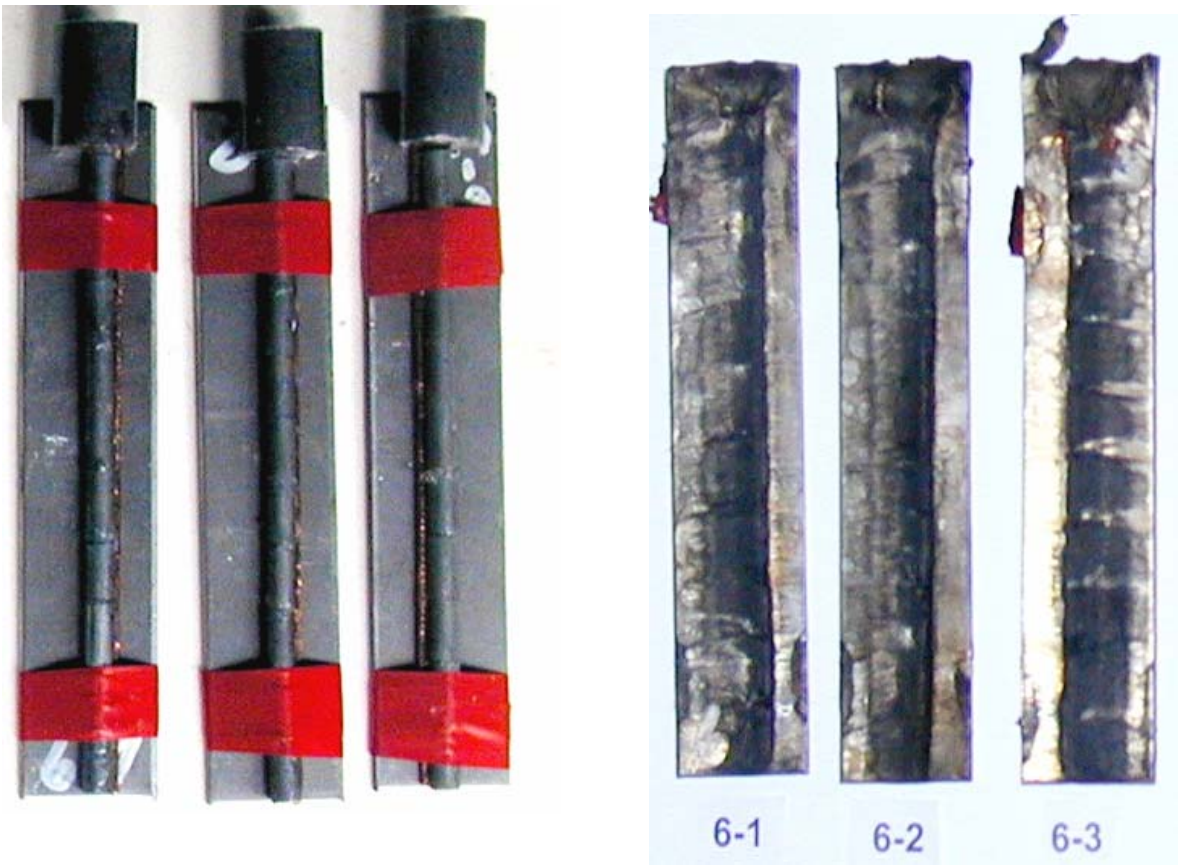

Figure 3.3 Pictures of charges used for testing of critical diameter, charge diameter 6.53 mm. The left picture shows the charges before testing and the right picture shows the witness plates after the charges were initiated.

From the right picture in Figure 3.3 it can bee seen that the reaction of the charges is not equal for all shots. Especially for shot 6-3 the witness plate shows clearly that the reaction changes from detonation to burning in the transition from on pellet to the next. However the reaction does not use very long distance before it goes from burning to detonation. This trend is also partly observed for shot 6-1. For shot 6-2 the reaction in the total length is clearly a detonation.

3.4 Charges with diameter 5.03 mm

The next charges produced and to be tested had a diameter of 5.03 mm and contained 9 pellets glued together. Before the pellets were glued together length and diameter were measured in addition to the weight. These properties and the calculated density for each pellet is given in Appendix E. Average density of all pellets was 2.055 ± 0.009 g/cm^3. Figure 3.4 shows a picture of the charges after they were placed on the witness plates and the booster was glued to the DPX-6 string. On the side of the charge sting a 2 mm copper wire was glued. The use of the copper wire gives residues of copper on the witness plates in the area where the charges detonate.

Figure 3.4 Pictures of charges used for testing of critical diameter, charge diameter 5.03 mm. The left picture shows the charges before testing and the right picture shows the witness plates after the charges were initiated.

From the right picture in Figure 3.4 the witness plates show a full detonation in the total length of the charges. There are fewer indications of changes in reaction when going from one pellet to the next. This result indicates that the critical diameter for DPX-6 is smaller than 5 mm. We therefore decided to produce pellets with diameter smaller than 5 mm.

3.5 Charges with diameter 4.11 mm

The last charges to be tested had a diameter of 4.11 mm and contained 9 pellets glued together. Before the pellets were glued together length and diameter were measured in addition to the weight. These properties and the calculated density for each pellets is given in Appendix E. Average density of all pellets was 2.063 ± 0.019 g/cm^3. Figure 3.5 shows a picture of the charges after they were placed on the witness plates and the booster was glued to the string. On the side of the charge sting a 1.5 mm copper wire was glued.

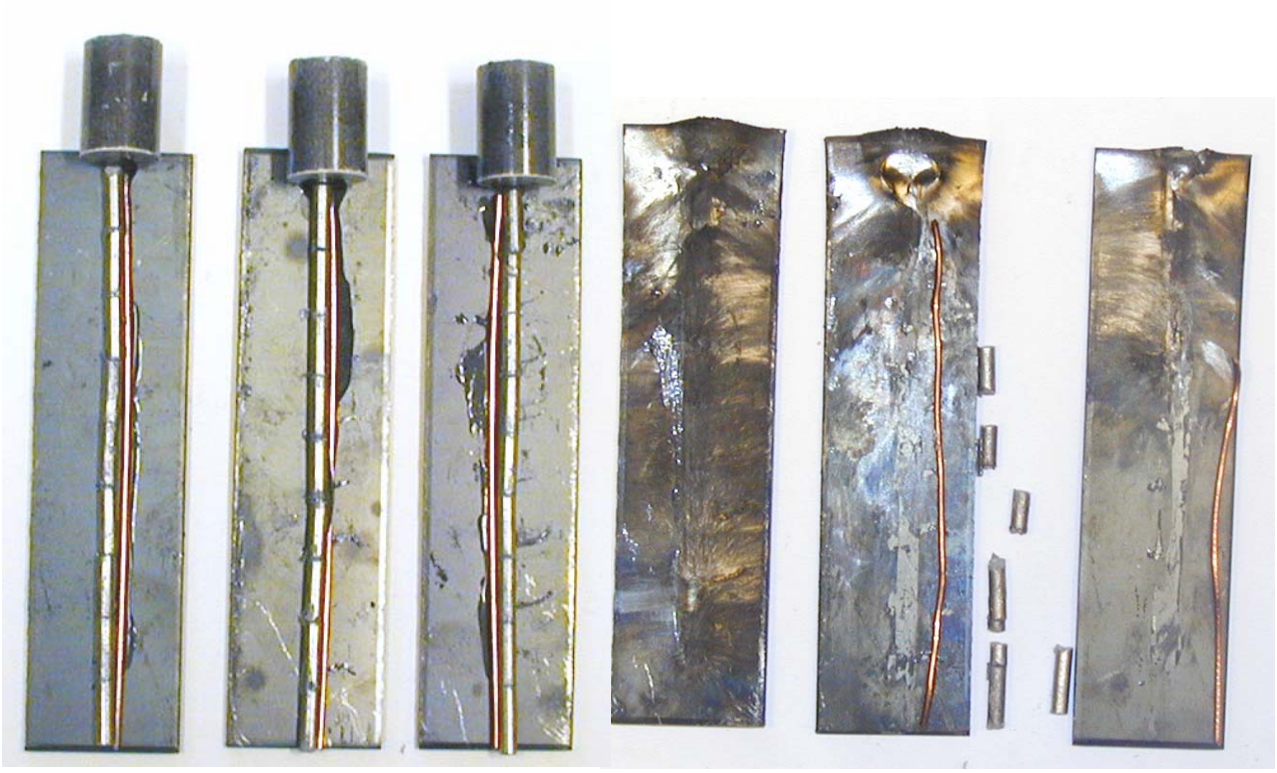

Figure 3.5 Pictures of charges used for testing of critical diameter, charge diameter 4.11 mm. The left picture shows the charges before testing and the right picture shows the witness plates after the charges were initiated.

From the right picture in Figure 3.5 the witness plates show that only for one of the charges we obtained a full detonation in the total length of the charge. For the last two charges the reaction stopped after having reached 2/3 and 1/3 of the charge length. In addition we did find parts of the charges that had not reacted. The number of tested charges is low but the results show that we are very close to the critical diameter of DPX-6. Testing of charges with diameter 3 mm or smaller will not been carried out.

4 SUMMARY

From the charges we have tested we conclude that the critical diameter for DPX-6 pressed to a density of 2.06 g/cm3 or 98% of TMD has a critical diameter close to 4.1 mm. Therefore, to have a reliable initiation and a steady state detonation of charges containing DPX-6 the diameter should not bee smaller than 5 mm.

APPENDIX

A CONTROL REPORT FOR DPX-6

DYNO
High Energy Materials

Kontrollrapport
etter EN 10204 – 2.3

Kjøper / Mottaker FFI v/ Gunnar Nevstad	Bestillingsnummer Telf. G.Nevstad	Rapportnummer RD-25/05
	Bestillingsdato 14.03.06	Kontroll dato 25.11.05
Produsent Dyno Nobel ASA N-3476 Sætre NORGE	Produksjonsdato 24.11.05	Offentlig oppdragsnummer
Lot nummer DDP05K0014E	Mengde 725 gram	
Sprengstofftype DPX-6 (PBXW-11 med 45 % Aluminium (kl 6))	Leveringsbetingelser/Teknisk underlag Kun informative verdier, 45 % aluminium	

Analyseresultater

	Sammensetning				Fuktighet	Volumvekt
	HMX	Aluminium	HyTemp	DOA		
KRAV	Informativ	Informativ	Informativ	Informativ	≤ 0,10 %	Informativ
RESULTAT Ch 06/05	50,0	45,9	1,1	3,0	0,02	0,90

	Granulatfordeling, % gjennom USSS Nr.					
	6 (3350 µ)	8 (2360 µ)	12 (1700 µ)	18 (1000 µ)	25 (710 µ)	40 (425 µ)
KRAV	Informativ	Informativ	Informativ	Informativ	Informativ	Informativ
RESULTAT Ch 06/05	100	100	99	55	28	5

Øyvind H. Johansen
FoU Sjef

Kjell-Tore Smith
Forsker

Figure App 1 Control report for used charge of DPX-6.

B PROPERTIES OF PELLETS WITH DIAMETER 9.97 mm

Pellet No	Weight (g)	Diameter (mm)	Radius (mm)	Length (mm)	Volume (mm^3)	Density (g/cm^3)
1	2.9964	9.97	4.985	18.80	1467.70	2.042
2	3.0914	9.97	4.985	19.37	1512.20	2.044
3	3.0474	9.97	4.985	19.12	1492.68	2.042
4	2.9879	9.97	4.985	18.78	1466.14	2.038
5	3.1018	9.97	4.985	19.45	1518.45	2.043
6	3.0532	9.97	4.985	19.18	1497.37	2.039
7	3.0735	9.97	4.985	19.25	1502.83	2.045
8	3.0151	9.97	4.985	18.87	1473.17	2.047
9	3.0550	9.97	4.985	19.13	1493.47	2.046
10	2.9990	9.97	4.985	18.80	1467.70	2.043
11	3.1105	9.97	4.985	19.46	1519.23	2.047
12	3.0772	9.97	4.985	19.26	1503.61	2.047
13	3.0188	9.97	4.985	18.92	1477.07	2.044
14	3.0326	9.97	4.985	19.03	1485.66	2.041
15	3.0395	9.97	4.985	19.04	1486.44	2.045
16	2.9572	9.97	4.985	18.51	1445.06	2.046
17	3.0743	9.97	4.985	19.24	1502.05	2.047
18	2.9958	9.97	4.985	18.75	1463.80	2.047
19	3.0386	9.97	4.985	19.01	1484.10	2.047
20	3.0710	9.97	4.985	19.23	1501.27	2.046
21	2.9986	9.97	4.985	18.80	1467.70	2.043
22	3.0765	9.97	4.985	19.26	1503.61	2.046
23	3.1216	9.97	4.985	19.56	1527.04	2.044
24	3.0749	9.97	4.985	19.23	1501.27	2.048
25	3.0785	9.97	4.985	19.26	1503.61	2.047
	Average Density					**2.045 ±0.003**

Table App 1 Properties of the DPX-6 pellets with diameter 9.97 mm.

C PROPERTIES OF PELLETS WITH DIAMETER 7.16 mm

Pellet No	Weight (g)	Diameter (mm)	Radius (mm)	Length (mm)	Volume (mm^3)	Density (g/cm^3)
1	1.2197	7.16	3.58	15.07	606.78	2.010
2	1.2351	7.16	3.58	15.11	608.39	2.030
3	1.1935	7.16	3.58	14.62	588.66	2.027
4	1.2273	7.16	3.58	15.00	603.96	2.032
5	1.1819	7.16	3.58	14.40	579.80	2.038
6	1.2386	7.16	3.58	15.06	606.37	2.043
7	1.2062	7.16	3.58	14.50	583.83	2.066
8	1.1977	7.16	3.58	14.50	583.83	2.051
9	1.2063	7.16	3.58	14.73	593.09	2.034
10	1.2230	7.16	3.58	14.90	599.93	2.039
11	1.1908	7.16	3.58	14.52	584.63	2.037
12	1.2178	7.16	3.58	15.07	606.78	2.007
13	1.2040	7.16	3.58	14.67	590.67	2.038
14	1.1885	7.16	3.58	14.53	585.03	2.032
15	1.2024	7.16	3.58	14.62	588.66	2.043
16	1.2001	7.16	3.58	14.68	591.07	2.030
17	1.2117	7.16	3.58	14.64	589.46	2.056
18	1.1878	7.16	3.58	14.56	586.24	2.026
19	1.2112	7.16	3.58	14.74	593.49	2.041
20	1.1808	7.16	3.58	14.40	579.80	2.037
21	1.2092	7.16	3.58	14.58	587.05	2.060
22	1.2107	7.16	3.58	14.66	590.27	2.051
23	1.2131	7.16	3.58	14.75	593.89	2.043
24	1.1848	7.16	3.58	14.39	579.40	2.045
25	1.2233	7.16	3.58	14.82	596.71	2.050
26	1.1971	7.16	3.58	14.51	584.23	2.049
27	1.2056	7.16	3.58	14.60	587.85	2.051
28	1.2209	7.16	3.58	14.76	594.30	2.054
29	1.2115	7.16	3.58	14.86	598.32	2.025
30	1.2407	7.16	3.58	15.21	612.41	2.026
	Average Density					**2.039 ±0.013**

Table App 2 Properties of the DPX-6 pellets with diameter 7.16 mm.

D PROPERTIES OF PELLETS WITH DIAMETER 6.53 mm

Pellet No	Weight (g)	Diameter (mm)	Radius (mm)	Length (mm)	Volume (mm^3)	Density (g/cm^3)
1	0.9665	6.53	3.265	14.07	471.21	2.051
2	0.9698	6.53	3.265	14.09	471.88	2.055
3	0.9619	6.53	3.265	14.00	468.86	2.052
4	0.9868	6.53	3.265	14.26	477.57	2.066
5	0.9475	6.53	3.265	13.72	459.48	2.062
6	0.9595	6.53	3.265	13.90	465.51	2.061
7	1.0151	6.53	3.265	14.68	491.63	2.065
8	0.9806	6.53	3.265	14.23	476.56	2.058
9	0.9517	6.53	3.265	13.80	462.16	2.059
10	0.9720	6.53	3.265	14.11	472.55	2.057
11	0.960	6.53	3.265	13.94	466.85	2.056
12	0.9736	6.53	3.265	14.18	474.89	2.050
13	0.9762	6.53	3.265	14.13	473.21	2.063
14	0.9552	6.53	3.265	13.89	465.18	2.053
15	0.9740	6.53	3.265	14.11	472.55	2.061
16	0.9547	6.53	3.265	13.81	462.50	2.064
17	0.9974	6.53	3.265	14.44	483.60	2.062
18	0.9804	6.53	3.265	14.19	475.22	2.063
19	0.9512	6.53	3.265	13.80	462.16	2.058
20	0.9566	6.53	3.265	13.87	464.51	2.059
21	0.9589	6.53	3.265	13.83	463.17	2.070
22	0.9706	6.53	3.265	14.04	470.20	2.064
23	0.9838	6.53	3.265	14.24	476.90	2.063
24	0.9458	6.53	3.265	13.65	457.14	2.069
25	0.9604	6.53	3.265	13.89	465.18	2.065
26	0.9481	6.53	3.265	13.72	459.48	2.063
27	0.9648	6.53	3.265	13.95	467.19	2.065
28	0.9771	6.53	3.265	14.18	474.89	2.058
29	0.9733	6.53	3.265	14.12	472.88	2.058
30	0.9581	6.53	3.265	13.92	466.18	2.055
Average Density						**2.060 ±0.005**

Table App 3 Properties of the DPX-6 pellets with diameter 6.53 mm.

E PROPERTIES OF PELLETS WITH DIAMETER 5.03 mm

Pellet No	Weight (g)	Diameter (mm)	Radius (mm)	Length (mm)	Volume (cm3)	Density (g/cm^3)
1	0.6567	5.03	2.515	16.06	319.13	2.058
2	0.6679	5.03	2.515	16.47	327.28	2.041
3	0.6495	5.03	2.515	15.88	315.56	2.058
4	0.6483	5.03	2.515	15.98	317.54	2.042
5	0.6797	5.03	2.515	16.72	332.25	2.046
6	0.6908	5.03	2.515	17.04	338.61	2.040
7	0.6497	5.03	2.515	15.93	316.55	2.052
8	0.6528	5.03	2.515	16.04	318.74	2.048
9	0.6716	5.03	2.515	16.47	327.28	2.052
10	0.6930	5.03	2.515	17.09	339.60	2.041
11	0.6566	5.03	2.515	16.10	319.93	2.052
12	0.6645	5.03	2.515	16.31	324.10	2.050
13	0.6531	5.03	2.515	16.06	319.13	2.046
14	0.6576	5.03	2.515	16.03	318.54	2.064
15	0.6503	5.03	2.515	15.93	316.55	2.054
16	0.6337	5.03	2.515	15.44	306.81	2.065
17	0.6338	5.03	2.515	15.48	307.61	2.060
18	0.6716	5.03	2.515	16.34	324.70	2.068
19	0.6547	5.03	2.515	15.94	316.75	2.067
20	0.6363	5.03	2.515	15.52	308.40	2.063
21	0.6998	5.03	2.515	17.09	339.60	2.061
22	0.6883	5.03	2.515	16.78	333.44	2.064
23	0.6793	5.03	2.515	16.54	328.67	2.067
24	0.6660	5.03	2.515	16.33	324.50	2.052
25	0.4994	5.03	2.515	12.18	242.03	2.063
Average Density						2.055 $\pm$0.009

Table App 4 Properties of the DPX-6 pellets with diameter 5.03 mm.

F PROPERTIES OF PELLETS WITH DIAMETER 4.11 mm

Pellet No	Weight (g)	Diameter (mm)	Radius (mm)	Length (mm)	Volume (cm^3)	Density (g/cm^3)
1	0.4207	4.11	2.055	15.54	206.17	2.041
2	0.3997	4.11	2.055	14.42	191.31	2.089
3	0.3933	4.12	2.06	14.15	188.64	2.085
4	0.4089	4.11	2.055	14.83	196.75	2.078
5	0.3994	4.12	2.06	14.41	192.11	2.079
6	0.3960	4.11	2.055	14.38	190.78	2.076
7	0.4154	4.11	2.055	15.08	200.07	2.076
8	0.4047	4.11	2.055	14.99	198.87	2.035
9	0.4101	4.11	2.055	14.98	198.74	2.063
10	0.3878	4.11	2.055	14.03	186.14	2.083
11	0.3854	4.11	2.055	13.96	185.21	2.081
12	0.3917	4.11	2.055	14.53	192.77	2.032
13	0.3919	4.11	2.055	14.29	189.59	2.067
14	0.3899	4.11	2.055	14.02	186.00	2.096
15	0.3995	4.11	2.055	14.57	193.30	2.067
16	0.3653	4.12	2.060	13.18	175.71	2.079
17	0.4079	4.11	2.055	15.01	199.14	2.048
18	0.4107	4.11	2.055	15.13	200.73	2.046
19	0.3597	4.11	2.055	13.10	173.80	2.070
20	0.4134	4.11	2.055	15.34	203.52	2.031
21	0.3939	4.11	2.055	14.52	192.64	2.045
22	0.4085	4.11	2.055	15.00	199.01	2.053
23	0.3982	4.11	2.055	14.50	192.37	2.070
24	0.4348	4.11	2.055	15.94	211.48	2.056
25	0.4139	4.11	2.055	15.02	199.27	2.077
26	0.3939	4.11	2.055	14.34	190.25	2.070
27	0.3942	4.11	2.055	14.29	189.59	2.079
28	0.4388	4.11	2.055	16.32	216.52	2.027
29	0.4119	4.11	2.055	15.11	200.46	2.055
30	0.3794	4.11	2.055	14.00	185.74	2.043
Average Density						**2.063 ±0.019**

Table App 5 Properties of the DPX-6 pellets with diameter 4.11 mm.

References

(1) NATO (AC/326 Subgroup 1) (2001): STANAG 4170 Edition 2 "Principles and Methodology for the Qualification of Explosive Materials for Military Use”.

(2) NATO (AC/326 Subgroup 1) (2004): AOP-7 Edition 2 Rev 1. "Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use".