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Director of Research

PROPERTIES OF DM72 MODULAR CHARGES

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8) ABSTRACT
The DM72 modular charge for 155 mm artillery has been studied with regard to content, dimensions and performance. All parameters and properties are important for the interior ballistics, and necessary to know to be able to calculate the interior ballistic properties for the modules. Grain dimensions such as length, diameter and web size have been measured for a representative numbers of grains. Obtained dimensions are in general accordance with values given by the producers.

Theoretical calculations of the performance of the main propellant have been carried out using the CHEETAH code. Some preliminary testing of the propellant has been carried out in Closed Vessel. The input file of the system for interior ballistic calculations using the IBHVG code is given.

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CONTENT

PROPERTIES OF DM72 MODULAR CHARGES

1 INTRODUCTION

Norway has procured DM72 modular propellant charges for our 155 mm artillery. By choosing modular charges as propelling charges, all the propellant can be used since the modules should all be equal. With the traditional system with bags of different content, all the unused propellant had to be burned. For short range firings as much as half of the propellant could not be used.

By changing the propelling charge, one obtains new internal ballistic properties. To be able to perform theoretical calculations of these internal ballistic properties one needs to know a lot of properties for the modular charges. Some of these properties have been given by the producer. By having good knowledge of the internal ballistic properties for one shell, one can with relative good accuracy predict the properties for another shell. This will reduce the number of firings necessary to obtain information about both internal and external ballistic properties.

Several DM72 modules from Lot RHU99B8217 have been studied to find important parameters necessary for performing internal ballistic calculations. Module weight, the number of grains in the module, grain dimensions such as D (diameter), PD (perforation diameter), WI (Internal web) and WO (Outer web) are among the parameters that have been measured.

Testing of the propellant in Closed Vessel will give us burning properties of the propellant. By performing the testing at different temperatures, the temperature dependence of the burn rate can be determined.

2 EXPERIMENTALLY

2.1 Grain dimensions

Grain dimensions have been measured by different techniques. Grain diameter was measured by use of a micrometer, grain length by use of measuring microscope and the webs from photographs taken in light microscope.

2.2 Closed Vessel testing

A 700 cm^3 Closed Vessel has been used for characterisation of the burning properties of the R 5730 main propellant. To ignite the grains have we used a brown/blue squib and 1 gram of

Black Powder. The pressure has been measured every microsecond with use of a NATO accepted 6215 Kistler Quartz high-pressure Sensor.

2.3 Propellant composition – theoretical calculation

We have not performed any chemical analysis of the content for any of the components that a complete module consists of. Calculations of energy content and product content of different components have been carried out by use of the CHEETAH code version 2.0 (1). The content of the components has been taken from different documents delivered by the producer of the modules. Chapter 3.7 gives the obtained results from the theoretical calculations.

3 RESULTS

3.1 Content of the module

Two modules have been studied with regard to what they contain. The grains have been weighted and the number of grains in each module has been counted. Other parts of the modules that need to be specified in the internal ballistic calculations by use of the IBHVG code (2) have also been weighted. The results are given in Table 3.1.

Figure 3.1 Photography of the cover with some of the modules.

	Module No. I	Module No. II
Total Weight (g)	2796.16	2817.19
Weight of propellant grains (g)	2181.41	2194.46
Weight of case + folio (g)	326.45	328.52
Central ignition tube and propellant (g)	267.38	270.75
Metal folio inside case (g)	3.35	3.23
Number of Grains	597	598

Table 3.1 *Weight of some parts of the modules.*

Module No II contains one grain more than module No. I. However, that does not explain the difference in weight of main propellant grains of 13 grams. The grains in module No II are in average heavier than the grains in module No I. Reference (3) gives two numbers for the weight of the modules: Mass of propelling charge approx. 2.440 kg, and total mass 2.800 kg. The total mass for the modules Norway has received is in average higher than 2800 g. In reference (4), WTD-91 has studied another lot of modules and for these found an average weight of 2856±2 g. This result is significantly higher than the Norwegian result. The difference in weight between the Norwegian procured modules and the WTD-91 modules will influence the muzzle velocity and the pressure in the cannon.

All 6 modules in the received cover have been weighted. The results are given in Table 3.2, and show a variation in the weight, that from the writers view, may be significant if it is representative for rest of the batch.

Module No from top	Weight (g)	Average weight (g)
I	2796.72	
II	2817.19	
III	2812.45	2811.92±7.13
IV	2813.60	
V	2818.35	
VI	2813.20	

Table 3.2 *Weight of measured modules.*

Weight of the grains in module No I is given in Table 3.3. Some grains contained glue from the top and were weighted separately and their weights are not included in the average weight. The obtained average grain weight of 3.6559±0.0061 g is only slightly higher than the weight given by the producer (4) 3.65 g. For module No. II is the average grain weight given in Table 3.4. For this module are the grains heavier than in module No I. In reference (4) WTD-91 has measured an average weight for 100 grains to 363.61±0.43 grams. A result which is lower than what we have found and also lower than given by the producer.

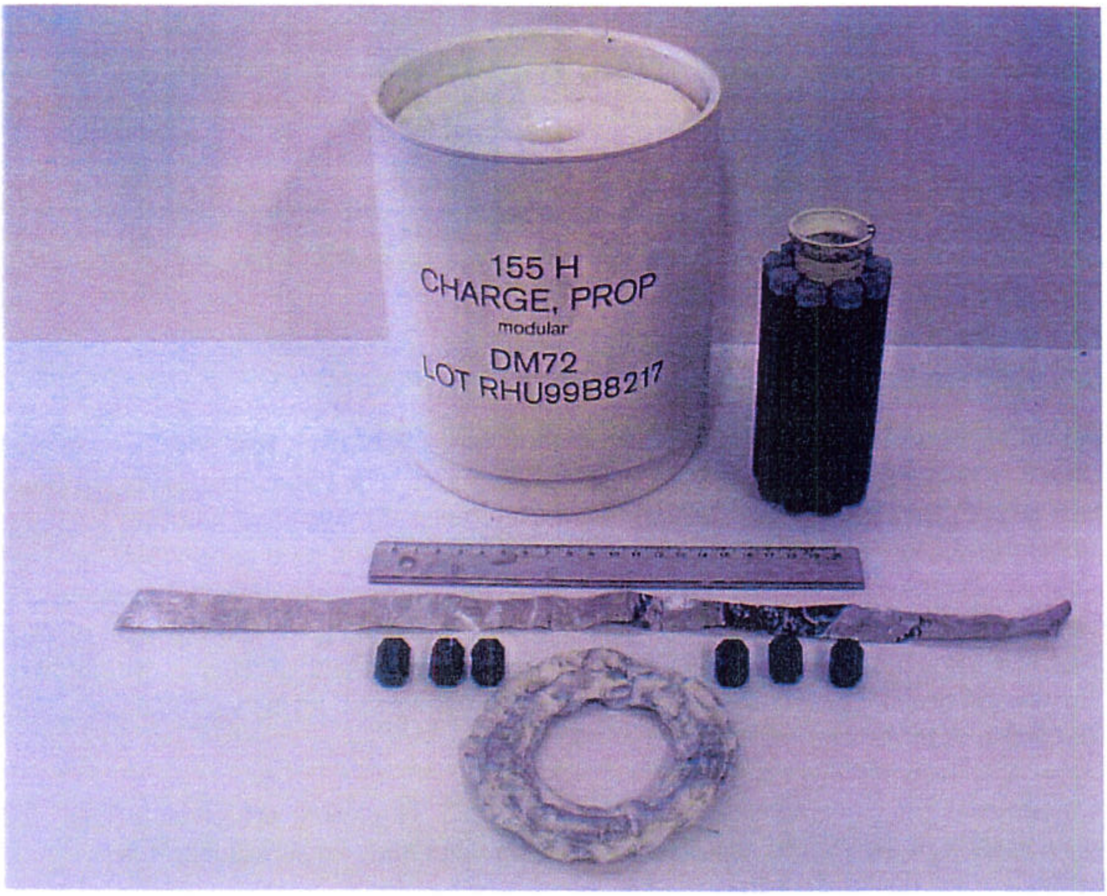

Figure 3.2 Photography of some of the parts in the DM72 module.

No. of grains	Weight of 50 grains (g)	Average grain weight for 50 grains (g)	Average grain weight all grains (g)
50	182.69	3.6538	**3.6559 ±0.0061**
50	182.30	3.6460	
50	183.01	3.6602	
50	182.38	3.6476	
50	182.38	3.6516	
50	183.07	3.6614	
50	182.90	3.658	
50	182.39	3.6478	
50	183.24	3.6648	
50	182.90	3.6580	
50	182.98	3.6596	
21	76.99	3.6662	
26*	93.90	3.6115	

*Contain glue.

Table 3.3 Weight of the grains in module I.

No. of grains	Weight of 50 grains (g)	Average grain weight for 50 grains (g)	Average grain weight for all grains (g)
50	183.06	3.6612	3.6697±0.0079
50	183.24	3.6648	
50	184.13	3.6826	
50	183.82	3.6764	
50	183.78	3.6756	
50	183.22	3.6644	
50	184.12	3.6824	
50	183.75	3.6750	
50	183.34	3.6668	
50	183.18	3.6636	
50	183.26	3.6652	
38	139.01	3.6582	
10*	36.55	3.6550	

*Contain glue.

Table 3.4 Weight of the propellant grains in module II.

3.2 Length of propellant grains

Grain length for grains in module No I and II has been measured by use of a measuring microscope. For both modules 30 grains have been measured. The obtained results are given in Table 3.5. From the results in Table 3.5 we can see that the grains in module No II are slightly longer than the grains in module No. I. For both modules are however the grains shorter than 16.2 mm given by the producer in (5). However, within the standard deviation we have obtained, there will be no significant differences between the producer measured and our measured grain lengths.

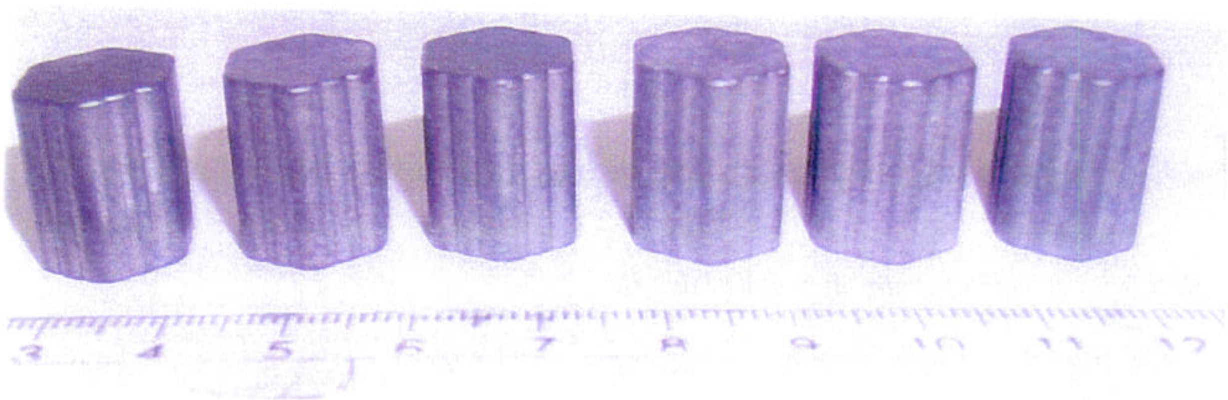

Figure 3.3 Photography of some grains from the main propellant R 5730.

Grain No	Module I		Module II	
	Length (mm)	Average length (mm)	Length (mm)	Average length (mm)
1	16.35		16.13	
2	16.06		16.11	
3	16.26		15.94	
4	16.11		16.09	
5	16.03		16.76	
6	16.21		16.22	
7	15.97		16.24	
8	15.95		16.26	
9	16.07		16.11	
10	16.53		15.93	
11	16.12		16.63	
12	16.13		16.17	
13	16.20		16.06	
14	16.10		16.09	
15	16.11		16.31	
16	16.04		16.12	
17	16.04		16.07	
18	16.09	**16.13±0.13**	16.14	**16.15±0.18**
19	16.04		16.00	
20	16.18		16.12	
21	16.02		15.99	
22	16.16		16.32	
23	16.03		15.99	
24	16.31		16.04	
25	16.06		16.22	
26	16.19		15.88	
27	16.04		16.08	
28	15.97		16.16	
29	16.09		16.09	
30	16.43		16.12	

Table 3.5 Length of grains in module I and II.

3.3 Grain diameter

Grain diameter can be measured in two ways, as the distance between the parallel surfaces in the hexagonal, or as the distance between the corners. Both distances have been measured for grains in module No. I. The results are given in Table 3.6 and 3.7 respectively. The results with regard to the distance between the corners for module No II are given in Table 3.8. For all diameter measurements have all three diagonals been measured and the obtained diameter is given as the average. The producer gives in (5) for the longest distance (corner to corner) 14.2 mm. The obtained results, Tables 3.7 and 3.8 gives a slightly larger diameter than ref. (5), but 14.2 mm is within the obtained standard deviation for both modules.

Grain No.	**Module I**		
	Diameter (mm)	**Average grain diameter (mm)**	**Average diameter all grains (mm)**
1	14.08	13.92	**13.86±0.07**
	13.83		
	13.86		
2	13.79	13.91	
	13.91		
	14.02		
3	13.80	13.77	
	13.78		
	13.74		
4	13.83	13.77	
	13.67		
	13.85		
5	13.84	13.85	
	13.78		
	13.92		
6	13.98	13.89	
	13.77		
	13.92		
7	13.72	13.83	
	13.90		
	13.88		
8	13.81	13.83	
	13.91		
	13.76		
9	13.76	13.85	
	13.86		
	13.92		
10	14.12	14.01	
	13.97		
	13.93		

Table 3.6 *Grain diameter measured as the distance between the parallel sides in the hexagon.*

Grain No.	Module I		
	Diameter at diagonal (mm)	Average grain diameter (mm)	Average diameter all grains (mm)
1	14.28, 14.30, 14.35	14.31	14.24±0.07
2	14.16, 14.22, 14.24	14.21	
3	14.34, 14.29, 14.31	14.31	
4	14.28, 14.24, 14.22	14.25	
5	14.26. 14.30. 14.28	14.24	
6	14.22, 14.18, 14.22	14.21	
7	14.30, 14.26, 14.23	14.26	
8	14.24, 14.27, 14.33	14.28	
9	14.26, 14.28, 14.32	14.29	
10	14.14, 14.22, 14.29	14.22	
11	14.22,14.18, 14.18	14.19	
12	14.32, 14.23, 14.24	14.26	
13	14.38,14.32, 14.35	14.35	
14	14.10, 14.15, 14.09	14.11	
15	14.18, 14.15, 14.25	14.19	
16	14.21, 14.16, 14.22	14.20	
17	14.28, 14.39, 14.31	14.33	
18	14.21, 14.20, 14.20	14.20	
19	14.38, 14.43, 14.41	14.41	
20	14.19, 14.27, 14.18	14.21	
21	14.20, 14.27, 14.20	14.22	
22	14.21, 14.27, 14.20	14.23	
23	14.33, 14.34, 14.32	14.33	
24	14.26, 14.32, 14.26	14.28	
25	14.17, 14.26, 14.17	14.20	
26	14.15, 14.21, 14.17	14.18	
27	14.28, 14.18, 14.22	14.23	
28	14.15, 14.18, 14.17	14.12	
29	14.18, 14.13, 14.11	14.14	
30	14.29, 14.26, 14.24	14.26	

Table 3.7 Diameter of the grains in module I.

3.4 Web and perforation diameter

The webs have been measured for some grains from pictures taken in light microscope. Figures 3.4 – 3.7 give some of the pictures. Figure 3.8 gives a drawing of the end surface for a grain, and the numbering used in the measurements. Tables A.1 to A.5 in the Appendix give all measured webs and distances between the perforations. Table 3.9 gives a summary of the average values for each grain and all measured grains. In (5) the producer gives for propellant R 5730 "mittlere web (Wa)" ca. 2.1 mm, which is slightly bigger than what we have measured. From the results in Table 3.9 it can be seen that the different webs are more or less equal. However, both outer webs are slightly shorter than inside webs. Therefore, if the ignition is homogeneous all over

Grain No.	Module II		
	Diameter at diagonal (mm)	Average grain diameter (mm)	Average diameter all grains (mm)
1	14.32, 14.27, 14.26	14.28	14.25±0.08
2	14.24, 14.27, 14.26	14.26	
3	14.36, 14.27, 14.27	14.30	
4	14.08, 14.05, 14.16	14.10	
5	14.30, 14.21, 14.20	14.24	
6	14.30, 14.26, 14.29	14.28	
7	14.12, 14.06, 14.14	14.11	
8	14.28, 14.29, 14.34	14.30	
9	14.14, 14.15, 14.20	14.16	
10	14.24, 14.20, 14.17	14.20	
11	14.16, 14.19, 14.24	14.20	
12	14.40, 14.39, 14.36	14.38	
13	14.37. 14.36, 14.32	14.35	
14	14.28, 14.25, 14.34	14.29	
15	14.25, 14.26, 14.31	14.27	
16	14.24, 14.30, 14.31	14.28	
17	14.22, 14.27,14.21	14.23	
18	14.35,14.37, 14.34	14.35	
19	14.14, 14.17, 14,18	14.16	
20	14.24. 14.26, 14.29	14.26	
21	14.26, 14.20, 14,20	14.22	
22	14.33, 14.36, 14.29	14.33	
23	14.26, 14.24, 14.19	14.23	
24	14.39, 14.42, 14.48	14.43	
25	14.12, 14.19, 14.25	14.19	
26	14.26, 14.37, 14.31	14.31	
27	14.26, 14.18, 14.18	14.21	
28	14.30, 14.27, 14.23	14.27	
29	14.20, 14.24, 14.23	14.22	
30	14.18, 14.14, 14.19	14.17	

Table 3.8 Diameter of the grain in module II.

the grain surface, burning through will first take place for the two outer rings of perforations. The perforation diameter has been measured to 0.31 mm, and it is only small variations from grain to grain and within each grain. In reference (4) the producer has for the perforation diameter given of 0.4 mm, which is significant larger than what we have measured.

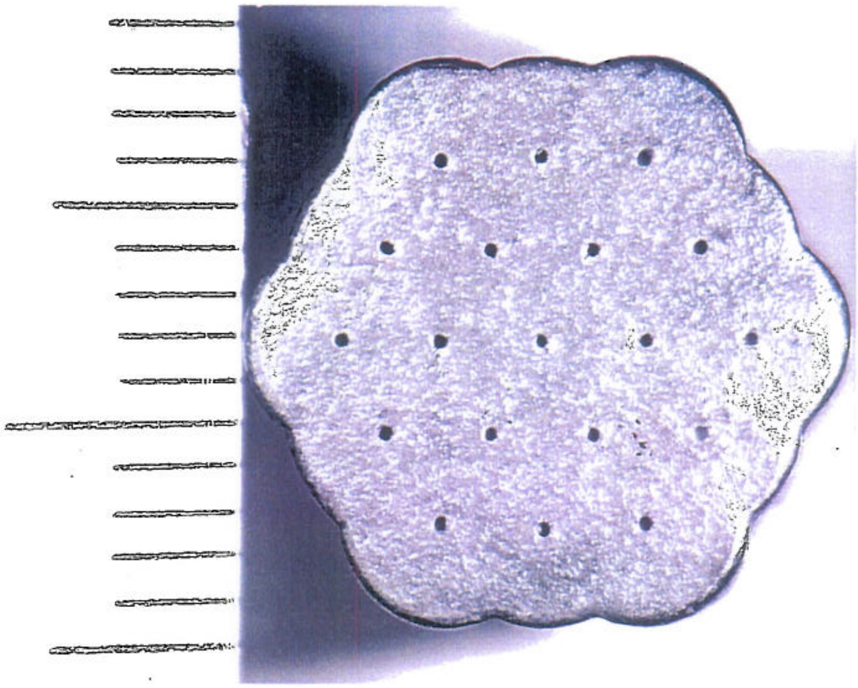

Figure 3.4 Photography of grain A from Module No. I.

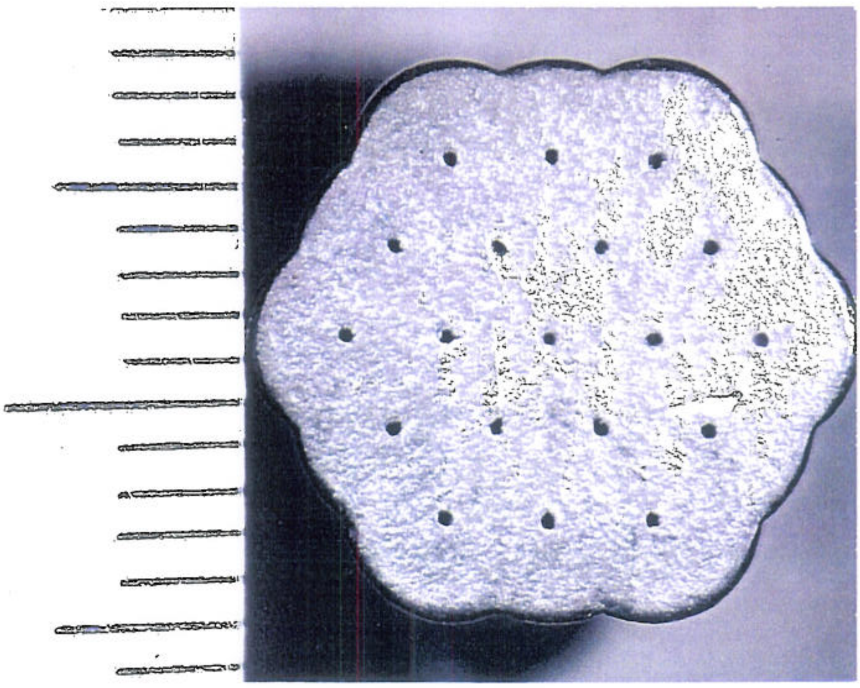

Figure 3.5 Photography of grain B from Module No. I.

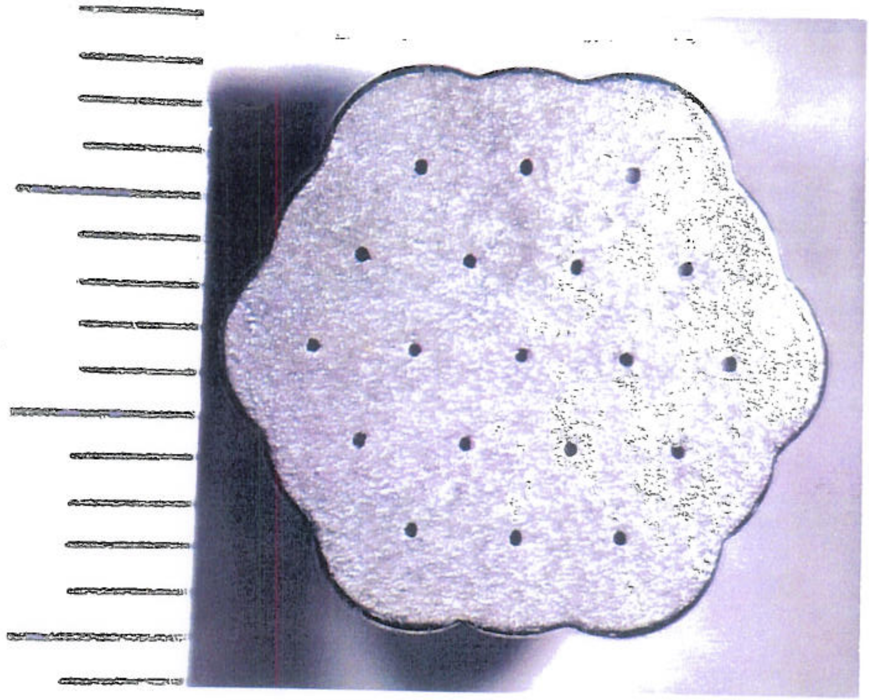

Figure 3.6 Photography of grain C from Module No. I.

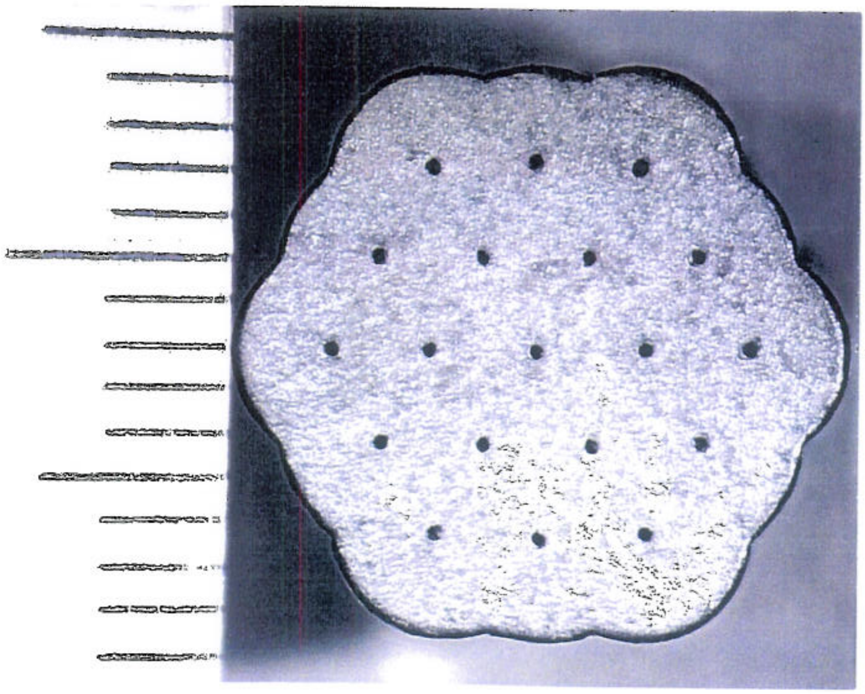

Figure 3.7 Photography of grain E from Module No. I.

Distance (mm)	Photography					Average
	A	B	C	D	E	
W_{O1}	2.104	1.893	2.013	1.780	1.892	1.936
W_{O2}	2.025	1.906	1.964	1.775	1.878	1.910
W_{i1}	2.076	1.999	2.039	2.119	2.070	2.061
W_{M1}	2.021	1.986	1.995	2.018	1.892	1.982
W_{D1}	2.104	2.083	2.079	2.083	2.075	2.085
W_{D2}	2.040	2.074	2.126	1.993	1.921	2.031
W_{D3}	2.140	2.085	2.134	2.113	2.100	2.114
W_{D4}	2.093	2.087	2.140	2.124	2.077	2.104
W_{H1}	2.057	2.005	2.065	2.030	1.926	2.017
W_{H2}	2.053	2.050	2.015	2.104	1.975	2.039
W_{H3}	2.092	1.998	2.025	2.111	2.027	2.051
W_{H4}	2.061	2.018	1.995	2.079	2.029	2.036

Table 3.9 Different average distances (webs) within the grains.

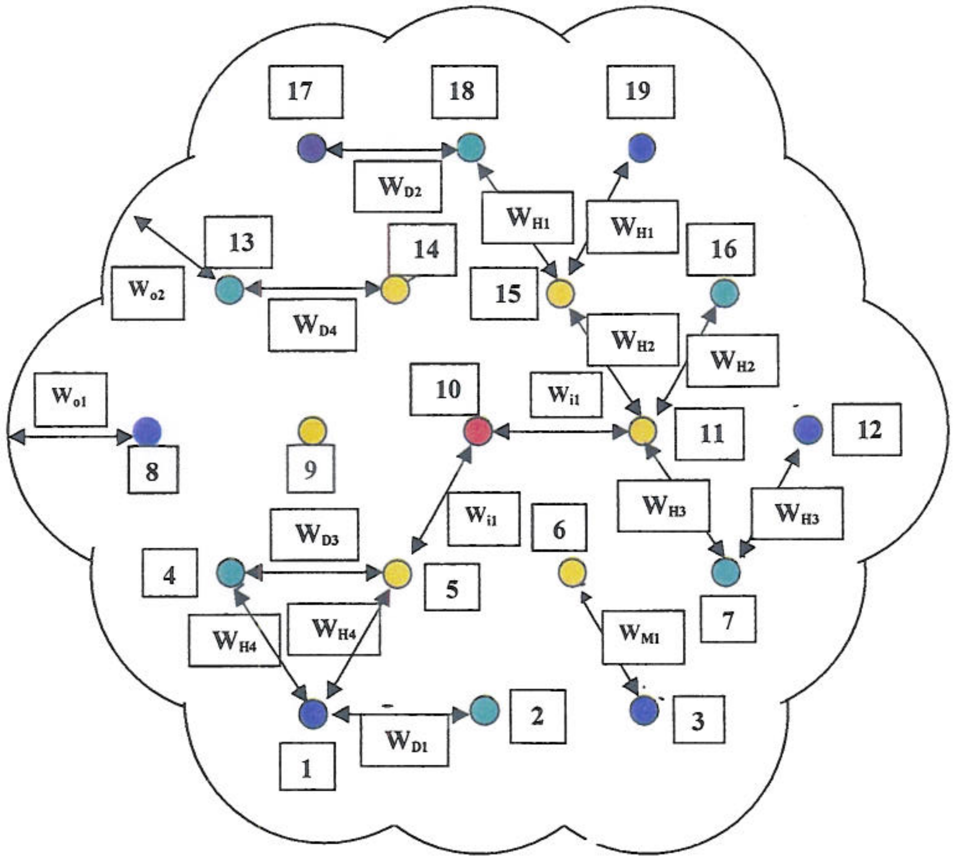

Figure 3.8 Drawing of the R 5730 propellant grain with numbering of the perforations.

3.5 Properties and dimensions of propellant R 5732

Around the central ignition tube, is placed 9 long grains of propellant. They have the same form with respect to end surface geometry and number of perforations as the main propellant R 5730. The difference is the grain length. Table 3.10 gives the results with regard to grain length and diameter. Figure 3.9 gives a photography of the ignition tube with the propellant grains.

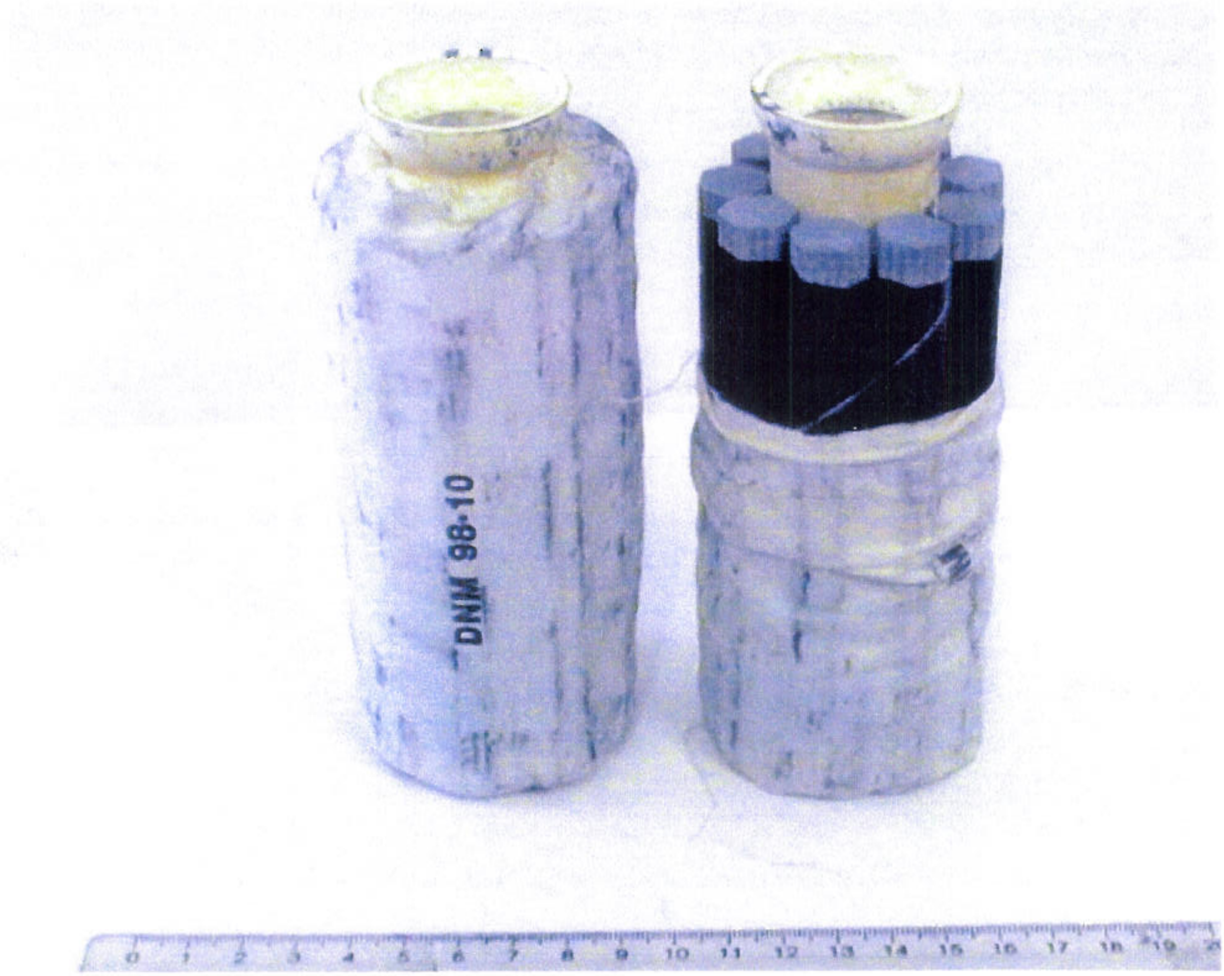

Figure 3.9 Photography of the R 5732 grains and Booster.

Grain No.	Grain length (mm)	Average grain length (mm)	Grain diameter at diagonal (mm)	Average grain diameter (mm)	Average diameter for all grains (mm)
1	113.96		14.01, 14.04, 14.11	14.08	
2	113.62		13.91, 14.02, 13.88	13.94	
3	113.83		14.04, 14.10, 14.03	14.06	
4	113.05		14.08, 14.01, 14.03	14.04	
5	113.72	113.33 ±0.98	14.02,14.00, 14.18	14.07	13.97±0.14
6	113.83		13.90, 13.93, 13.91	13.91	
7	110.68		13.47, 13.48, 13.81	13.59	
8	113.98		14.03. 13.95, 13.97	13.98	
9	113.32		14.06, 14.01, 14.03	14.03	

Table 3.10 Grain dimensions for propellant R 5732.

In reference (6) the producer states that the grain length should be 114 mm and the diameter should be 14.2 mm. The average measured grain length and diameter in Table 3.10 are both smaller than given by the producer.

3.6 Closed Vessel testing

The main propellant will be tested in Closed Vessel for determination of burning properties. So far only two shots have been tested at room temperature. The time-pressure curves for these two shots are given in Figure 3.10.

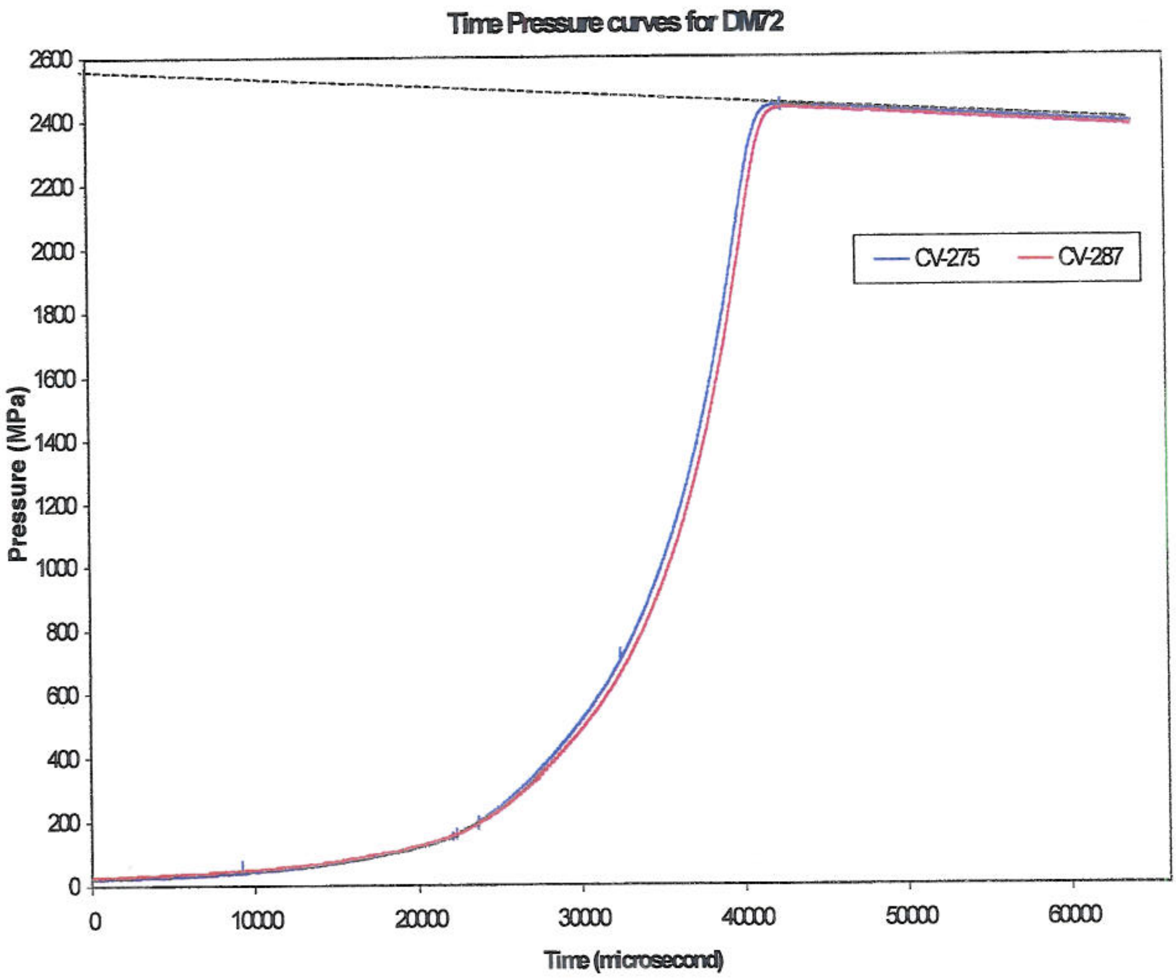

Figure 3.10 Time-pressure curves for two firings of R 5730 propellant.

For firing CV-275 142.6762 gram propellant was used, while firing CV-287 contained 142.456 gram, giving a load density of 0.2038 g/cm^3 and 0.2035 g/cm^3 respectively. Observed maximum pressure for firing CV-275 was 2446 bars and for firing CV-287 2438.5 bars. Both maximum pressures are lower than theoretically calculated. Due to relatively slowly burning propellant, the energy loss to the environment is higher than usual.

3.7 Theoretical calculations

3.7.1 Propellant R 5730/R 5732

References (4, 5) give the nominal content of the R 5730/R 5732 propellants. Propellant R 5730 is the main propellant in the module, while propellant R 5732 is placed around the ignition tube, Figure 3.9. Table 3.11 gives the content used in the calculations. Since we have not performed any chemical analysis, we have used the nominal values including graphite and solvent residues given in (4, 5) .

Ingredient	Content (wt. %)
Nitrocellulose (%N=12.5)	34.9 ± 2.0
Diglycoldinitrate	22.5 ± 1.5
Nitroguanidine	32.5 ± 1.5
Akardit II	0.8 ± 0.1
Diphenylurethan	0.7 ± 0.1
Ethylphenylurethan	0.7 ± 0.2
Hexogen Type A or Type B	7.4 ± 0.6
Potassium sulfate	0.3 ± 0.1
Magnesium Oxide	0.2
Graphite	0.2
Volatile residue	0.85 ± 0.2
Content Non Volatile component	Max 0.6

Table 3.11 Content of propellant R 5730/R 5732

3.7.2 CHEETAH calculations for propellant R 5730/R 5732

The content of the propellant R 5732 given in Table 3.11 has been used for the thermochemical calculations with CHEETAH code version 2.0. Table 3.12 gives the used input data that the CHEETAH library contain and the programme has used. Table 3.13 gives the performance for different loading densities. In Appendix A.2 is the product compositions and concentrations for the different loading densities given.

Product library title: the Blake product library
Executing library command: gas eos, virial
Reactant library title :# Version 2.0 by P. Clark Souers
Input>composition, ncellulose-12.5, 34.9, rdx, 7.4, graphite, 0.2, potass sul, 0.3, ethanol, 0.4, etactate, 0.45, degdn, 22.5, nq, 32.5, akardi ii, 0.8, etphure, 0.7, etcbam, 0.7, weight

Name	% wt.	% mol	% vol.	Heat of Formation (cal/mol)	Standard volume (cc/mol)	Mol. wt.	Formula
RDX	7.34	5.28	6.51	16496	122.99	222.12	$C_3H_6N_6O_6$
NC-12.5%N	34.61	20.4	33.51	-170172	163.77	271.03	$C_6H_{7.58}N_{2.42}O_{9.84}$
Graphite	0.2	2.64	0.15	0	5.72	12.01	C_1
Potassium sulfate	0.3	0.27	0.18	-343451	65.46	174.26	$O_4K_2S_1$
Ethanol	0.4	1.38	0.81	-66444	58.39	46.07	$C_2H_6O_1$
Ethylacetate	0.45	0.81	0.79	-114723	97.9	88.11	$C_4H_8O_2$
DEGDN	22.31	18.17	25.73	-102772	141.09	196.12	$C_4H_8N_2O_7$
NQ	32.23	49.47	29.18	-22228	58.8	104.07	$C_1H_4N_4O_2$
Akardit II	0.79	0.56	1.06	-22706	188.57	226.28	$C_{14}H_{14}N_2O_1$
Ethylphenylurethane	0.69	0.57	1.07	-100382	185.28	193.25	$C_{11}H_{15}N_1O_2$
Diphenyl urethane	0.69	0.46	1.01	-67161	219.35	241.29	$C_{15}H_{15}N_1O_2$

Table 3.12 Content of the propellant performed calculations for.

Heat of formation = -421.3 cal/g
Standard volume = 0.624 $cm^3/g \Rightarrow \sigma = 1.6026\ g/cm^3$
Standard entropy = 0 cal/kg/g
Standars energy = -421.316 cal/g

The elements and percent by mole

C	17.674
H	34.587
N	19.341
O	28.349
K	0.033
S	0.017

The average mol wt = 159.743 g/mol

Rho g/cc	Temp K	Pressure MPa	Impetus J/g	Mol Wt. Gas	Covol cc/g	Frozen Cp/Cv	Phi
0.1	2652.1	114.1	1011.11	21.809	1.141	1.253	1.129
0.15	2655	182.3	1011.43	21.826	1.117	1.255	1.201
0.2	2657.8	258.8	1011.47	21.848	1.091	1.257	1.279
0.25	2660.9	344.4	1011.26	21.878	1.064	1.26	1.362
0.3	2664.6	439.8	1010.79	21.919	1.035	1.264	1.45
0.35	2669.1	545.4	1010.02	21.973	1.005	1.268	1.543
0.4	2674.7	661.8	1008.89	22.044	0.976	1.272	1.64
0.45	2681.6	789.1	1007.33	22.135	0.946	1.277	1.741
0.5	2689.9	927.3	1005.28	22.248	0.916	1.282	1.845
0.55	2699.4	1076.2	1002.67	22.385	0.887	1.287	1.952
0.6	2710	1235.6	999.44	22.545	0.858	1.292	2.06
0.65	2721.2	1404.7	995.54	22.727	0.83	1.297	2.171

Table 3.13 Theoretical interior ballistic properties of R 5730/R 5732 propellants obtained by use of CHEETAH.

3.8 Interior ballistic calculations

In October 1999 a meeting between representatives from WTD 91 and FFI took place in Meppen. An agreement was reached to base the internal ballistic calculations on the IBHVG 506 code, and take as the a starting point the input file given below.

```
$COMM       M3.in  Version : 2 / 28.10.1999
     NO/GE Input Data File
                WTD 91 - Dez 210
                IBHVG2 155 mm, MTLS

$HEAT
  TSHL=.000200
$INFO
  POPT=1,1,1,0  RUN='M109 A3 GE A1,155-mm-MTLS, 3 MODULE'
  GRAD=1  $Lagrange
  DELT=0.0001
$RECO
     RECO=1  RCWT=2380 $Quelle RH 3611/3.85/OMD
$GUN
  NAME='M109 A3 GE, 155-MM 48 ZUG'
  $CHAM=0.018845    $ L-Raum für L15A1 oder DM108A1
  CHAM=0.01987      $ L-Raum für DM 642 oder DM 619A1
  GRVE=0.15748  LAND=0.15494
  G/L=1.446 TRAV=5.132 TWST=20 CLEN=0.564
$PRIM
  NAME='BLK POWDER'   CHWT=0.0069
  GAMA=1.25  FORC=286950  COV=0.00108381  $
  TEMP=2000
$PROP(1)
  NAME='BLK POWDER'   CHWT=0.075  $25gSP/Modul  im ND-Anz□nder
  GRAN='CORD'LEN=0.0050292 DIAM=0.0024892
  RHO=1660.794  GAMA=1.25  FORC=286950
  COV=0.00108381   TEMP=2000
  ALPH=0.0    BETA=1.27    EROS=0.00000
$PROP(2)
  NAME='R5732' CHWT=0.672 GRAN='ROSE'  $.224 pro MOD
  LEN=0.0322 DIAM=0.01416 PD=0.000310 WEB=0.0021
  RHO=1605   GAMA=1.25  FORC=952000
  COV=0.001088 TEMP=2800 NRNG=2
  NTBL=0     ALPH=0.940   BETA=0.0009

$PROP(3)
  NAME='R5730' CHWT=6.726 GRAN='ROSE'   $2.242 pro MOD
  LEN=0.01622 DIAM=0.01416 PD=0.000310 WEB=0.0021 $m Report 09/96/91-320
  RHO=1605.00 GAMA=1.265    FORC=1001200  $Force from Blake Code
  COV=0.001088  TEMP=2800 NRNG=2
  NTBL=0    ALPH=0.904  BETA=0.00101  $ m/sec MPa


$PROP(4)
  NAME='NC CASE' CHWT=0.9750 $ 0.325 Kg/Modul
  GRAN='RECT'
```

```
  LEN=0.360 WDTH=0.36 THCK=0.0025  $DIAM=0.400  WEB=0.002500
  FORC=529000 COV=0.00125 TEMP=2280
  RHO=1040.   GAMA=1.23
  NTBL=0 ALPH=1.20 BETA=0.001

$PROJ
  $NAME='L15A1' PRWT=43.60        $43.545
  NAME='DM642' PRWT=46.95
$RESI
  NPTS=7
  TRAV= 0,   0.01,   0.02,  0.03,  0.04,  0.10,  5.132,
 $ PRES= 20,   30,    25,    18,   12,    8,     6,   $ autom. Ansetzer
  PRES= 10,    15,    12,    10,    9,    8,     6,    $ Reibdr.
  HTFR=0.1
$COMMPMAX
  VARY='BETA'  NTH=3
  TRY1=0.0009 TRY2=0.00110 PMAX=108.9
$COMMPARA
 VARY='PRWT' DECK='PROJ' FROM=45.25 TO=48.75 BY=.25
 $END
```

Several of the above parameters have to be updated for use under Norwegian conditions and with the modules procured by Norway. This will be performed when we have carried out necessary testing of the propellant in Closed Vessel, and determined burn rates of the propellants.

4 SUMMARY

The modules in the studied cover have different weights, from 2796.72 g to 2818.35 g with an average weight of 2812±7 g. Compared with the module weights found at WTD-91, the investigated Norwegian modules have significantly lower weight. The difference will influence the muzzle velocity as well as the maximum pressure.

The propellant grains have in general a reproducible geometry with small variation in webs, perforation diameter and grain length. However, the results obtained for some of the dimensions are different from what is given in the specification from the producer. How much these differences will influence the interior ballistic properties has so far not been studied.

APPENDIX

A.1 WEB DIMENSIONS

Hole no.	Hole distance (mm)	Average hole distance (mm)	Hole No.	Hole distance (mm)	Average hole distance (mm)
10-5	2.130	2.076	5-1	2.018	2.021
10-9	2.061		9-8	2.018	
10-14	1.993		14-17	1.993	
10-15	2.061		15-19	2.061	
10-11	2.104		11-12	2.061	
10-6	2.104		6-3	1.975	
1	2.147	2.104	4	1.975	2.025
8	2,147		13	1.890	
17	2.061		18	2.061	
19	2.061		16	2.104	
12	2.147		7	2.061	
3	2.061		2	2.061	
1-2	2.147	2.104	1-4	2.061	2.061
2-3	2.061		1-5	2.018	
4-5	2.147	2.136	2-5	2.147	
5-6	2.087		2-6	2.104	
6-7	2.173		3-6	1.975	
4-8	1.975	2.092	3-7	2.061	
4-9	2.061		8-13	2.018	2.053
5-9	2.061		9-13	2.061	
5-10	2.130		9-14	2.061	
6-10	2.104		10-14	1.993	
6-11	2.130		10-15	2.061	
7-11	2.130		11-15	2.061	
7-12	2.147		11-16	2.104	
13-17	2.044	2.057	12-16	2.061	
14-17	1.993		13-14	2.104	2.093
14-18	2.079		14-15	2.061	
15-18	2.104		15-16	2.113	
15-19	2.061		17-18	2.018	2.040
16-19	2.061		18-19	2.061	

Table A 1 Distance between perforations for grain 1A

Hole no.	Hole distance (mm)	Average hole distance (mm)	Hole No.	Hole distance (mm)	Average hole distance (mm)
10-5	1.944	1.999	5-1	2.014	1.986
10-9	2.057		9-8	1.953	
10-14	1.988		14-17	1.901	
10-15	2.031		15-19	1.988	
10-11	2.074		11-12	2.074	
10-6	1.901		6-3	1.988	
1	1.901	1.893	4	1.884	1.906
8	1.815		13	1.815	
17	1.815		18	1.815	
19	1.936		16	2.031	
12	1.988		7	1.988	
3	1.901		2	1.901	
1-2	2.074	2.083	1-4	1.988	2.018
2-3	2.091		1-5	2.014	
4-5	2.074	2.085	2-5	2.014	
5-6	2.091		2-6	2.074	
6-7	2.091		3-6	1.988	
4-8	1.944	1.998	3-7	2.031	
4-9	2.074		8-13	2.014	2.050
5-9	2.031		9-13	2.074	
5-10	1.944		9-14	2.031	
6-10	1.901		10-14	1.988	
6-11	1.988		10-15	2.031	
7-11	2.057		11-15	2.074	
7-12	2.048		11-16	2.117	
13-17	2.074	2.005	12-16	2.074	
14-17	1.901		13-14	2.074	2.087
14-18	2.074		14-15	2.031	
15-18	2.005		15-16	2.161	
15-19	1.988		17-18	2.074	2.074
16-19	1.988		18-19	2.074	

Table A 2 Distance between perforations for grain IB.

Hole no.	Hole distance (mm)	Average hole distance (mm)	Hole No.	Hole distance (mm)	Average hole distance (mm)
10-5	2.032	2.039	5-1	1.955	1.995
10-9	2.134		9-8	2.006	
10-14	2.049		14-17	2.015	
10-15	1.963		15-19	2.049	
10-11	2.049		11-12	1.980	
10-6	2.006		6-3	1.963	
1	1.963	2.013	4	1.878	1.964
8	1.878		13	1.793	
17	2.049		18	2.049	
19	2.049		16	2.006	
12	2.091		7	2.049	
3	2.049		2	2.006	
1-2	2.109	2.079	1-4	1.963	1.995
2-3	2.049		1-5	1.955	
4-5	2.134	2.134	2-5	2.049	
5-6	2.134		2-6	1.989	
6-7	2.134		3-6	1.963	
4-8	2.049	2.025	3-7	2.049	
4-9	2.049		8-13	1.963	2.015
5-9	2.091		9-13	2.091	
5-10	2.032		9-14	2.023	
6-10	2.006		10-14	2.049	
6-11	2.049		10-15	1.963	
7-11	2.006		11-15	1.989	
7-12	1.921		11-16	2.049	
13-17	2.023	2.065	12-16	1.989	
14-17	2.015		13-14	2.134	2.140
14-18	2.117		14-15	2.134	
15-18	2.134		15-16	2.151	
15-19	2.049		17-18	2.134	2.126
16-19	2.049		18-19	2.117	

Table A 3 Distance between perforations for grain IC.

Hole no.	Hole distance (mm)	Average hole distance (mm)	Hole No.	Hole distance (mm)	Average hole distance (mm)
10-5	2.130	2.119	5-1	2.018	2.018
10-9	2.147		9-8	1.975	
10-14	2.061		14-17	1.975	
10-15	2.079		15-19	2.018	
10-11	2.147		11-12	2.061	
10-6	2.147		6-3	2.061	
1	1.632	1.780	4	1.675	1.775
8	1.718		13	1.632	
17	1.632		18	1.761	
19	1.890		16	1.890	
12	2.001		7	1.890	
3	1.804		2	1.804	
1-2	2.061	2.083	1-4	2.104	2.079
2-3	2.104		1-5	2.018	
4-5	2.104	2.113	2-5	2.147	
5-6	2.173		2-6	2.121	
6-7	2.061		3-6	2.061	
4-8	2.018	2.111	3-7	2.020	
4-9	2.070		8-13	2.061	2.104
5-9	2.079		9-13	2.061	
5-10	2.130		9-14	2.061	
6-10	2.147		10-14	2.061	
6-11	2.147		10-15	2.079	
7-11	2.147		11-15	2.190	
7-12	2.147		11-16	2.173	
13-17	1.975	2.030	12-16	2.147	
14-17	1.975		13-14	2.061	2.124
14-18	2.061		14-15	2.147	
15-18	2.061		15-16	2.164	
15-19	2.018		17-18	1.975	1.993
16-19	2.087		18-19	2.010	

Table A 4 Distance between perforations for grain ID.

Hole no.	Hole distance (mm)	Average hole distance (mm)	Hole No.	Hole distance (mm)	Average hole distance (mm)
10-5	2.049	2.070	5-1	1.878	1.892
10-9	2.049		9-8	1.878	
10-14	2.049		14-17	1.878	
10-15	2.049		15-19	1.878	
10-11	2.134		11-12	1.878	
10-6	2.091		6-3	1.963	
1	1.878	1.892	4	1.878	1.878
8	1.878		13	1.878	
17	1.878		18	1.707	
19	1.707		16	1.793	
12	1.963		7	2.049	
3	2.049		2	1.963	
1-2	2.049	2.075	1-4	2.049	2.029
2-3	2.100		1-5	1.878	
4-5	2.006	2.100	2-5	2.134	
5-6	2.160		2-6	2.100	
6-7	2.134		3-6	1.963	
4-8	1.963	2.027	3-7	2.049	
4-9	1.963		8-13	1.878	1.975
5-9	2.091		9-13	1.963	
5-10	2.049		9-14	1.989	
6-10	2.091		10-14	2.049	
6-11	2.134		10-15	2.049	
7-11	2.049		11-15	2.015	
7-12	1.878		11-16	1.895	
13-17	1.827	1.926	12-16	1.963	
14-17	1.878		13-14	2.049	2.077
14-18	1.963		14-15	2.134	
15-18	2.049		15-16	2.049	
15-19	1.878		17-18	1.878	1.921
16-19	1.963		18-19	1.963	

Table A 5 Distance between perforations for grain IE

A.2 PRODUCT CONCENTRATIONS

The product compositions and concentrations at different loading desities for the propellants R 5730/R 5732 are given in Table A5 and A6.

Product		Product concentrations (mol/kg)					
		Load density (g/cm^3)					
Name		0.10	0.15	0.20	0.25	0.30	0.35
CO	Gas	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01
N_2	Gas	9.92E+00	9.91E+00	9.89E+00	9.87E+00	9.85E+00	9.82E+00
H_2	Gas	8.97E+00	8.89E+00	8.80E+00	8.69E+00	8.54E+00	8.37E+00
H_2O	Gas	8.70E+00	8.75E+00	8.79E+00	8.84E+00	8.90E+00	8.96E+00
CO_2	Gas	2.24E+00	2.20E+00	2.17E+00	2.14E+00	2.11E+00	2.09E+00
KOH	Gas	2.94E-02	3.03E-02	3.08E-02	3.12E-02	3.15E-02	3.18E-02
H	Gas	2.71E-02	2.09E-02	1.70E-02	1.43E-02	1.22E-02	1.06E-02
NH_3	Gas	2.24E-02	3.83E-02	5.84E-02	8.37E-02	1.15E-01	1.55E-01
H_2S	Gas	1.43E-02	1.45E-02	1.45E-02	1.45E-02	1.44E-02	1.43E-02
HCN	Gas	8.07E-03	1.43E-02	2.25E-02	3.34E-02	4.78E-02	6.64E-02
OH	Gas	6.38E-03	4.95E-03	4.06E-03	3.44E-03	2.98E-03	2.62E-03
K	Gas	4.26E-03	3.41E-03	2.86E-03	2.45E-03	2.12E-03	1.86E-03
CH_2O	Gas	2.38E-03	4.12E-03	6.37E-03	9.28E-03	1.30E-02	1.78E-02
CH_4	Gas	1.57E-03	4.25E-03	9.13E-03	1.73E-02	3.00E-02	4.89E-02
CHO	Gas	1.42E-03	1.92E-03	2.46E-03	3.06E-03	3.76E-03	4.56E-03
formac	Gas	1.38E-03	2.40E-03	3.72E-03	5.46E-03	7.75E-03	1.08E-02
SH	Gas	1.33E-03	1.09E-03	9.39E-04	8.30E-04	7.48E-04	6.83E-04
COS	Gas	1.18E-03	1.31E-03	1.46E-03	1.61E-03	1.80E-03	2.01E-03
HNCO	Gas	1.15E-03	2.06E-03	3.30E-03	5.01E-03	7.34E-03	1.05E-02
NO	Gas	5.18E-04	4.05E-04	3.35E-04	2.87E-04	2.51E-04	2.25E-04
KH	Gas	4.56E-04	4.70E-04	4.80E-04	4.85E-04	4.88E-04	4.89E-04
NH_2	Gas	2.23E-04	2.94E-04	3.67E-04	4.44E-04	5.27E-04	6.19E-04
CH_3	Gas	1.23E-04	2.74E-04	5.13E-04	8.77E-04	1.41E-03	2.17E-03
SO	Gas	1.22E-04	7.80E-05	5.57E-05	4.23E-05	3.35E-05	2.75E-05
SO_2	Gas	1.08E-04	6.91E-05	4.94E-05	3.76E-05	3.01E-05	2.49E-05
S	Gas	3.25E-05	2.08E-05	1.48E-05	1.12E-05	8.81E-06	7.14E-06
ketene	Gas	1.63E-05	4.94E-05	1.20E-04	2.58E-04	5.15E-04	9.75E-04
C_2H_2	Gas	1.37E-05	4.14E-05	1.00E-04	2.15E-04	4.26E-04	7.95E-04
O	Gas	1.24E-05	7.53E-06	5.13E-06	3.73E-06	2.83E-06	2.22E-06
CH_4O	Gas	1.22E-05	3.48E-05	7.92E-05	1.60E-04	2.99E-04	5.29E-04

CS	Gas	7.70E-06	8.62E-06	9.59E-06	1.07E-05	1.19E-05	1.32E-05
KO	Gas	5.74E-06	4.65E-06	3.95E-06	3.45E-06	3.07E-06	2.77E-06
O_2	Gas	4.51E-06	2.68E-06	1.78E-06	1.26E-06	9.39E-07	7.25E-07
S_2	Gas	4.40E-06	2.98E-06	2.23E-06	1.77E-06	1.46E-06	1.25E-06
NH	Gas	4.17E-06	4.31E-06	4.46E-06	4.62E-06	4.81E-06	5.02E-06
NS	Gas	4.02E-06	3.43E-06	3.07E-06	2.84E-06	2.69E-06	2.60E-06
HNO	Gas	3.74E-06	3.87E-06	4.01E-06	4.18E-06	4.38E-06	4.63E-06
CN	Gas	2.24E-06	3.15E-06	4.20E-06	5.44E-06	6.95E-06	8.78E-06
CH_2OH	Gas	1.96E-06	4.38E-06	8.27E-06	1.43E-05	2.34E-05	3.68E-05
$K_2H_2O_2$	Gas	1.54E-06	2.73E-06	4.22E-06	6.10E-06	8.45E-06	1.14E-05
NCO	Gas	1.50E-06	2.11E-06	2.82E-06	3.68E-06	4.74E-06	6.07E-06
C_2H_4	Gas	1.12E-06	5.17E-06	1.69E-05	4.56E-05	1.09E-04	2.36E-04
H_2O_2	Gas	8.51E-07	8.54E-07	8.57E-07	8.65E-07	8.80E-07	9.04E-07
CH_2	Gas	7.55E-07	1.32E-06	2.06E-06	3.03E-06	4.28E-06	5.87E-06
N	Gas	7.00E-07	5.66E-07	4.84E-07	4.28E-07	3.87E-07	3.57E-07
N_2O	Gas	5.25E-07	5.61E-07	6.03E-07	6.52E-07	7.13E-07	7.88E-07
K_2	Gas	4.85E-07	5.22E-07	5.50E-07	5.71E-07	5.88E-07	6.01E-07
CH_3CN	Gas	2.91E-07	1.50E-06	5.53E-06	1.70E-05	4.65E-05	1.17E-04
HO_2	Gas	1.42E-07	1.11E-07	9.27E-08	8.00E-08	7.10E-08	6.47E-08
CS_2	Gas	1.30E-07	1.54E-07	1.81E-07	2.11E-07	2.46E-07	2.89E-07
S_2O	Gas	9.78E-08	6.66E-08	5.02E-08	4.03E-08	3.37E-08	2.93E-08
HNO_2	Gas	2.68E-08	2.79E-08	2.92E-08	3.07E-08	3.27E-08	3.53E-08
NO_2	Gas	9.26E-09	7.52E-09	6.49E-09	5.83E-09	5.40E-09	5.15E-09
C	Gas	3.68E-10	3.95E-10	4.24E-10	4.55E-10	4.91E-10	5.31E-10
C(s)	solid	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*KOH	liquid	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	Gas	4.59E+01	4.58E+01	4.58E+01	4.57E+01	4.56E+01	4.55E+01
Total	Cond.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A 6 Product compositions and concentrations for load densities 0.10 – 0.35 g/cm³.

Product		Product concentrations (mol/kg)					
		Load density (g/cm^3)					
Name		0.40	0.45	0.50	0.55	0.60	0.65
CO	Gas	1.59E+01	1.58E+01	1.57E+01	1.55E+01	1.53E+01	1.51E+01
N_2	Gas	9.78E+00	9.73E+00	9.68E+00	9.62E+00	9.54E+00	9.46E+00
H_2O	Gas	9.02E+00	9.10E+00	9.18E+00	9.27E+00	9.36E+00	9.46E+00
H_2	Gas	8.15E+00	7.88E+00	7.56E+00	7.20E+00	6.79E+00	6.35E+00
CO_2	Gas	2.07E+00	2.06E+00	2.06E+00	2.07E+00	2.09E+00	2.13E+00
NH_3	Gas	2.02E-01	2.58E-01	3.24E-01	3.98E-01	4.79E-01	5.66E-01
HCN	Gas	9.01E-02	1.20E-01	1.55E-01	1.98E-01	2.46E-01	3.00E-01
CH_4	Gas	7.56E-02	1.11E-01	1.55E-01	2.08E-01	2.65E-01	3.25E-01
KOH	Gas	3.20E-02	3.22E-02	3.24E-02	3.25E-02	3.26E-02	3.28E-02
CH_2O	Gas	2.39E-02	3.14E-02	4.06E-02	5.16E-02	6.45E-02	7.94E-02
HNCO	Gas	1.48E-02	2.06E-02	2.83E-02	3.84E-02	5.15E-02	6.81E-02
formac	Gas	1.48E-02	2.00E-02	2.69E-02	3.58E-02	4.73E-02	6.21E-02
H_2S	Gas	1.41E-02	1.39E-02	1.36E-02	1.32E-02	1.28E-02	1.23E-02
H	Gas	9.21E-03	8.09E-03	7.15E-03	6.34E-03	5.63E-03	5.01E-03
CHO	Gas	5.49E-03	6.58E-03	7.83E-03	9.27E-03	1.09E-02	1.27E-02
CH_3	Gas	3.22E-03	4.61E-03	6.37E-03	8.54E-03	1.11E-02	1.39E-02
OH	Gas	2.35E-03	2.14E-03	1.98E-03	1.86E-03	1.76E-03	1.69E-03
COS	Gas	2.25E-03	2.54E-03	2.87E-03	3.25E-03	3.69E-03	4.19E-03
ketene	Gas	1.77E-03	3.08E-03	5.19E-03	8.43E-03	1.32E-02	2.01E-02
K	Gas	1.63E-03	1.44E-03	1.26E-03	1.11E-03	9.78E-04	8.59E-04
C_2H_2	Gas	1.42E-03	2.41E-03	3.92E-03	6.11E-03	9.11E-03	1.31E-02
CH_4O	Gas	8.96E-04	1.46E-03	2.30E-03	3.50E-03	5.15E-03	7.34E-03
NH_2	Gas	7.19E-04	8.30E-04	9.51E-04	1.08E-03	1.22E-03	1.36E-03
SH	Gas	6.32E-04	5.89E-04	5.55E-04	5.26E-04	5.00E-04	4.77E-04
KH	Gas	4.86E-04	4.81E-04	4.72E-04	4.60E-04	4.45E-04	4.27E-04
C_2H_4	Gas	4.74E-04	8.85E-04	1.55E-03	2.53E-03	3.88E-03	5.62E-03
CH_3CN	Gas	2.76E-04	6.09E-04	1.27E-03	2.49E-03	4.63E-03	8.18E-03
NO	Gas	2.06E-04	1.92E-04	1.82E-04	1.76E-04	1.74E-04	1.73E-04
CH_2OH	Gas	5.61E-05	8.35E-05	1.22E-04	1.73E-04	2.40E-04	3.27E-04
SO	Gas	2.32E-05	2.02E-05	1.81E-05	1.66E-05	1.56E-05	1.49E-05
SO_2	Gas	2.15E-05	1.91E-05	1.76E-05	1.68E-05	1.65E-05	1.67E-05
$K_2H_2O_2$	Gas	1.50E-05	1.94E-05	2.48E-05	3.14E-05	3.92E-05	4.86E-05

CS	Gas	1.47E-05	1.64E-05	1.82E-05	2.03E-05	2.24E-05	2.45E-05
CN	Gas	1.10E-05	1.38E-05	1.70E-05	2.09E-05	2.55E-05	3.08E-05
CH_2	Gas	7.89E-06	1.04E-05	1.34E-05	1.69E-05	2.09E-05	2.52E-05
NCO	Gas	7.77E-06	9.96E-06	1.28E-05	1.64E-05	2.11E-05	2.70E-05
S	Gas	5.92E-06	5.02E-06	4.34E-06	3.82E-06	3.41E-06	3.08E-06
NH	Gas	5.26E-06	5.55E-06	5.88E-06	6.25E-06	6.65E-06	7.08E-06
HNO	Gas	4.95E-06	5.35E-06	5.86E-06	6.50E-06	7.28E-06	8.21E-06
NS	Gas	2.55E-06	2.55E-06	2.58E-06	2.65E-06	2.76E-06	2.89E-06
KO	Gas	2.54E-06	2.37E-06	2.24E-06	2.14E-06	2.07E-06	2.02E-06
O	Gas	1.80E-06	1.50E-06	1.29E-06	1.14E-06	1.03E-06	9.42E-07
S_2	Gas	1.09E-06	9.75E-07	8.91E-07	8.29E-07	7.85E-07	7.51E-07
H_2O_2	Gas	9.41E-07	9.95E-07	1.07E-06	1.17E-06	1.30E-06	1.46E-06
N_2O	Gas	8.84E-07	1.01E-06	1.17E-06	1.37E-06	1.64E-06	1.98E-06
K_2	Gas	6.09E-07	6.11E-07	6.08E-07	5.99E-07	5.85E-07	5.66E-07
O_2	Gas	5.81E-07	4.82E-07	4.15E-07	3.69E-07	3.39E-07	3.20E-07
CS_2	Gas	3.39E-07	3.98E-07	4.68E-07	5.50E-07	6.44E-07	7.50E-07
N	Gas	3.35E-07	3.19E-07	3.09E-07	3.03E-07	3.01E-07	3.00E-07
HO_2	Gas	6.05E-08	5.82E-08	5.76E-08	5.86E-08	6.10E-08	6.49E-08
HNO_2	Gas	3.88E-08	4.37E-08	5.02E-08	5.91E-08	7.09E-08	8.64E-08
S_2O	Gas	2.63E-08	2.44E-08	2.34E-08	2.30E-08	2.33E-08	2.40E-08
NO_2	Gas	5.07E-09	5.16E-09	5.42E-09	5.89E-09	6.58E-09	7.54E-09
C	Gas	5.78E-10	6.32E-10	6.93E-10	7.61E-10	8.35E-10	9.11E-10
C(s)	solid	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
*KOH	liquid	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	Gas	4.54E+01	4.52E+01	4.50E+01	4.47E+01	4.44E+01	4.40E+01
Total	Cond.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A 7 Product compositions and concentrations for propellant R-5730/R-5732 at load densities 0.40 – 0.65 g/cm^3.

Literature

(1) Laurence E. Fried, W. Michael Howard, P. Clark Souers (August 20, 1998): Cheetah 2.0 User's Manual, Lawrence Livermore National Laboratory, UCRL-MA-117541 Rev.5.

(2) Ronald D. Andersen and Kurt D. Fickie (Jun 30, 1986): IBHVG2 -- A User's Guide, Ballistic Research Laboratory, Aberdeen proving Ground, MD 210005-5006, Technical Report.

(3) Rheinmetall W&M (03.08.98): Module DM 72 Technical Documentation Technical Manual (Description of Product).

(4) WTD-91,"Chemisch-technishe Untersuchungen, MTLS 155mm Pilotloserprobung", Protokoll Nr.: 09/96/91 – 320, WTA Nr.: E/W44B/N0207/H5329, TA Nr.: 763.

(5) Rheinmetall W&M (03.08.98):Module DM 72 Technical Documentation Technical Data Package (TDP), Technical Terms of Delivery TTD (TL) 1376 - 0573, Part 1; Propellant R 5730 for Propelling Charge 155mm, DM, modular.

(6) Rheinmetall W&M (03.08.98):Module DM 72 Technical Documentation Technical Data Package (TDP), Technical Terms of Delivery TTD (TL) 1376 - 0573, Part 3; Propellant R 5732 for propellant R 5731.