FFI RAPPORT

DETERMINATION OF DETONATION VELOCITY AND PLATE DENT PROPERTIES FOR DPX-6

NEVSTAD Gunnar Ove

FFI/RAPPORT-2006/03060

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

REPORT DOCUMENTATION PAGE

1) PUBL/REPORT NUMBER FFI/RAPPORT-2006/03060	2) SECURITY CLASSIFICATION UNCLASSIFIED	3) NUMBER OF PAGES 31
1a) PROJECT REFERENCE FFI-V/873/130	2a) DECLASSIFICATION/DOWNGRADING SCHEDULE -	

4) TITLE

DETERMINATION OF DETONATION VELOCITY AND PLATE DENT PROPERTIES 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)	DPX-6	DPX-6
b)	Detonation Velocity	detonasjonshastighet
c)	Plate Dent	Plate Dent
d)		
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 need an explosive filling that is optimized for this purpose. The selected explosive is a pressable composition containing 45 wt.% aluminium. 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 characterized is the detonation velocity. To experimentally determine the detonation velocity for DPX-6, pellets with 25.5 mm diameter were pressed to a density of 97.5 %TMD. These pellets were glued together to charges of approximately 400 mm in length, giving a distance between the start and stop sensors of 270 mm. The experimentally determined average detonation velocity for DPX-6 is 7854 m/s, which is approximately 100 m/s lower than calculated by use of Cheetah code.

Detonation pressure determined by use of Plate Dent test gave a pressure slightly above 200 kbar, which is in accordance with theoretically calculated pressure by use of the Cheetah code.

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

ISBN 978-82-464-1091-3

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

CONTENTS

DETERMINATION OF DETONATION VELOCITY AND PLATE DENT PROPERTIES 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 those used in shaped charge warheads. Selected explosive composition DPX-6 is an aluminized PBX which is press filled into the warhead. This composition is not qualified, and before DPX-6 can be used in weapons it has to be qualified according to STANAG 4170 (1) and accompanying AOP-7 (2). Detonation velocity is an important property of explosives since it has influence on the performance. To experimental determination of the detonation velocity have we used a cylindrical charge with two sensors of twisted Copper wires. The first sensor was placed 8 cm from the booster to register the start and the second sensor 4 cm from the opposite end of the charge to register the stop. After measuring the distance between the start and stop and the time the reaction front used between these points we easily can calculate the detonation velocity.

To determine the detonation pressure we used the same charges as for the detonation velocity measurement to perform the Plate Dent test.

2 EXPERIMENTALLY

2.1 Measurement of detonation velocity

The tested DPX-6 charges consist of single pellet glued together to a length of the charges that reduce the uncertainty in the measurement to an acceptable level. The used pellets were pressed by Dyno Nobel ASA. Dimensions, weight and density of each pellet is given in Appendix A. The used material DPX-6 was from Ch. 06/05, and the control report for this Charge is given in Appendix B. We did receive 29 pellets and used them to produce three test items. The first item contained 9 pellets (pellet 1-9) while the last two contained 10 pellets each (10-19 and 20-29). As sensors or measuring probes we used twisted copper wires (3).The Copper wire had a diameter of 0.15 mm and a 0.005 mm thick layer of lacquer. Two wires were twisted together and at the ends was the lacquer removed to obtain contact. We used two measuring probes. The start placed between the second and third pellet and the stop between the two last ones. The position of the start measuring probes was selected to get a stable detonation front/velocity before starting the measurements and the position of the stop was chosen so as to not influence the Dent.

To initiate the charges we use a 16 g RDX/wax booster and a detonator No 8. Picture of the test items is given in Figure 3.3.

To measure the velocity we used the set-up shown in Figure 2.1 in addition to two power supplies and a scope of type: HEWLETT PACKARD 54510A, Digitizing Oscilloscope, 250 MHz 1G Sa/s. When the detonation front passes the start sensor a current will pass through the circuit and a signal is observed on the oscilloscope. The same will happen when the detonation front reaches the stop probe. And it is the time between these two signals that is used to calculate the detonation velocity in addition to the distance between the two sensors.

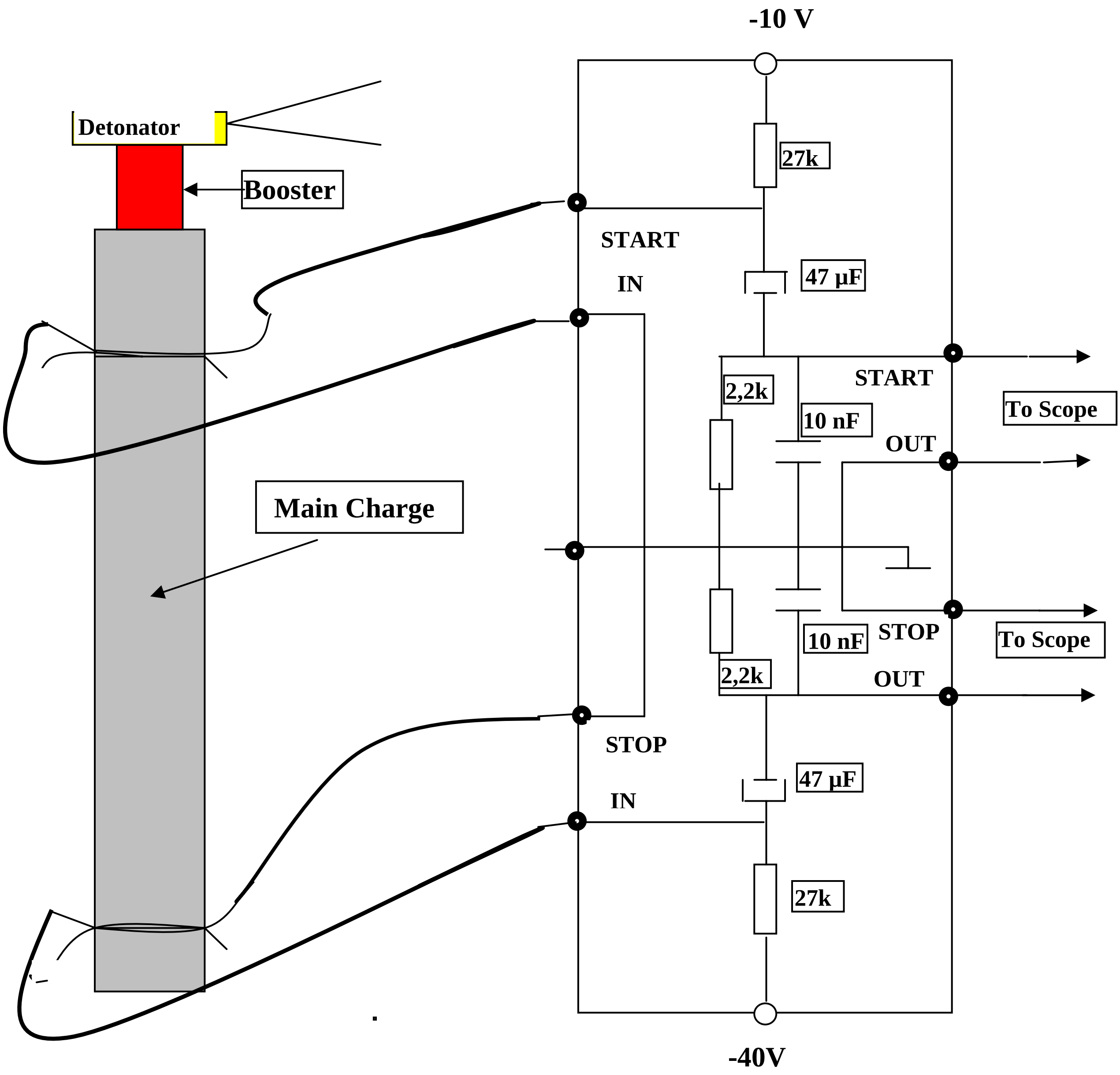

Figure 2. 1 Sketch of the instrumentation for measuring the detonation velocity.

To test the equipment and cabling we used a green detonation cord. Figure 3.2 shows a picture of the test item.

2.2 Plate Dent Test

The Plate Dent test as described in (4) was performed for all three shots. As witness plate was used round steel plate diameter 150 mm thickness 50 mm of ST-37 material.

2.3 Theoretical Calculations

The theoretical calculations were performed with the Cheetah 2.0 code (5).

3 RESULTS

3.1 Theoretical Calculations

To calculate the performance of DPX-6 we have used the Cheetah 2.0 code (5) and the BKWC products database. These calculations have been performed for different densities from TMD (theoretical maximum density) down to 95 %TMD. DPX-6 is a composition that is filled by pressing and normally will not TMD been obtained.

In Appendix C.1 is the complete printout for a standard Cheetah run at TMD given, and it shows that a relatively high portion of the aluminium has not reacted. Appendix C.2 gives the Cheetah summary reports for different densities. Table 3.1 summaries the properties at the C-J conditions for DPX-6 of different density. From the table it can been seen that a reduction in density of the filling by less than 5% gives a reduction in the C-J pressure of close to 20 % or 4.46 GPa. For the same density reduction we have a reduction in detonation velocity of 750 m/s.

The C-J Conditions	**Density (g/cm^3)**									
	2.1014	**2.08**	**2.07**	**2.06**	**2.05**	**2.04**	**2.03**	**2.02**	**2.01**	**2.00**
%TMD	100.00	98.987	98.511	98.035	97.559	97.084	96.608	96.132	95.656	95.180
The pressure (GPa)	23.29	22.27	21.80	21.35	20.91	20.47	20.05	19.63	19.23	18.83
The volume (cc/g)	0.400	0.404	0.406	0.407	0.409	0.411	0.413	0.415	0.416	0.418
The density (g/cc)	2.500	2.477	2.466	2.455	2.444	2.434	2.423	2.412	2.402	2.391
The energy (kJ/cc)	1.86	1.78	1.75	1.72	1.69	1.66	1.63	1.60	1.57	1.54
Temperature (K)	4505	4498	4495	4492	4488	4485	4482	4478	4475	4472
Shock velocity (m/s)	8337	8175	8099	8024	7950	7876	7803	7730	7658	7587
Particle velocity (m/s)	1329	1310	1301	1292	1283	1274	1266	1257	1249	1241
Speed of sound (m/s)	7008	6865	6799	6733	6667	6602	6537	6473	6409	6345
Gamma	5.272	5.242	5.228	5.213	5.197	5.181	5.165	5.148	5.130	5.112

Table 3.1 Calculated properties at C-J conditions for different densities of DPX-6.

In Figure 3.1 has the calculated detonation velocities in Table 3.1 been plotted as function of density. This gives a nearly straight line.

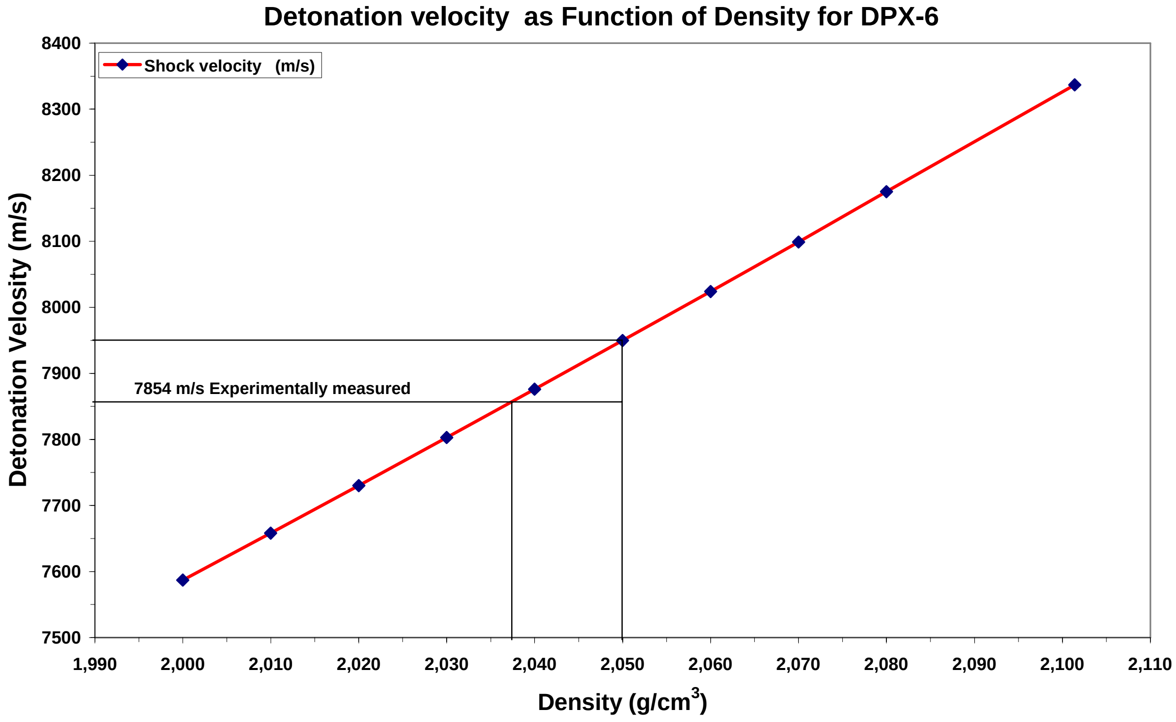

Figure 3.1 Plot of calculated detonation velocity as function of density.

3.2 Measurement of Detonation Velocity

Three charges containing 9 and 10 pellets were glued together with the sensor between the second and third pellets for registration of the start signal and between the last two pellets for registration of the stop signal. Figure 3.3 gives a picture of the three charges before testing. To test that the equipment functioned as expected we used a detonating cord as shown in Figure 3.2.

Shot No	Material	Measuring Distance (cm)	Time (μs)	Velocity (m/s)
1	DPX-6	23.521	29.9	7867
2	DPX-6	27.393	34.9	7849
3	DPX-6	27.465	35.0	7847
4	Det.cord	60.0	82.4	7282
Average detonation velocity DPX-6				7854

Table 3. 2 Results from determination of detonation velocity.

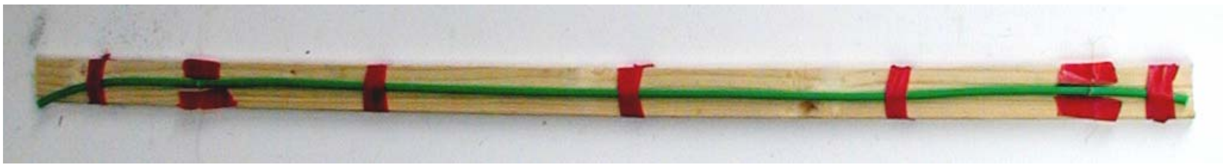

Figure 3.2 Picture of the detonating cord used to test registration equipment and cabling.

The results with regard to distance between the sensors for each charge, the time the detonation front used between start and stop sensors and calculated detonation velocity for all shots is given in table 3.2. The average detonation velocity found for DPX-6 of 7854 m/s is slightly below the calculated velocity of 7950 m/s for a charge with density of 2.05 g/cm^3

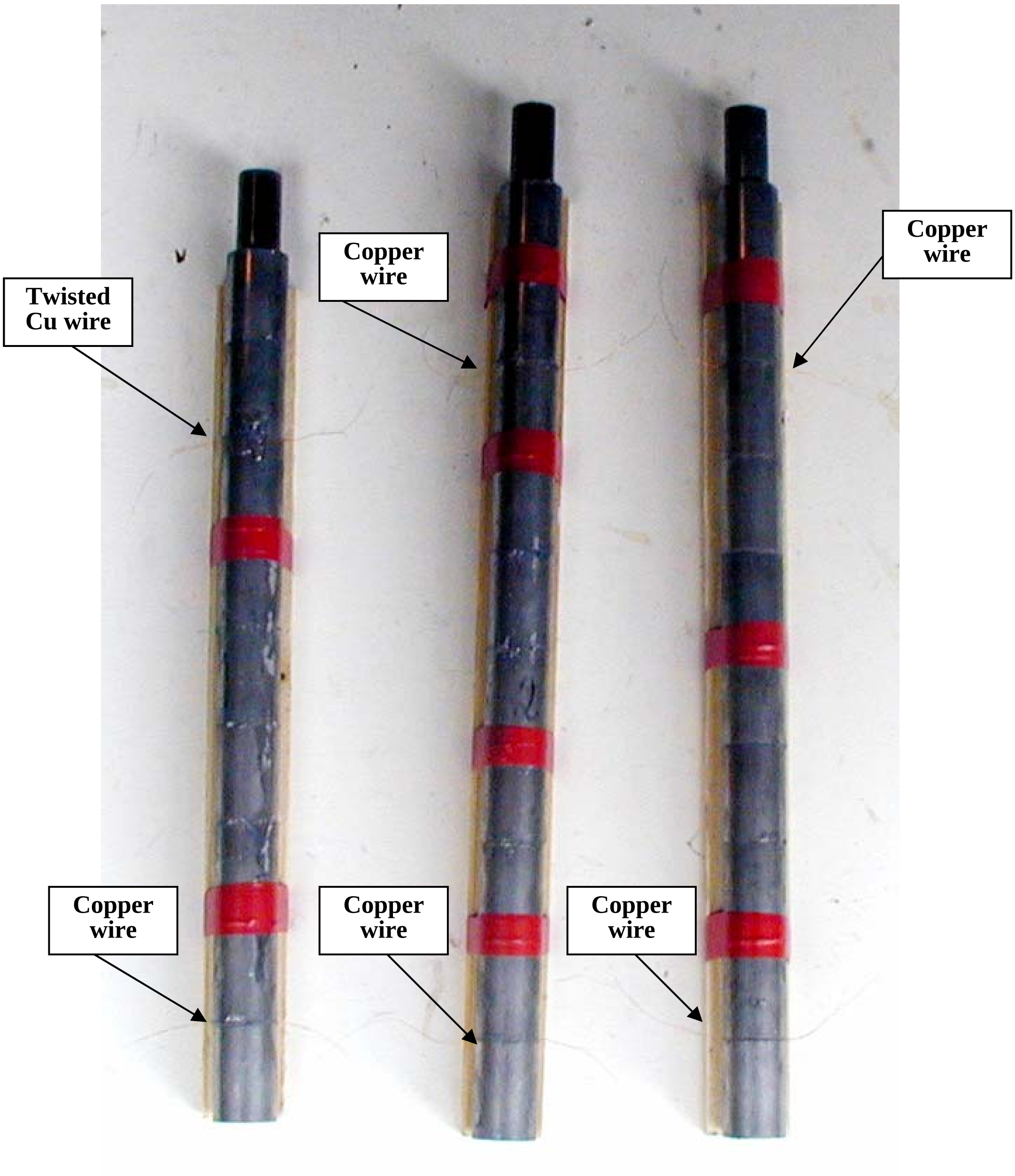

Figure3.3 Picture of the test items used for determination of the detonation velocity.

3.3 Plate Dent Test

The Plate Dent tests give results with respect to pressure performance. The depth of the dent in the witness plate is proportional to the detonation pressure and the diameter of the charge. The results obtained are given in table 3.3. Comparing the results for DPX-6 with earlier tests performed in reference 3 for TNT and other compositions, the obtained Dent is equal to a pressure of approximately 205 kbar. Comparing this result with theoretically calculated pressures in Appendix C.2 or in Table 3.1 gives good agreement between experimentally determined and theoretically calculated J-C pressures.

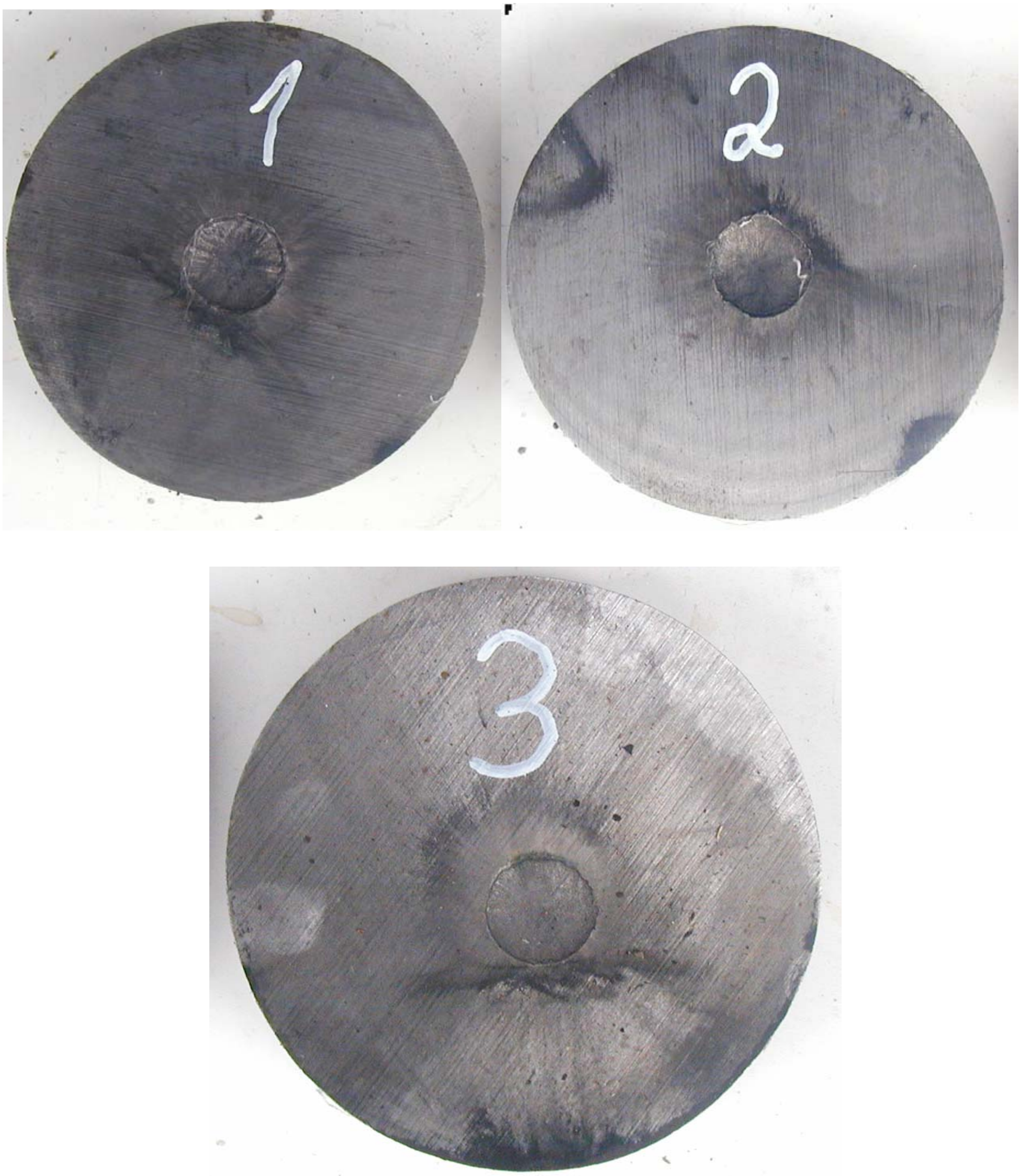

Figure 3.4 Pictures of the Dent Plates for all shots.

Shot No.	Charge diameter (mm)	Dent Depth (mm)
1	25.678	3.80
2	25.667	3.78
3	25.685	3.80
Average		**3.79**

Table 3. 3 Results for Plate Dent Test of DPX-6 charges.

4 SUMMARY

Detonation velocity for DPX-6 has been determined both experimentally and theoretically by use of the Cheetah code. The experimental result, with an average detonation velocity of 7854 m/s, is closed to the theoretically calculated detonation velocity.

The Plate Dent result of 3.79 mm indicates a detonation pressure slightly above 200 kbar, a result in good agreement with the theoretically calculated pressure by the Cheetah code.

APPENDIX

A DENSITY OF DPX-6 PELLETS

	DPX-6 Ch 06/05									
	Diam 1 (mm)	**Diam 2 (mm)**	**Diam 3 (mm)**	**Diam 4 (mm)**	**Height 1 (mm)**	**Height 2 (mm)**	**Weight (g)**	**Average diameter (mm)**	**Average height (mm)**	**Density (g/cm^3)**
1	25.672	25.688	25.673	25.676	39.15	39.15	41,5779	25,677	39,150	2,051
2	25.668	25.669	25.666	25.663	39.10	39.10	41,5956	25,667	39,100	2,056
3	25.670	25.674	25.672	25.675	39.17	39.19	41,5975	25,673	39,180	2,051
4	25.666	25.678	25.656	25.650	39.26	39.22	41,6622	25,663	39,240	2,053
5	25.678	25.675	25.670	25.678	39.12	39.13	41,5387	25,675	39,125	2,051
6	25.662	25.653	25.654	25.666	39.23	39.21	41,5948	25,659	39,220	2,051
7	25.663	25.659	25.656	25.661	39.20	39.20	41,6024	25,660	39,200	2,052
8	25.684	25.678	25.679	25.687	39.14	39.13	41,5756	25,682	39,135	2,051
9	25.681	25.676	25.680	25.674	39.15	39.17	41,5614	25,678	39,160	2,049
10	25.673	25.681	25.688	25.669	39.20	39.14	41,5825	25,678	39,170	2,050
11	25.652	25.667	25.672	25.658	39.16	39.20	41,5718	25,662	39,180	2,051
12	25.681	25.681	25.683	25.670	39.16	39.19	41,5819	25,679	39,175	2,050
13	25.681	25.682	25.692	25.677	39.13	39.13	41,5533	25,683	39,130	2,050
14	25.666	25.671	25.671	25.680	39.22	39.24	41,6145	25,672	39,230	2,049
15	25.688	25.671	25.678	25.684	39.06	39.04	41,4984	25,680	39,050	2,052
16	25.666	25.669	25.673	25.666	39.15	39.15	41,5810	25,669	39,150	2,052
17	25.685	25.700	25.721	25.718	39.12	39.15	41,6605	25,706	39,135	2,051
18	25.718	25.711	25.706	25.745	39.05	39.05	41,5630	25,720	39,050	2,049
19	25.671	25.666	25.668	25.664	39.12	39.15	41,5689	25,667	39,135	2,053
20	25.680	25.684	25.679	25.685	39.20	39.18	41,6035	25,682	39,190	2,049
21	25.670	25.681	25.680	25.676	39.20	39.25	41,5941	25,677	39,225	2,048
22	25.711	25.701	25.703	25.738	39.05	39.05	41,5594	25,713	39,050	2,049
23	25.669	25.670	25.683	25.684	39.18	39.20	41,5921	25,677	39,190	2,050
24	25.680	25.663	25.676	25.681	39.10	39.13	41,5550	25,675	39,115	2,052
25	25.685	25.685	25.688	25.681	39.15	39.18	41,5711	25,685	39,165	2,049
26	25.684	25.671	25.680	25.690	39.10	39.11	41,5435	25,681	39,105	2,051
27	25.679	25.675	25.682	25.680	39.11	39.14	41,5498	25,679	39,125	2,051
28	25.693	25.683	25.700	25.686	39.10	39.13	41,5599	25,691	39,115	2,050
29	25.680	25.688	25.690	25.683	39.10	39.16	41,5633	25,685	39,130	2,050

Table App. 1 Dimensions, weights and densities of pellets used for determination of detonation velocity.

B CONTROL REPORT FOR USED EXPLOSIVE

DYNO
High Energy Materials

Kontrollrapport
etter EN 10204 – 2.3

Kjøper / Mottaker	Bestillingsnummer	Rapportnummer
FFI v/ Gunnar Nevstad	Telf. G.Nevstad	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 tested explosive.

C THEORETICAL CALCULTIONS

C.1 Complete printout for TMD

```
Product library title: bkwc
Executing library command: gas eos, bkw
Executing library command: set, bkw, alpha, 0.499123809964
Executing library command: set, bkw, beta, 0.402655787895
Executing library command: set, bkw, theta, 5441.84607543
Executing library command: set, bkw, kappa, 10.8636743138
Reactant library title:# Version 2.0 by P. Clark Souers
```

The Composition

Name	% wt.	% mol	% vol.	Heat of formation (cal/mol)	Standard volume (cc/mol)	Standard entropy (cal/K/mol)	Mol. wt.	Formula
hytemp	1.10	0.31	2.31	-205067	188.60	0.000	188.60	$C_{10}H_{15.46}O_{3.307}$
hmx	50.00	8.96	55.15	17866	155.47	0.000	296.17	$C_4H_8N_8O_8$
doa	3.00	0.43	6.81	-290392	400.60	0.000	370.56	$C_{22}H_{42}O_4$
al	45.90	90.30	35.72	0	9.99	0.000	26.98	Al_1

```
Heat of formation =     -5.309 cal/gm
Standard volume   =      0.476 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =     -5.321 cal/gm

The elements and percent by mole
     c             12.757
     h             24.918
     o             19.621
     n             18.898
     al            23.805
The average mol. wt. =  53.078 g/mol
Input>composition, hytemp, 1.1, hmx, 50, doa, 3, al, 45.9, weight
```

The Composition

Name	% wt.	% mol	% vol.	Heat of formation (cal/mol)	Standard volume (cc/mol)	Standard entropy (cal/K/mol)	Mol. wt.	Formula
hytemp	1.10	0.31	2.31	-205067	188.60	0.000	188.60	$C_{10}H_{15.46}O_{3.307}$
hmx	50.00	8.96	55.15	17866	155.47	0.000	296.17	$C_4H_8N_8O_8$
doa	3.00	0.43	6.81	-290392	400.60	0.000	370.56	$C_{22}H_{42}O_4$
al	45.90	90.30	35.72	0	9.99	0.000	26.98	Al_1

```
Heat of formation =     -5.309 cal/gm
Standard volume   =      0.476 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =     -5.321 cal/gm

The elements and percent by mole
     c             12.757
     h             24.918
     o             19.621
     n             18.898
     al            23.805
The average mol. wt. =  53.078 g/mol
Input>standard run, rho, 2.101283
```

The hugoniot reference state:
P0 = 1.000000 ATM, V0 = 0.475900 cc/gm, E0 = -5.320798 cal/gm
Using 100266 ATM as a lower bound for the C-J pressure
Using 250666 ATM as an upper bound for the C-J pressure
The C-J point was bracketed in cjbrent
The CJ state was found in 5 iterations

The C-J condition

The shock velocity = 8.33688e+003 m/s
The particle velocity = 1.32931e+003 m/s
The speed of sound = 7.00757e+003 m/s

P0 = 1 atm, V0 = 0.47590 cc/gm, E0 = -5.32080 cal/gm

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	229826.4	0.4000	4505.2	2437.64	211.18	1.429	0.1797

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
n2	Gas	6.711e+000	3.562e-001
c2h4	Gas	2.196e+000	1.166e-001
ch4	Gas	2.103e+000	1.116e-001
h2o	Gas	1.357e-001	7.204e-003
h3n	Gas	8.314e-002	4.413e-003
h2	Gas	4.071e-002	2.161e-003
co	Gas	3.214e-003	1.706e-004
ch3oh	Gas	1.005e-003	5.334e-005
c2h6	Gas	4.916e-004	2.609e-005
ch3	Gas	6.849e-005	3.635e-006
no	Gas	1.410e-005	7.482e-007
co2	Gas	9.914e-006	5.262e-007
ch2o	Gas	4.755e-006	2.524e-007
ch2o2	Gas	1.771e-006	9.402e-008
alo	Gas	1.511e-008	8.020e-010
o2	Gas	1.884e-009	9.998e-011
no2	Gas	3.617e-016	1.920e-017
*al	solid	7.758e+000	4.118e-001
al2o3	solid	4.628e+000	2.456e-001
*c	solid	2.616e+000	1.389e-001
al2o3	liquid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total	Gas	1.128e+001	5.985e-001
Total	Cond.	1.500e+001	7.962e-001

The C-J Adiabat

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	97878.0	0.4759	4124.7	1061.94	-66.12	1.429	0.2415

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
n2	Gas	6.655e+000	3.532e-001
ch4	Gas	2.489e+000	1.321e-001
c2h4	Gas	1.512e+000	8.026e-002
h2	Gas	3.978e-001	2.111e-002
h3n	Gas	1.960e-001	1.040e-002
h2o	Gas	1.836e-001	9.744e-003
co	Gas	5.602e-002	2.974e-003
c2h6	Gas	6.234e-003	3.309e-004
ch3	Gas	2.656e-003	1.410e-004
ch3oh	Gas	1.881e-003	9.982e-005
co2	Gas	1.801e-004	9.558e-006
ch2o	Gas	1.754e-004	9.308e-006
no	Gas	3.523e-005	1.870e-006
ch2o2	Gas	1.975e-005	1.049e-006
alo	Gas	4.489e-007	2.383e-008
o2	Gas	6.928e-009	3.677e-010
no2	Gas	1.566e-013	8.315e-015
*al	solid	7.826e+000	4.154e-001
al2o3	solid	4.593e+000	2.438e-001
*c	solid	3.531e+000	1.874e-001
al2o3	liquid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total Gas		1.150e+001	6.104e-001
Total Cond.		1.595e+001	8.466e-001

Reference state = reactants

H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	9870.2	1.0470	3172.8	-261.29	-511.54	1.429	0.7404

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
n2	Gas	6.671e+000	3.541e-001
h2	Gas	4.659e+000	2.473e-001
ch4	Gas	1.616e+000	8.579e-002
c2h4	Gas	3.201e-001	1.699e-002
co	Gas	2.136e-001	1.134e-002
h3n	Gas	1.642e-001	8.716e-003
ch3	Gas	3.868e-002	2.053e-003
h2o	Gas	1.861e-002	9.879e-004
c2h6	Gas	1.629e-002	8.645e-004
ch2o	Gas	3.721e-004	1.975e-005
ch3oh	Gas	6.257e-005	3.321e-006
co2	Gas	5.793e-005	3.075e-006
alo	Gas	5.660e-006	3.004e-007
no	Gas	1.721e-006	9.133e-008
ch2o2	Gas	7.795e-007	4.138e-008
o2	Gas	2.762e-011	1.466e-012
no2	Gas	4.241e-014	2.251e-015
*al	solid	7.819e+000	4.150e-001
*c	solid	6.575e+000	3.490e-001

```
    al2o3 liquid 4.597e+000  2.440e-001
    al2o3  solid 0.000e+000  0.000e+000
      *al liquid 0.000e+000  0.000e+000

     Total Gas   1.372e+001  7.281e-001
     Total Cond. 1.899e+001  1.008e+000


                          Reference state = reactants
                H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00


          P        V       T       H(R)      E(R)      S(R)     VGS
        (ATM)   (CC/GM)   (K)    (CAL/GM)  (CAL/GM) (CAL/K/GM) (CC/GM)
 1.) 3105.0   1.9512  2937.7   -481.60   -628.31    1.429    1.6448

Product concentrations
         Name   (mol/kg) (mol gas/mol explosive)
       h2  Gas   6.815e+000  3.617e-001
       n2  Gas   6.713e+000  3.563e-001
      ch4  Gas   8.255e-001  4.382e-002
       co  Gas   3.429e-001  1.820e-002
     c2h4  Gas   1.204e-001  6.390e-003
      h3n  Gas   7.891e-002  4.188e-003
      ch3  Gas   3.604e-002  1.913e-003
      h2o  Gas   8.233e-003  4.370e-004
     c2h6  Gas   5.529e-003  2.934e-004
     ch2o  Gas   2.562e-004  1.360e-005
      co2  Gas   4.368e-005  2.319e-006
      alo  Gas   1.107e-005  5.875e-007
    ch3oh  Gas   1.093e-005  5.801e-007
       no  Gas   6.066e-007  3.220e-008
    ch2o2  Gas   1.842e-007  9.778e-009
       o2  Gas   4.885e-012  2.593e-013
      no2  Gas   1.073e-014  5.695e-016
      *al  solid 7.899e+000  4.192e-001
       *c  solid 7.661e+000  4.066e-001
    al2o3 liquid 4.557e+000  2.419e-001
    al2o3  solid 0.000e+000  0.000e+000
      *al liquid 0.000e+000  0.000e+000

     Total Gas   1.495e+001  7.933e-001
     Total Cond. 2.012e+001  1.068e+000


                          Reference state = reactants
                H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00


           P        V       T       H(R)      E(R)      S(R)     VGS
         (ATM)  (CC/GM)   (K)    (CAL/GM)  (CAL/GM) (CAL/K/GM) (CC/GM)
 1.)  1580.1   3.0933  2820.3   -570.30   -688.66    1.429    2.7881

Product concentrations
         Name   (mol/kg) (mol gas/mol explosive)
       h2  Gas   7.597e+000  4.033e-001
       n2  Gas   6.729e+000  3.572e-001
      ch4  Gas   5.269e-001  2.797e-002
       co  Gas   3.948e-001  2.095e-002
```

c2h4	Gas	6.393e-002	3.393e-003
h3n	Gas	4.778e-002	2.536e-003
ch3	Gas	2.727e-002	1.447e-003
h2o	Gas	5.106e-003	2.710e-004
c2h6	Gas	2.312e-003	1.227e-004
ch2o	Gas	1.671e-004	8.869e-006
co2	Gas	3.258e-005	1.729e-006
alo	Gas	1.262e-005	6.700e-007
ch3oh	Gas	3.639e-006	1.932e-007
no	Gas	3.164e-007	1.679e-008
ch2o2	Gas	6.910e-008	3.668e-009
o2	Gas	1.701e-012	9.030e-014
no2	Gas	3.497e-015	1.856e-016
*c	solid	8.036e+000	4.265e-001
*al	solid	7.931e+000	4.210e-001
al2o3	liquid	4.541e+000	2.410e-001
al2o3	solid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total	Gas	1.539e+001	8.171e-001
Total	Cond.	2.051e+001	1.088e+000

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	900.7	4.7590	2730.3	-632.45	-736.24	1.429	4.4551

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
h2	Gas	8.036e+000	4.265e-001
n2	Gas	6.738e+000	3.576e-001
co	Gas	4.209e-001	2.234e-002
ch4	Gas	3.561e-001	1.890e-002
c2h4	Gas	3.682e-002	1.955e-003
h3n	Gas	3.074e-002	1.632e-003
ch3	Gas	1.989e-002	1.056e-003
h2o	Gas	3.424e-003	1.817e-004
c2h6	Gas	1.026e-003	5.447e-005
ch2o	Gas	1.081e-004	5.740e-006
co2	Gas	2.412e-005	1.280e-006
alo	Gas	1.266e-005	6.721e-007
ch3oh	Gas	1.408e-006	7.474e-008
no	Gas	1.801e-007	9.557e-009
ch2o2	Gas	2.874e-008	1.526e-009
o2	Gas	6.881e-013	3.652e-014
no2	Gas	1.212e-015	6.430e-017
*c	solid	8.245e+000	4.376e-001
*al	solid	7.947e+000	4.218e-001
al2o3	liquid	4.533e+000	2.406e-001
al2o3	solid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total	Gas	1.564e+001	8.303e-001
Total	Cond.	2.072e+001	1.100e+000

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	393.5	9.5180	2607.3	-712.48	-803.17	1.429	9.2162

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
h2	Gas	8.436e+000	4.478e-001
n2	Gas	6.745e+000	3.580e-001
co	Gas	4.340e-001	2.304e-002
ch4	Gas	1.962e-001	1.041e-002
c2h4	Gas	1.585e-002	8.412e-004
h3n	Gas	1.566e-002	8.314e-004
ch3	Gas	1.141e-002	6.057e-004
h2o	Gas	1.887e-003	1.001e-004
c2h6	Gas	2.824e-004	1.499e-005
ch2o	Gas	5.192e-005	2.756e-006
co2	Gas	1.438e-005	7.635e-007
alo	Gas	1.119e-005	5.939e-007
ch3oh	Gas	3.322e-007	1.763e-008
no	Gas	7.577e-008	4.022e-009
ch2o2	Gas	7.283e-009	3.866e-010
o2	Gas	1.726e-013	9.161e-015
no2	Gas	2.173e-016	1.153e-017
*c	solid	8.443e+000	4.482e-001
*al	solid	7.955e+000	4.222e-001
al2o3	liquid	4.529e+000	2.404e-001
al2o3	solid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total	Gas	1.586e+001	8.417e-001
Total	Cond.	2.093e+001	1.111e+000

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	180.5	19.0360	2499.7	-780.03	-863.24	1.429	18.7364

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
h2	Gas	8.645e+000	4.589e-001
n2	Gas	6.749e+000	3.582e-001
co	Gas	4.246e-001	2.254e-002
ch4	Gas	1.107e-001	5.878e-003
h3n	Gas	8.181e-003	4.343e-004
c2h4	Gas	7.007e-003	3.719e-004
ch3	Gas	6.353e-003	3.372e-004
h2o	Gas	1.064e-003	5.649e-005
c2h6	Gas	7.894e-005	4.190e-006
ch2o	Gas	2.426e-005	1.288e-006
alo	Gas	8.999e-006	4.776e-007
co2	Gas	8.302e-006	4.407e-007
ch3oh	Gas	8.213e-008	4.359e-009
no	Gas	3.230e-008	1.714e-009
ch2o2	Gas	1.868e-009	9.913e-011

```
        o2  Gas   4.434e-014  2.353e-015
       no2  Gas   3.795e-017  2.014e-018
        *c  solid 8.561e+000  4.544e-001
       *al  solid 7.948e+000  4.219e-001
     al2o3 liquid 4.532e+000  2.406e-001
       *al liquid 1.819e-017  9.657e-019
     al2o3  solid 0.000e+000  0.000e+000

      Total Gas   1.595e+001  8.467e-001
      Total Cond. 2.104e+001  1.117e+000

                              Reference state = reactants
                    H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

          P        V       T       H(R)      E(R)       S(R)      VGS
       (ATM)   (CC/GM)   (K)    (CAL/GM)  (CAL/GM) (CAL/K/GM) (CC/GM)
  1.)   89.2   38.0720 2473.9   -837.94   -920.15     1.429   37.7638

Product concentrations
         Name   (mol/kg) (mol gas/mol explosive)
        h2  Gas   8.769e+000  4.655e-001
        n2  Gas   6.751e+000  3.583e-001
        co  Gas   7.231e-001  3.838e-002
       ch4  Gas   5.715e-002  3.033e-003
       ch3  Gas   4.286e-003  2.275e-004
       h3n  Gas   4.137e-003  2.196e-004
      c2h4  Gas   3.406e-003  1.808e-004
       h2o  Gas   9.272e-004  4.921e-005
      c2h6  Gas   2.045e-005  1.085e-006
      ch2o  Gas   2.041e-005  1.083e-006
       alo  Gas   1.465e-005  7.775e-007
       co2  Gas   1.243e-005  6.595e-007
     ch3oh  Gas   3.463e-008  1.838e-009
        no  Gas   3.413e-008  1.811e-009
     ch2o2  Gas   1.351e-009  7.172e-011
        o2  Gas   5.387e-014  2.859e-015
       no2  Gas   3.264e-017  1.733e-018
        *c  solid 8.326e+000  4.419e-001
       *al liquid 7.427e+000  3.942e-001
     al2o3 liquid 4.433e+000  2.353e-001
       *al  solid 7.201e-001  3.822e-002
     al2o3  solid 0.000e+000  0.000e+000

      Total Gas   1.631e+001  8.659e-001
      Total Cond. 2.091e+001  1.110e+000

                              Reference state = reactants
                    H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

        P     V      T       H(R)      E(R)       S(R)      VGS
     (ATM) (CC/GM)   (K)    (CAL/GM)  (CAL/GM) (CAL/K/GM) (CC/GM)
  1.) 42.1 76.1440 2371.1   -897.98   -975.67    1.429   75.8371

Product concentrations
         Name   (mol/kg) (mol gas/mol explosive)
        h2  Gas   8.827e+000  4.685e-001
        n2  Gas   6.752e+000  3.584e-001
        co  Gas   6.678e-001  3.544e-002
       ch4  Gas   3.315e-002  1.759e-003
```

```
       ch3  Gas   2.274e-003  1.207e-004
       h3n  Gas   2.209e-003  1.173e-004
      c2h4  Gas   1.514e-003  8.037e-005
       h2o  Gas   5.305e-004  2.816e-005
       alo  Gas   9.718e-006  5.158e-007
      ch2o  Gas   9.142e-006  4.852e-007
       co2  Gas   6.893e-006  3.659e-007
      c2h6  Gas   5.834e-006  3.097e-007
        no  Gas   1.380e-008  7.326e-010
     ch3oh  Gas   8.731e-009  4.634e-010
     ch2o2  Gas   3.408e-010  1.809e-011
        o2  Gas   1.286e-014  6.824e-016
       no2  Gas   5.087e-018  2.700e-019
        *c  solid 8.411e+000  4.464e-001
       *al liquid 8.110e+000  4.305e-001
     al2o3 liquid 4.451e+000  2.363e-001
       *al  solid 0.000e+000  0.000e+000
     al2o3  solid 0.000e+000  0.000e+000

      Total Gas   1.629e+001  8.645e-001
      Total Cond. 2.097e+001  1.113e+000


                                The End of the Adiabat

                             Reference state = reactants
                   H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

        P       V        T       H(R)       E(R)       S(R)      VGS
      (ATM) (CC/GM)     (K)    (CAL/GM)   (CAL/GM) (CAL/K/GM) (CC/GM)
  1.)   1.0 2683.9991 2014.9   -1170.86   -1235.85     1.429  2683.7372

Product concentrations
         Name   (mol/kg) (mol gas/mol explosive)
        h2  Gas   8.900e+000  4.724e-001
        n2  Gas   6.753e+000  3.584e-001
        co  Gas   5.728e-001  3.040e-002
       ch4  Gas   1.832e-003  9.724e-005
       ch3  Gas   1.093e-004  5.800e-006
       h3n  Gas   8.648e-005  4.590e-006
       h2o  Gas   3.516e-005  1.866e-006
      c2h4  Gas   2.677e-005  1.421e-006
       alo  Gas   2.004e-006  1.063e-007
       co2  Gas   4.892e-007  2.597e-008
      ch2o  Gas   2.043e-007  1.085e-008
      c2h6  Gas   8.710e-009  4.623e-010
        no  Gas   2.752e-010  1.461e-011
     ch3oh  Gas   1.001e-011  5.316e-013
     ch2o2  Gas   4.863e-013  2.581e-014
        o2  Gas   2.581e-017  1.370e-018
       no2  Gas   1.190e-021  6.319e-023
        *c  solid 8.543e+000  4.534e-001
       *al liquid 8.046e+000  4.271e-001
     al2o3  solid 4.483e+000  2.380e-001
     al2o3 liquid 0.000e+000  0.000e+000
       *al  solid 0.000e+000  0.000e+000

      Total Gas   1.623e+001  8.613e-001
      Total Cond. 2.107e+001  1.118e+000
```

The Products at room temperature and pressure

The initial equation error was huge: 305439.227162

Reference state = reactants
H(R) = H--5.31, E(R) = E--5.32, S(R) = S- 0.00

	P (ATM)	V (CC/GM)	T (K)	H(R) (CAL/GM)	E(R) (CAL/GM)	S(R) (CAL/K/GM)	VGS (CC/GM)
1.)	1.0	274.8441	298.0	-1946.38	-1953.03	0.637	274.6258

Product concentrations

Name		(mol/kg)	(mol gas/mol explosive)
n2	Gas	6.753e+000	3.584e-001
ch4	Gas	4.451e+000	2.363e-001
h3n	Gas	6.854e-004	3.638e-005
h2	Gas	2.487e-004	1.320e-005
c2h6	Gas	7.130e-008	3.784e-009
c2h4	Gas	5.707e-021	3.029e-022
ch3	Gas	1.376e-032	7.305e-034
no	Gas	0.000e+000	0.000e+000
o2	Gas	0.000e+000	0.000e+000
ch2o2	Gas	0.000e+000	0.000e+000
co	Gas	0.000e+000	0.000e+000
no2	Gas	0.000e+000	0.000e+000
co2	Gas	0.000e+000	0.000e+000
alo	Gas	0.000e+000	0.000e+000
h2o	Gas	0.000e+000	0.000e+000
ch3oh	Gas	0.000e+000	0.000e+000
ch2o	Gas	0.000e+000	0.000e+000
*al	solid	7.664e+000	4.068e-001
al2o3	solid	4.674e+000	2.481e-001
*c	solid	4.666e+000	2.477e-001
al2o3	liquid	0.000e+000	0.000e+000
*al	liquid	0.000e+000	0.000e+000
Total	Gas	1.120e+001	5.947e-001
Total	Cond.	1.700e+001	9.026e-001

The mechanical energy of detonation = -10.865 kJ/cc
The thermal energy of detonation = -6.305 kJ/cc
The total energy of detonation = -17.171 kJ/cc

JWL Tail Fit results:
Initial E0 = -18.927, Final E0 = -19.248
E0(V=infty) = -19.248
C = 0.959, omega = 0.065
Final fitting error = 0.000858

V/V0	Actual E (kJ/cc)	Fit E (kJ/cc)	Actual P (GPa)	Fit P (GPa)
10.000	-6.473	-6.486	0.091	0.083
20.000	-7.061	-7.046	0.040	0.039
40.000	-7.589	-7.582	0.018	0.019
80.000	-8.090	-8.094	0.009	0.009
160.000	-8.578	-8.583	0.004	0.004

JWL Fit results:

```
E0(V=infty) =    -19.248
R[1] =     7.472, R[2] = 1.137, omega =  0.065
A    =  9999.994, B    = 10.694, C    =  0.959
Final fitting error = 0.012899
```

V/V0	Actual E (kJ/cc)	Fit E (kJ/cc)	Actual P (GPa)	Fit P (GPa)
0.841	1.857	1.857	23.287	23.992
1.000	-0.581	-0.655	9.917	10.079
2.200	-4.497	-4.400	1.000	1.292
4.100	-5.524	-5.639	0.315	0.315
6.500	-6.055	-6.120	0.160	0.137
10.000	-6.473	-6.486	0.091	0.083
20.000	-7.061	-7.046	0.040	0.039
40.000	-7.589	-7.582	0.018	0.019
80.000	-8.090	-8.094	0.009	0.009
160.000	-8.578	-8.583	0.004	0.004

C.2 Summary printout for different densities

Product library title: bkwc
Reactant library title: # Version 2.0 by P. Clark Souers

The composition:

Name	% wt.	% mol	% vol	Heat of formation (cal/mol)	Mol. wt.	TMD (g/cc)	
hytemp	1.10	0.31	2.31	-205067	188.60	1.00	$C_{10}H_{15.46}O_{3.307}$
hmx	50.00	8.96	55.15	17866	296.17	1.91	$C_4H_8N_8O_8$
doa	3.00	0.43	6.81	-290392	370.56	0.93	$C_{22}H_{42}O_4$
al	45.90	90.30	35.72	0	26.98	2.70	Al_1

Density = 2.1013 g/cc Mixture TMD= 2.1013 g/cc % TMD = 100.000

```
The C-J condition:
The pressure          =         23.29 GPa
The volume            =         0.400 cc/g
The density           =         2.500 g/cc
The energy            =          1.86 kJ/cc explosive
The temperature       =          4505 K
The shock velocity    =         8.337 mm/us
The particle velocity =         1.329 mm/us
The speed of sound    =         7.008 mm/us
Gamma                 =         5.272
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.58					
2.20	-4.50	93	71	60	50	103
4.10	-5.52	95	72	62	52	100
6.50	-6.05	97	73	64	54	99
10.00	-6.47	99	74	66	56	99
20.00	-7.06	103	77	69	59	98
40.00	-7.59	106	80	72	62	98
80.00	-8.09	110	83	76	66	98
160.00	-8.58					

```
The mechanical energy of detonation =    -10.865 kJ/cc
The thermal energy of detonation    =     -6.305 kJ/cc
The total energy of detonation      =    -17.171 kJ/cc

JWL Fit results:
E0 =  -19.248 kJ/cc
A  =  9999.99 GPa, B = 10.69 GPa , C = 0.96 GPa
R[1] = 7.47,    R[2] = 1.14,   omega = 0.06
RMS fitting error =   1.29 %
```

Density = 2.0800 g/cc Mixture TMD = 2.1013 g/cc % TMD = 98.9871

The C-J condition:
The pressure = 22.27 GPa
The volume = 0.404 cc/g
The density = 2.477 g/cc
The energy = 1.78 kJ/cc explosive
The temperature = 4498 K
The shock velocity = 8.175 mm/us
The particle velocity = 1.310 mm/us
The speed of sound = 6.865 mm/us
Gamma = 5.242

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.56					
2.20	-4.39	90	69	59	48	101
4.10	-5.40	93	70	61	51	98
6.50	-5.93	95	71	63	53	97
10.00	-6.34	97	73	65	55	97
20.00	-6.93	101	76	68	58	97
40.00	-7.45	104	78	71	61	96
80.00	-7.95	108	81	74	64	96
160.00	-8.43					

The mechanical energy of detonation = -10.703 kJ/cc
The thermal energy of detonation = -6.294 kJ/cc
The total energy of detonation = -16.997 kJ/cc

JWL Fit results:
E0 = -18.906 kJ/cc
A = 9999.88 GPa, B = 10.75 GPa , C =0.96 GPa
R[1] = 7.55, R[2] = 1.14, omega = 0.07
RMS fitting error = 1.26 %

Density = 2.0700 g/cc Mixture TMD = 2.1013 g/cc % TMD = 98.5112

The C-J condition:
The pressure = 21.80 GPa
The volume = 0.406 cc/g
The density = 2.466 g/cc
The energy = 1.75 kJ/cc explosive
The temperature = 4495 K
The shock velocity = 8.099 mm/us
The particle velocity = 1.301 mm/us
The speed of sound = 6.799 mm/us
Gamma = 5.228

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.55					
2.20	-4.34	89	68	58	48	99
4.10	-5.34	92	69	60	51	97
6.50	-5.87	94	71	62	53	96
10.00	-6.28	96	72	64	55	96
20.00	-6.86	100	75	67	58	96
40.00	-7.39	103	78	70	61	96
80.00	-7.88	107	81	74	64	96
160.00	-8.37					

The mechanical energy of detonation = -10.628 kJ/cc
The thermal energy of detonation = -6.287 kJ/cc
The total energy of detonation = -16.915 kJ/cc

JWL Fit results:
E0 = -19.210 kJ/cc
A = 9999.89 GPa, B = 10.79 GPa , C = 0.93 GPa
R[1] = 7.59, R[2] = 1.13, omega = 0.06
RMS fitting error = 1.34 %

Density = 2.0600 g/cc Mixture TMD = 2.1013 g/cc % TMD=98.0353

```
The C-J condition:
The pressure          =          21.35 GPa
The volume            =          0.407 cc/g
The density           =          2.455 g/cc
The energy            =           1.72 kJ/cc explosive
The temperature       =           4492 K
The shock velocity    =          8.024 mm/us
The particle velocity =          1.292 mm/us
The speed of sound    =          6.733 mm/us
Gamma                 =          5.213
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.54					
2.20	-4.29	88	68	57	47	98
4.10	-5.29	91	68	60	50	96
6.50	-5.81	93	70	62	52	95
10.00	-6.22	95	72	64	54	95
20.00	-6.80	99	74	67	57	95
40.00	-7.32	102	77	70	60	95
80.00	-7.82	106	80	73	63	95
160.00	-8.30					

```
The mechanical energy of detonation =    -10.553 kJ/cc
The thermal energy of detonation    =     -6.281 kJ/cc
The total energy of detonation      =    -16.833 kJ/cc
```

```
JWL Fit results:
E0   =  -18.958 kJ/cc
A    =  9999.90 GPa, B =  10.80 GPa , C  =  0.93 GPa
R[1] =  7.63, R[2] = 1.14,  omega =  0.06
RMS fitting error =   1.33 %
```

Density = 2.0500 g/cc Mixture TMD = 2.1013 g/cc % TMD = 97.5594

```
The C-J condition:
The pressure          =          20.91 GPa
The volume            =          0.409 cc/g
The density           =          2.444 g/cc
The energy            =           1.69 kJ/cc explosive
The temperature       =           4488 K
The shock velocity    =          7.950 mm/us
The particle velocity =          1.283 mm/us
The speed of sound    =          6.667 mm/us
Gamma                 =          5.197
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.54					
2.20	-4.24	87	67	57	47	97
4.10	-5.23	90	68	59	50	95
6.50	-5.75	92	69	61	52	94
10.00	-6.16	95	71	63	54	94
20.00	-6.74	98	74	66	57	94
40.00	-7.26	102	76	69	60	94
80.00	-7.75	105	79	72	63	94
160.00	-8.23					

```
The mechanical energy of detonation =    -10.478 kJ/cc
The thermal energy of detonation    =     -6.273 kJ/cc
The total energy of detonation      =    -16.752 kJ/cc
```

```
JWL Fit results:
E0 = -18.804 kJ/cc
A = 9999.60 GPa, B  =   10.78 GPa , C =  0.94 GPa
R[1]  7.67,     R[2] = 1.15,      omega = 0.06
RMS fitting error =   1.23 %
```

Density = 2.0400 g/cc Mixture TMD = 2.1013 g/cc % TMD = 97.0835

```
The C-J condition:
The pressure          =          20.47 GPa
The volume            =          0.411 cc/g
The density           =          2.434 g/cc
The energy            =           1.66 kJ/cc explosive
The temperature       =           4485 K
The shock velocity    =          7.876 mm/us
The particle velocity =          1.274 mm/us
The speed of sound    =          6.602 mm/us
Gamma                 =          5.181

Cylinder runs:                % of standards
  V/V0     Energy    TATB     PETN      HMX    CL-20   TRITON
 (rel.)   (kJ/cc)  1.83g/cc 1.76g/cc 1.89g/cc 2.04g/cc 1.70g/cc
   1.00    -0.53
   2.20    -4.19      86       66       56       46       96
   4.10    -5.18      89       67       58       49       94
   6.50    -5.69      91       69       60       51       93
  10.00    -6.10      94       70       62       53       93
  20.00    -6.68      97       73       66       56       93
  40.00    -7.20     101       76       69       59       93
  80.00    -7.69     104       79       72       62       93
 160.00    -8.17

The mechanical energy of detonation =    -10.404 kJ/cc
The thermal energy of detonation    =     -6.266 kJ/cc
The total energy of detonation      =    -16.670 kJ/cc

JWL Fit results:
E0   =  -18.742 kJ/cc
A    = 9974.76 GPa, B = 10.77 GPa , C  =  0.94 GPa
R[1] =  7.71,      R[2] = 1.15,       omega = 0.06
RMS fitting error =    1.22 %
```

Density = 2.0300 g/cc Mixture TMD = 2.1013 g/cc % TMD=96.6076

```
The C-J condition:
The pressure          =          20.05 GPa
The volume            =          0.413 cc/g
The density           =          2.423 g/cc
The energy            =           1.63 kJ/cc explosive
The temperature       =           4482 K
The shock velocity    =          7.803 mm/us
The particle velocity =          1.266 mm/us
The speed of sound    =          6.537 mm/us
Gamma                 =          5.165

Cylinder runs:                % of standards
  V/V0     Energy    TATB     PETN      HMX    CL-20   TRITON
 (rel.)   (kJ/cc)  1.83g/cc 1.76g/cc 1.89g/cc 2.04g/cc 1.70g/cc
   1.00    -0.52
   2.20    -4.14      85       65       55       46       95
   4.10    -5.12      88       66       58       49       93
   6.50    -5.64      91       68       60       51       92
  10.00    -6.05      93       70       62       53       92
  20.00    -6.62      96       72       65       56       92
  40.00    -7.14     100       75       68       59       92
  80.00    -7.63     103       78       71       62       93
 160.00    -8.10

The mechanical energy of detonation =    -10.330 kJ/cc
The thermal energy of detonation    =     -6.258 kJ/cc
The total energy of detonation      =    -16.588 kJ/cc

JWL Fit results:
E0   = -18.536 kJ/cc
A    =  9736.29 GPa, B  =  10.68 GPa , C  =  0.94 GPa
R[1] =  7.71,      R[2] =  1.15,       omega = 0.06
RMS fitting error =    1.22 %
```

Density = 2.0200 g/cc Mixture TMD = 2.1013 g/cc % TMD=96.1317

```
The C-J condition:
The pressure          =          19.63 GPa
The volume            =          0.415 cc/g
The density           =          2.412 g/cc
The energy            =           1.60 kJ/cc explosive
The temperature       =           4478 K
The shock velocity    =          7.730 mm/us
The particle velocity =          1.257 mm/us
The speed of sound    =          6.473 mm/us
Gamma                 =          5.148
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.51					
2.20	-4.09	84	64	55	45	94
4.10	-5.07	87	66	57	48	92
6.50	-5.58	90	67	59	50	91
10.00	-5.99	92	69	61	52	91
20.00	-6.56	96	72	64	55	92
40.00	-7.08	99	75	68	58	92
80.00	-7.56	103	77	71	61	92
160.00	-8.04					

```
The mechanical energy of detonation =    -10.257 kJ/cc
The thermal energy of detonation    =     -6.249 kJ/cc
The total energy of detonation      =    -16.506 kJ/cc

JWL Fit results:
E0   =  -18.521 kJ/cc
A    =  9492.46 GPa, B    = 10.57 GPa , C     = 0.93 GPa
R[1] =  7.71,     R[2] = 1.15,      omega = 0.06
RMS fitting error =   1.22 %
```

Density = 2.0100 g/cc Mixture TMD = 2.1013 g/cc % TMD=95.6558

```
The C-J condition:
The pressure          =          19.23 GPa
The volume            =          0.416 cc/g
The density           =          2.402 g/cc
The energy            =           1.57 kJ/cc explosive
The temperature       =           4475 K
The shock velocity    =          7.658 mm/us
The particle velocity =          1.249 mm/us
The speed of sound    =          6.409 mm/us
Gamma                 =          5.130
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.50					
2.20	-4.05	83	64	54	45	93
4.10	-5.02	86	65	57	48	91
6.50	-5.53	89	67	59	50	90
10.00	-5.93	91	68	61	52	90
20.00	-6.50	95	71	64	55	91
40.00	-7.02	98	74	67	58	91
80.00	-7.50	102	77	70	61	91
160.00	-7.98					

```
The mechanical energy of detonation =    -10.185 kJ/cc
The thermal energy of detonation    =     -6.240 kJ/cc
The total energy of detonation      =    -16.425 kJ/cc

JWL Fit results:
E0   =  -18.476 kJ/cc
A    = 9253.32 GPa, B    = 10.47 GPa , C  = 0.93 GPa
R[1] = 7.72,     R[2] = 1.15,      omega = 0.06
RMS fitting error =   1.22 %
```

Density = 2.0000 g/cc Mixture TMD = 2.1013 g/cc % TMD=95.1799

```
The C-J condition:
The pressure          =          18.83 GPa
The volume            =          0.418 cc/g
The density           =          2.391 g/cc
The energy            =           1.54 kJ/cc explosive
The temperature       =           4472 K
The shock velocity    =          7.587 mm/us
The particle velocity =          1.241 mm/us
The speed of sound    =          6.345 mm/us
Gamma                 =          5.112
```

Cylinder runs: % of standards

V/V0 (rel.)	Energy (kJ/cc)	TATB 1.83g/cc	PETN 1.76g/cc	HMX 1.89g/cc	CL-20 2.04g/cc	TRITON 1.70g/cc
1.00	-0.50					
2.20	-4.00	83	63	54	44	92
4.10	-4.97	85	64	56	47	90
6.50	-5.47	88	66	58	49	90
10.00	-5.88	90	68	60	51	90
20.00	-6.45	94	70	63	54	90
40.00	-6.96	97	73	66	57	90
80.00	-7.44	101	76	69	60	90
160.00	-7.91					

```
The mechanical energy of detonation =    -10.112 kJ/cc
The thermal energy of detonation    =     -6.231 kJ/cc
The total energy of detonation      =    -16.343 kJ/cc

JWL Fit results:
E0   =      -18.956 kJ/cc
A    =  8993.04 GPa, B =  10.34 GPa , C  = 0.91 GPa
R[1] = 7.72,     R[2] = 1.14,      omega =  0.06
RMS fitting error =   1.22 %
```

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