Introduction of a smokeless less sensitive Propellant for an Infantry Sustainer Rocket Motor System

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Contents

Objective and Scope

Development and Test of a Minimum Smoke IM Propellant for propulsion elements of small rocket motor sustainers in ballistic projectiles for infantry weapons

Adaption of a propellant based on AN/RDX/GAP on a grain

- with 50 mm diameter, 36 mm length;

To achieve:

- 100 N average thrust, burning time: 1,7 – 1,8 s

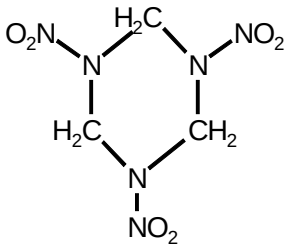
Propellant Ingredients: Energetic Solids

SCAN
spherical
Ammoniumnitrate

NH_4NO_3

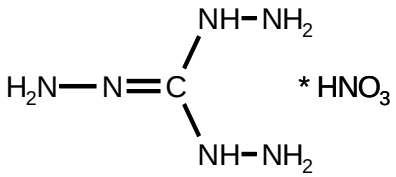
O_2: +19,99 %
ΔH: -4567 kJ/kg
d: 1,72 g/cm³

RDX
Hexogen 5 µ



O_2: -21,61 %
ΔH: +301,4 kJ/kg
d: 1,81 g/cm³

TAGN
Triaminoguanidinnitrate



O_2: -33,51 %
ΔH: -287,9 kJ/kg
d: 1,54 g/cm³

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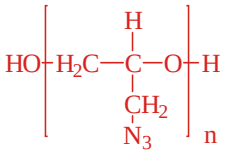
Propellant Ingredients – Binder and Plasticizers

Energetic Binder

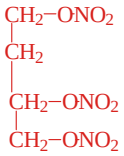
GAP
Glycidylazido - Polymer



O_2: -121,09 %
ΔH: +1150,2 kJ/kg
d: 1,27 g/cm³

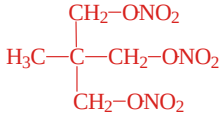
Energetic Plasticizers

BTTN
1,2,4-Butantrioltrinitrate



O_2: -16,59 %
ΔH: -1683,9 kJ/kg
d: 1,52 g/cm³

TMETN
Trimethylolethantrinitrate



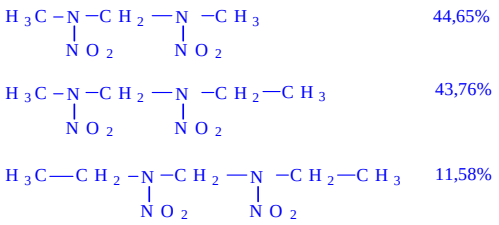
O_2: -34,49 %
ΔH: -1738,3 kJ/kg
d: 1,488 g/cm³

DNDA 57

2,4-Dinitro-2,4-diazapentane

2,4-Dinitro-2,4-diazahexane

2,4-Dinitro-2,4-diazaheptan



O_2: -72,33 %
ΔH: -384,2 kJ/kg
d: 1,345 g/cm³

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Propellant Formulations

Ingredients	**IMS 10**	**IMS 26**	**IMS 13a**
	(ma%)	**(ma%)**	**(ma%)**
SCAN 160 / 55 um	60	59	51
TAGN 24 um ground	--	--	15
RDX 3-5 um	4	5	--
GAP diole + Isocyanates	16	16	15
TMETN/BTTN 1:1	16	--	--
DNDA 57	--	16,2	15,6
Stabilizers DPA / MgO	0,8	0,8	0,6
Pb citrate	--	--	2
MOVO (MoO_3/V_2O_5)	2.2	2.0	--
Zirconcarbide/Carbon	1.0	1.0	0.8
Total solids	***67***	***67***	***68,8***
Total	**100**	**100**	**100**
Calcul. density	**1,60**	**1,57**	**1,54**
Oxygen balance	**-17,21**	**-25,70**	**-30,78**

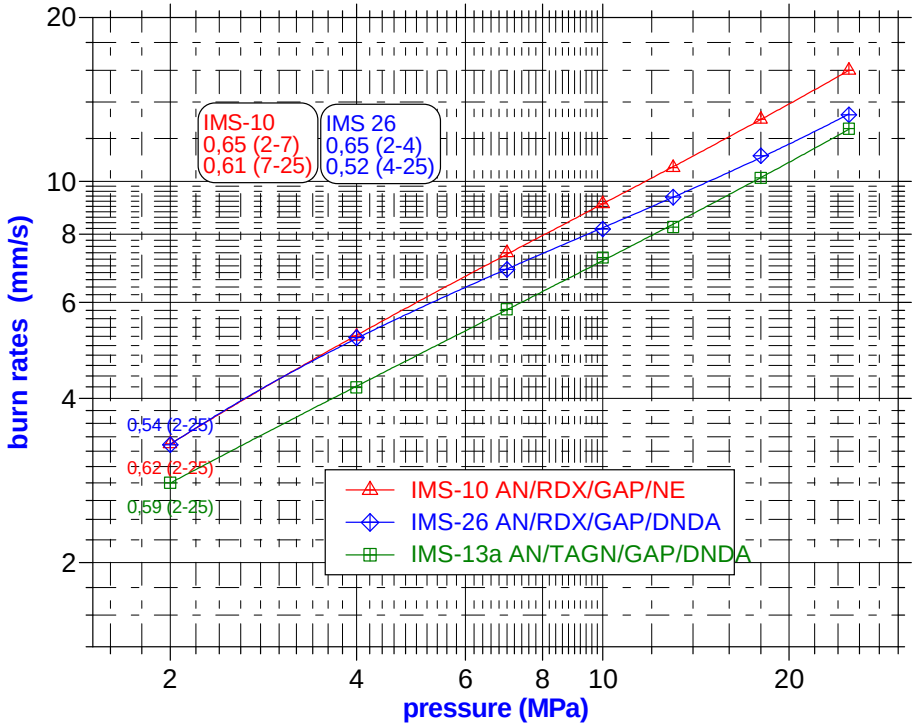
Thermodynamics

Thermodynamics (70:1)		IMS 10	IMS 26	IMS 13a
Energetic Solids		AN/RDX	AN/RDX	AN/TAGN
Binder		GAP/NE	GAP/DNDA	GAP/DNDA
Spec. Impulse	Ns/kg	2224	2156	2118
Spec. Impulse	s	226,7	219,7	215,9
density	g/cm³	1,60	1,57	1,54
Volum. Spec. Impuls	Ns/dm³	3563	3380	3264
Char. Velocity c*	m/s	1400	1369	1355
Tc Combust. Temperature	K	2320	2081	1944
Molnumber Gases n	mol/kg	43,36	46,72	49,31
Mean Mol. Weight	g	23,07	21,41	20,28
Gasvolume (1 bar/273 K)	Nl/kg	971	1046	1104
AGARD signature class.		AA	AA	AA

Burning Behaviour

Crawford Values, RT

burn rates r(p)		IMS 10	IMS 26	IMS 13a
r (4)	mm/s	5.2	5.2	4.2
r (7)	mm/s	7.4	6.9	5.8
r (10)	mm/s	9.1	8.2	7.25
r (13)	mm/s	10.6	9.35	8.25
r (18)	mm/s	13.0	11.15	10.15
n (4-18)		0.61	0.54	0.59



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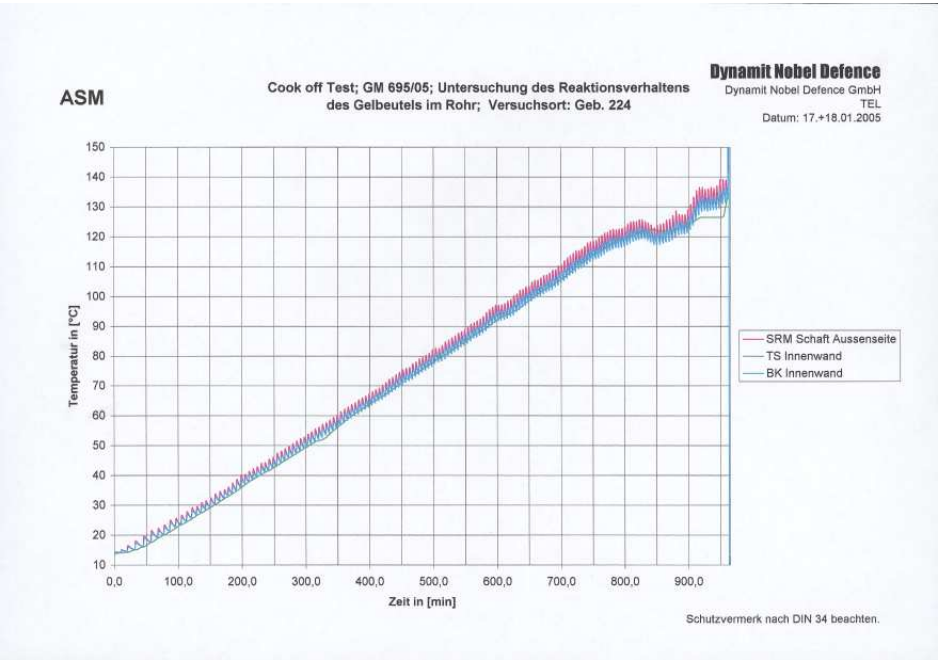
Processibility, Stability, Mechanical Properties

Properties	**Units**	**IMS 10**	**IMS 26**	**IMS 13a**
Energetic Solids		AN/RDX	AN/RDX	AN/TAGN
Binder		GAP/NE	GAP/DNDA	GAP/DNDA
Processibility 50°C				
viscosity EOM	Pas	72	156	168
Chem. stability				
Flash Point 20°/min	°C	182	197	211
Dutch Test 8-72h, 105°	%	3,32	0,25	0,19
vacuum stab. 40 h / 100°	ml/g	0,42	0,26	0,18
Mechanics 20°/50 mm/min				
max. Tensile strenghth	N/mm²	0,61	0,31	0,41
elongation at break	%	31	25	10
E-modulus	N/mm²	3,19	2,14	6,83

Thermal Sensitivity, SCO



IMS 10: AN/RDX/GAP/NE

Heating Rate:	8,4 °/h; 6 °/h
Exotherm Onset:	127 °C
Deflagration:	134 °C

IMS 10: AN/RDX/GAP/NE

Debris formed upon deflagration;

→ Reaction Type III

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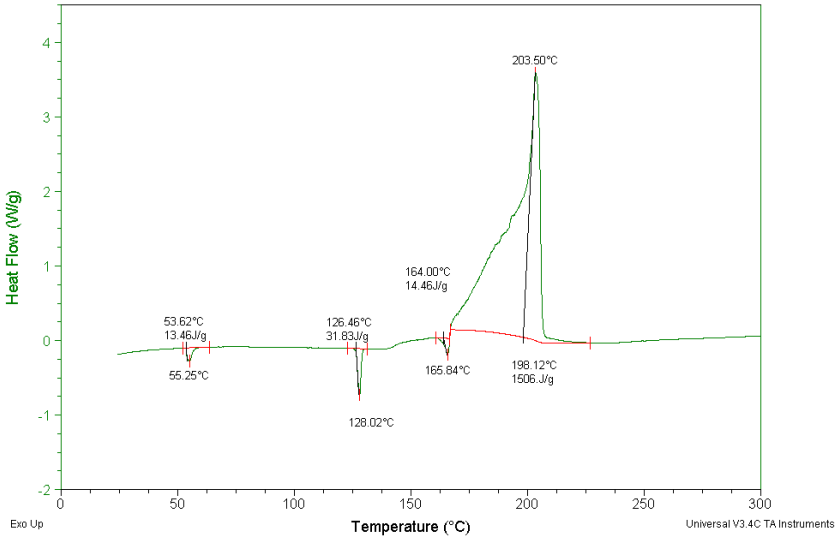
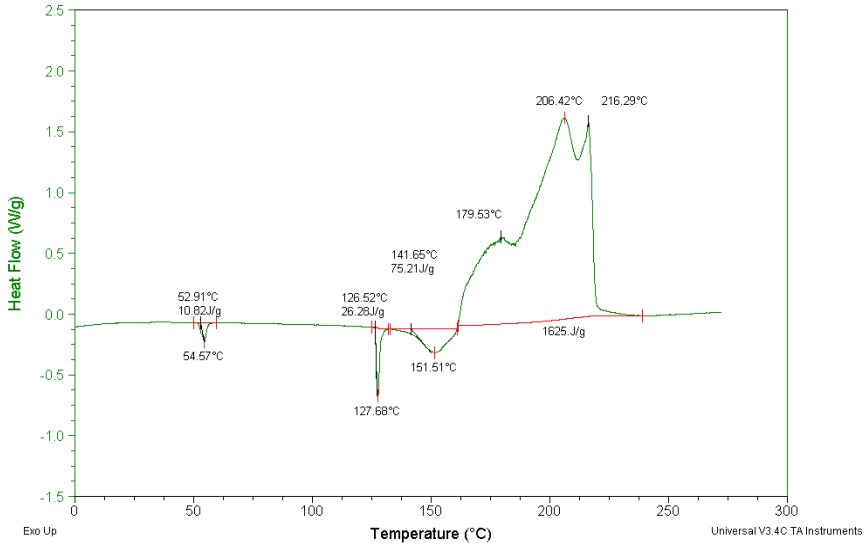
Thermal Sensitivity, DSC





IMS 26: AN/RDX/GAP/DNDA	
Heating Rate:	5 °/min
Exotherm Onset:	165.8 °C
Peak Temperature:	203.5 °C

IMS 13a: AN/TAGN/GAP/DNDA	
Heating Rate:	5 °/min
Endotherm Onset:	141.6 °C
Exotherm Onset:	166 °C
Peak Temperatures:	206.4 °C/ 216.3 °C

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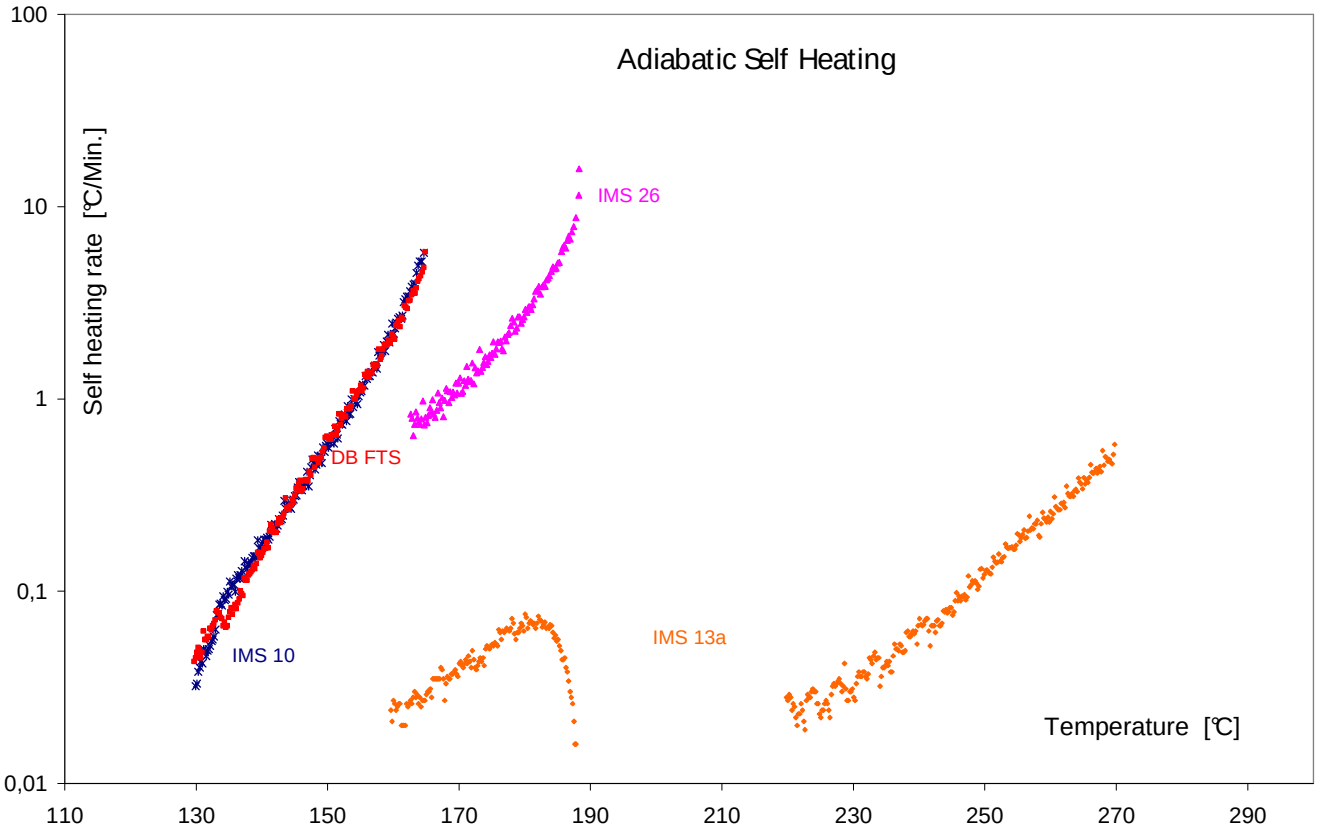
Thermal Sensitivity, ARC



Thermal Data:	IMS 10	DB	IMS 26	IMS 13a
ARC Onset:	125 °C	126 °C	162.6 °C	166 °C / 221 °C
Deflagration:	165 °C	168 °C	187.8 °C	290.9 °C

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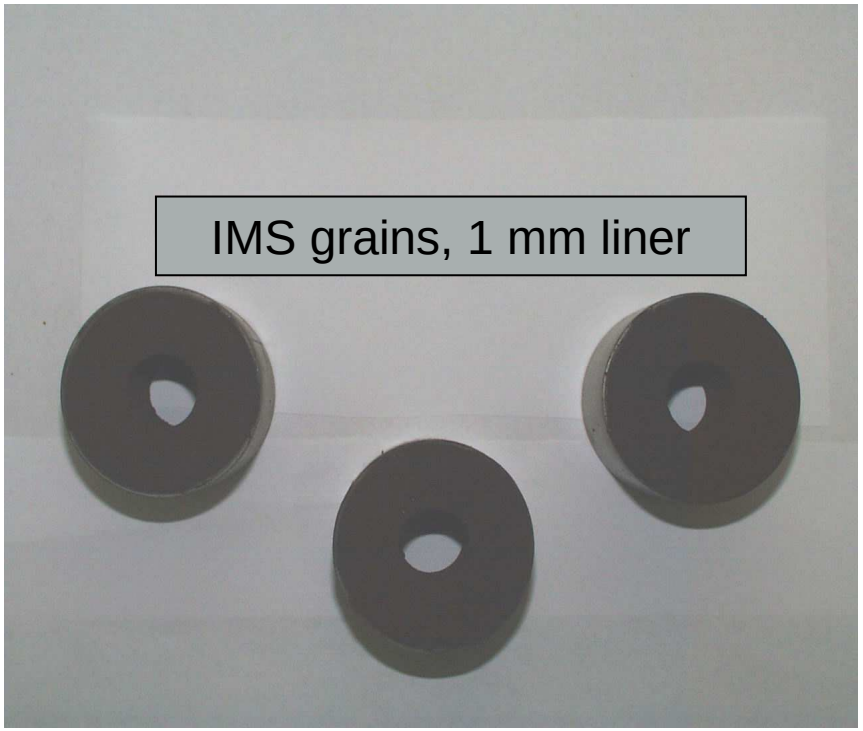
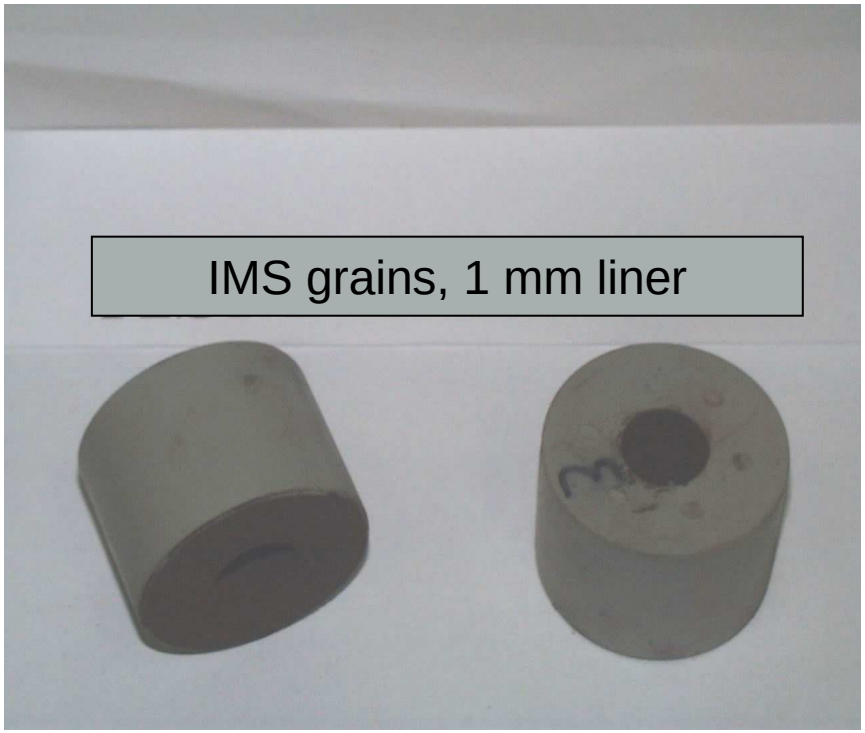
Sensitivity – Lab properties

Sensitivity	**Units**	**IMS 10**	**IMS 26**	**IMS 13a**
Energetic Solids		AN/RDX	AN/RDX	AN/TAGN
Binder		GAP/NE	GAP/DNDA	GAP/DNDA
Mechanical Sens. 20°C				
Friction (BAM)	N	192	360	240
Impact (BAM)	Nm	7,5	20	15
Thermal Sensitivity				
ARC Onset 1	°C	125	162.6	166
ARC Onset 2	°C			221.2
ARC deflagration	°C	165	187.8	290.9
Gap test 50 mm ∅				
PMMA gap thickness	mm	25+	0-	0-
initiation pressure	kbar	91.6	--	--

IMS grains with liner and ignition layer





Grains of IMS 10 and IMS 26 for ballistic firing tests, 50mm ∅, 18 mm bore, 36 mm length

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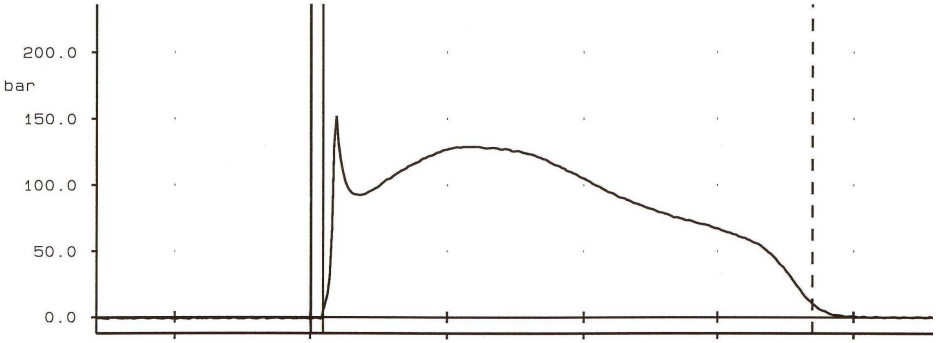
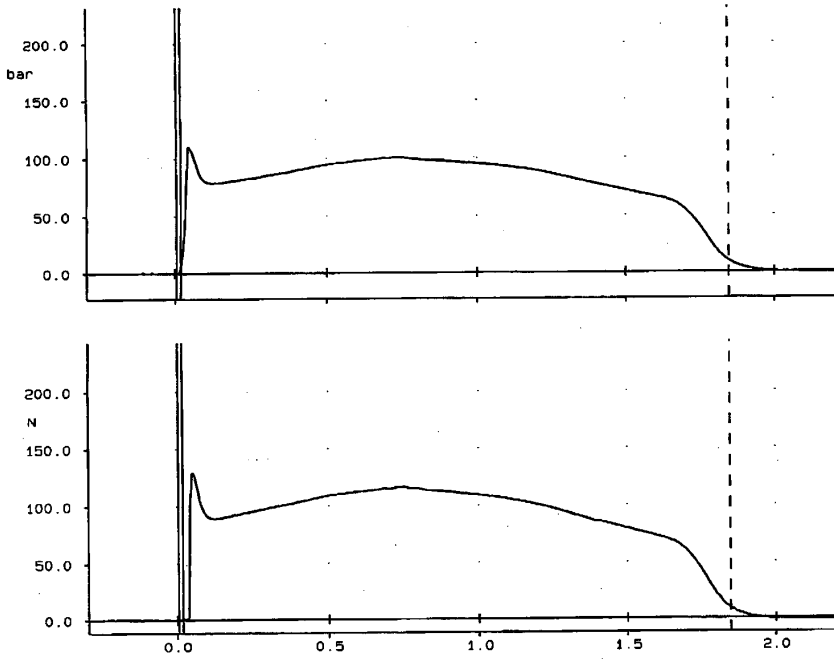
Ballistic Firing Tests with IMS grains



Pressure and thrust of IMS 26 with K=530 at 71 ℃, av. P = 82 bar

Pressure curve of IMS 10 with K=440 at 21 ℃, av. P = 92.4 bar



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Results of Ballistic Firing Tests with IMS grains

50 mm ∅, 36 mm length, 18 mm bore

Propellant	Prop. mass	Temp.	Throat ∅	Klemmung	web	Burn time exp.	Av. Burn rate exp.
	g	°C	mm		mm	s	mm/s
IMS 10	98.5	21	3.3	440	16	1.80	8.9
IMS 26/1	93.6	21	3.3	440	16	2.65	6.05
IMS 26/2	93.6	71	3.0	530	16	1.84	8.72
IMS26/th	93.6	21	2.6	682	16	1.70	9.4

Propellant	Av. exp. Pressure	Av. exp. Thrust	Isp total exp.	Spec. Isp theor.	Isp total theor.	Isp total exp/theor
	bar	N	Ns	Ns/kg	Ns	%
IMS 10	92.4	99.8	179.6	2269	223.5	80.4
IMS 26/1	57.4	63.8	168.9	2129	199.5	84.7
IMS 26/2	82	92.8	170.3	2186	204.8	83.2
IMS26/th	140	103	175.6	2261	211.6	83.0

Conclusion 1

- Due to the better oxygen balance AN/RDX/GAP/NE Propellants give the highest thermodynamic specific impulse 227 s at 7 MPa, temperature of combustion and characteristic velocity

- For AN/RDX/GAP/DNDA Propellants specific impulse is about 3% lower than for AN/RDX/GAP/NE propellants, Tc 10%, c* 2,2%; for AN/TAGN/GAP/DNDA prop. Isp is 6%, Tc 16.2% and c* 3,2% lower.

- All 3 propellants show applicable burn rates and pressure exponents at RT, but need tube forming grains to achieve applicable thrust

- All 3 propellants are endowed with applicable processibility, mechanical properties and chemical stability, AN/RDX/GAP/NE propellants with better processibility and mechanical properties, AN/GAP/DNDA propellants with better chemical stability

Conclusion 2

- Due to the presence of NE - AN/RDX/GAP/NE Propellants have an enhanced thermal sensitivity and sensitivity to detonation, show an early deflagration reaction Type III in slow cook off test at 134 ℃
- Thermal, impact and detonation sensitivity of both DNDA containing propellants is significantly reduced, without reaction in 50mm gap test and high temperatures for deflagration > 290 ℃ for IMS 13a.
- Although IMS 10 with TMETN/BTTN is sensitive to detonation in the 50 mm gap test, all 3 propellants obey to hazard classification 1.3
- Controlled burning and desired thrust delivery could be achieved from a small tube burning grain from IMS 10 and IMS 26 at RT and high temperatures

Acknowledgement

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