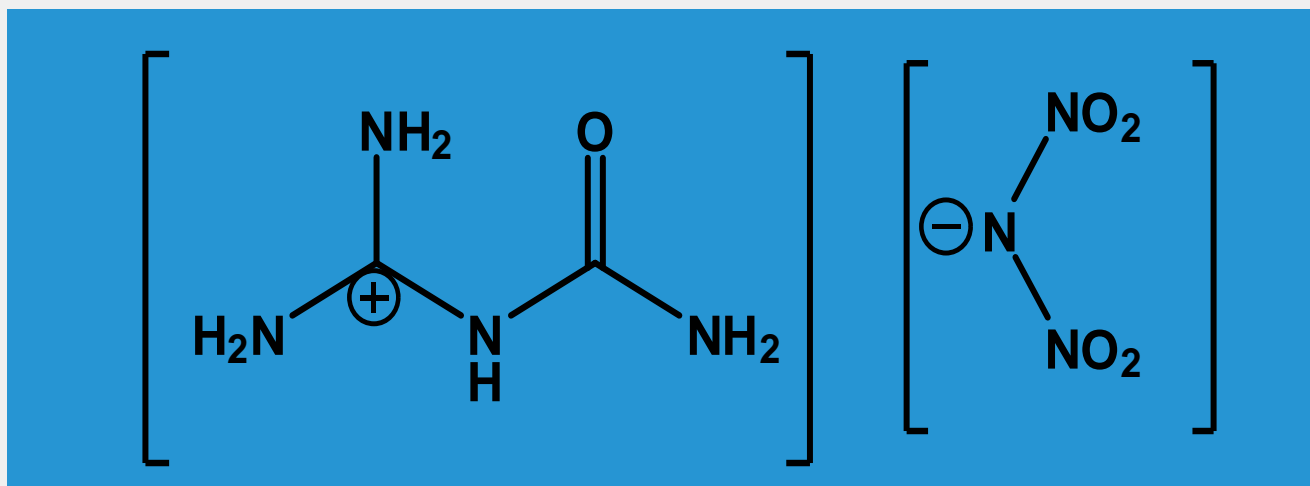


FOX-12 (GuDN): An IM Ingredient Candidate – Where Are We Today?



Helen Stenmark, EURENCO Bofors AB SE- 691 86 Karlskoga, Sweden
Henric Östmark and Helena Bergman, Swedish Defence Research Agency, FOI,
SE-164 90 Stockholm, Sweden

New Explosives: GuDN, FOX-12



- Low sensitivity
- Non-hygroscopic
- Non-toxic
- Very low solubility in water
- Nice overall performance as propellant

Drop weight sensitivity : >159 cm (RDX 38 cm)

Friction sensitivity : > 350 N (RDX 120 N)

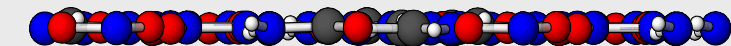
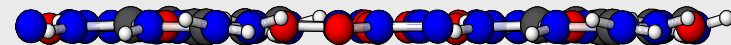
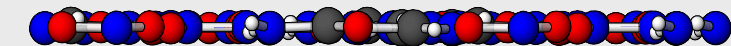
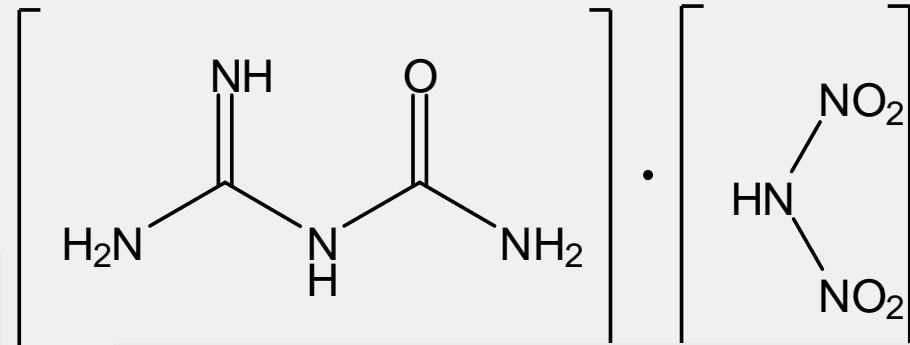
Explosion temperature: 192 °C (RDX 220 °C)

Heat of formation: -85 kcal/mole

Density(x-ray): 1.75 g/cm³

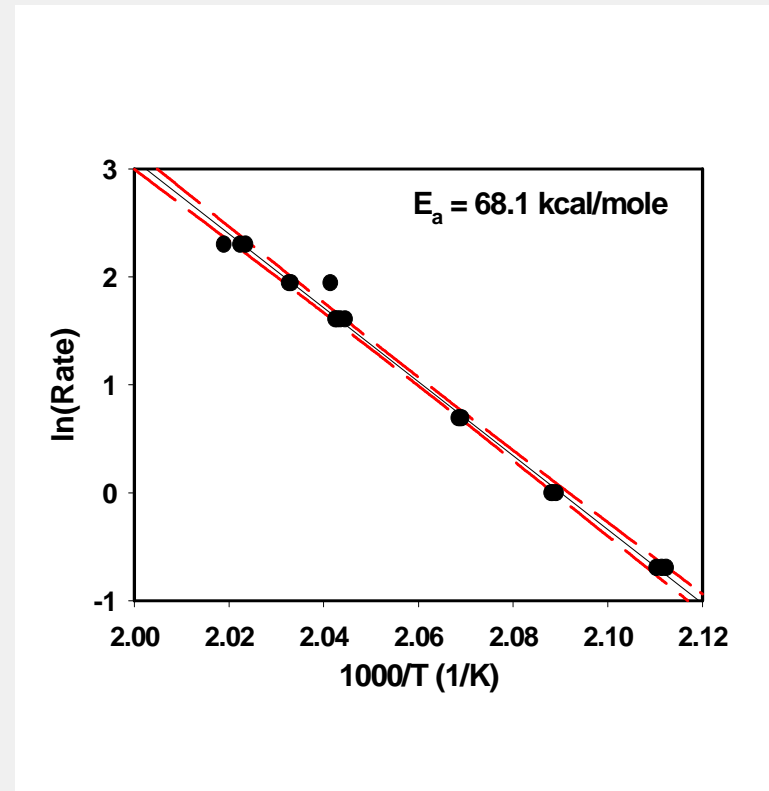
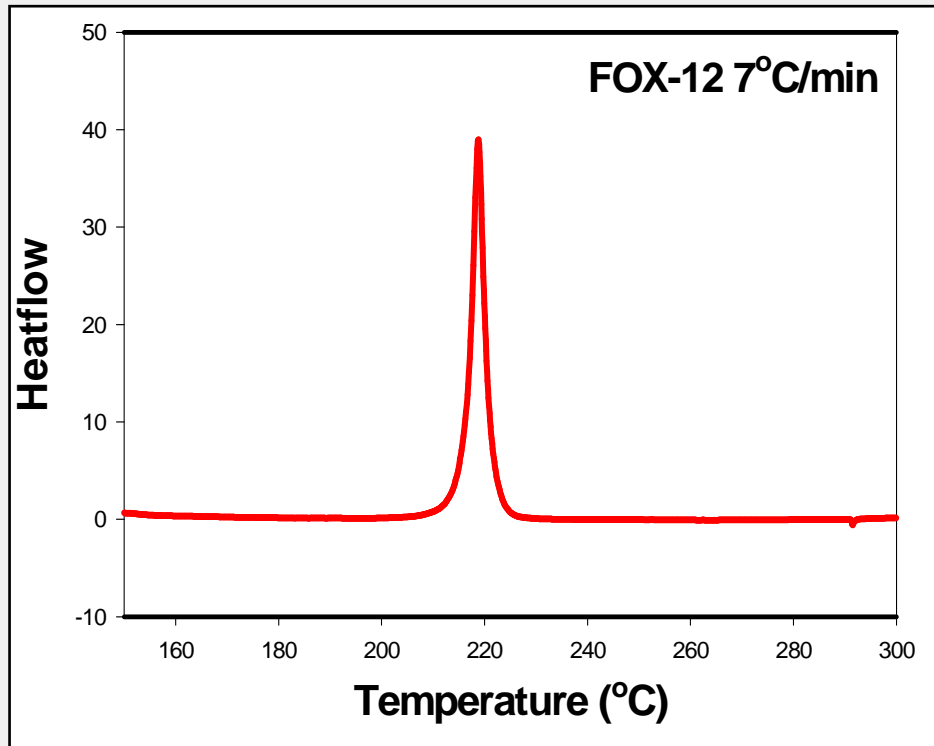
Melting point: Decomposes at 215 °C
(DSC onset 214.8 °C)

Produced by Eurenco Bofors AB
under license by Swedish Government

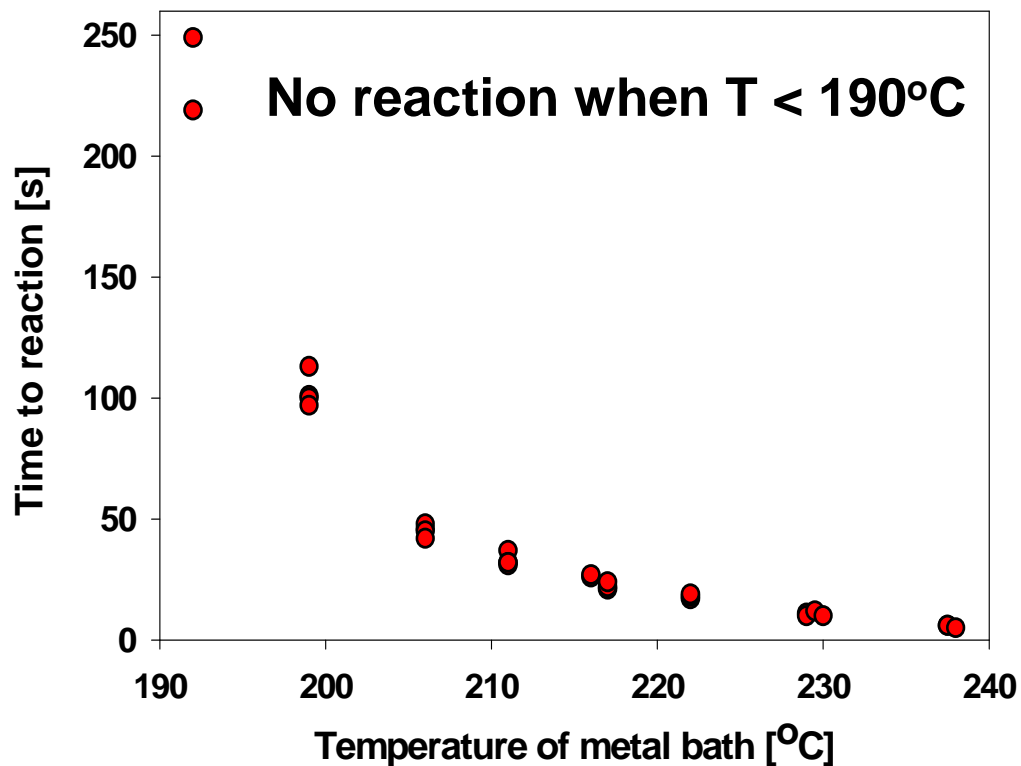


UN Transportation Classification: 1.4S

GuDN, FOX-12: DSC measurement



FOX-12/GuDN: Wood's Metal Bath, Ignition Temperature.



Activation energy (kcal/mol)

FOX-12	68.1	DSC
FOX-12	35.5	Wood
ADN	37.7	DSC
ADN	30.3	Wood
RDX	48.1	DSC

FOX-12/GuDN: Calculated performance

Calculated performance

	FOX-12	TNT	RDX
Detonation Velocity	8210 m/s	6900 m/s	8900 m/s
Detonation Pressure	25.7 GPa	19.4 GPa	34.6 GPa

Calculated gun propellant properties

	FOX-12	NC(12%)	NC(13%)
Impetus	953 J/g	986 J/g	1099 J/g
Temperature	2680 K	2860 K	3420 K

Calculated rocket propellant properties

	FOX-12	NC(12%)	AP/HTPB (70/30)
Specific Impulse	213.1 s	218.6 s	238.5 s

(TMD 100%, BKW EOS, BKWC library Cheetah 1.40)

Detonation of FOX-12/GuDN

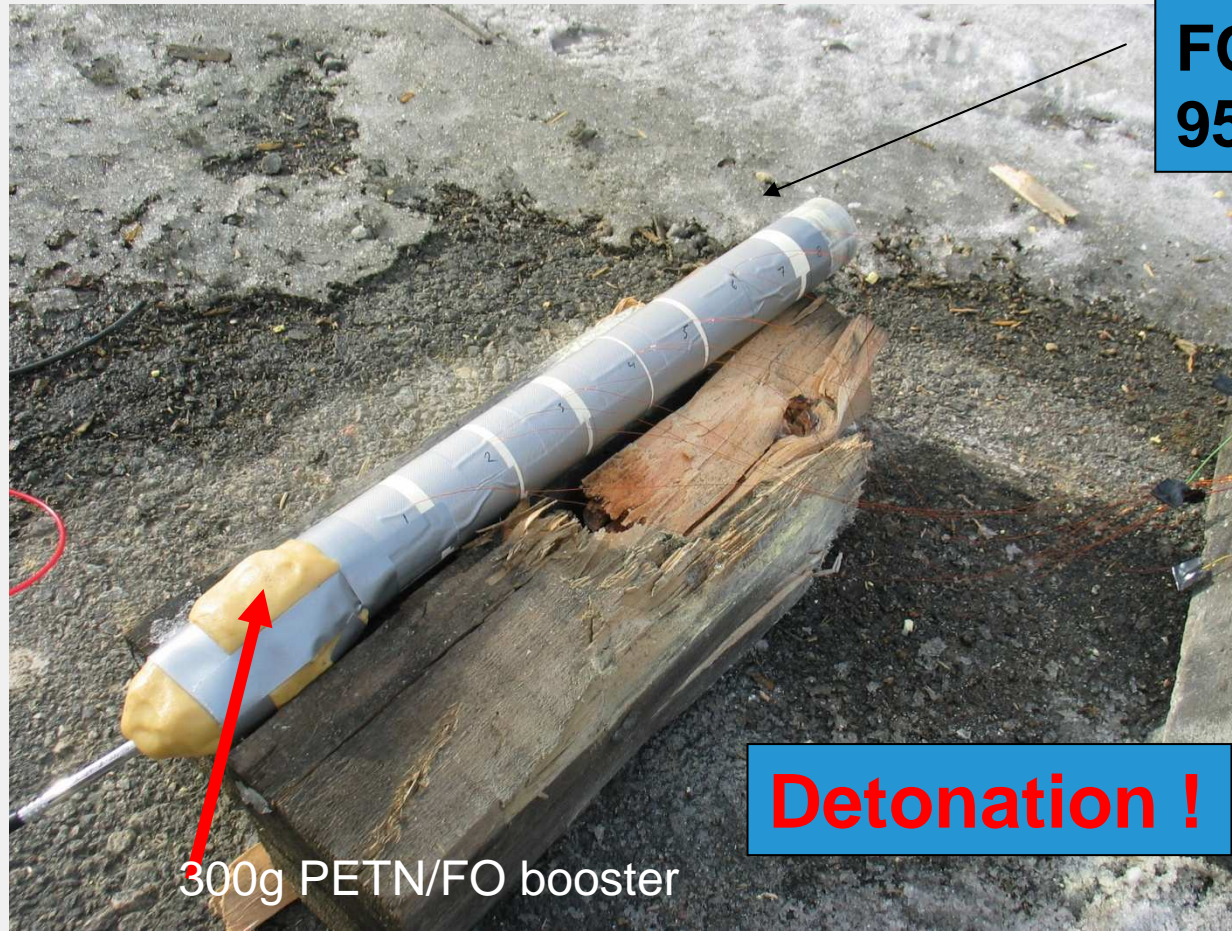


**FOX-12 $\phi=52\text{mm}$
95% TMD**

60g PETN/FO booster

NO Detonation

Detonation of FOX-12/GuDN



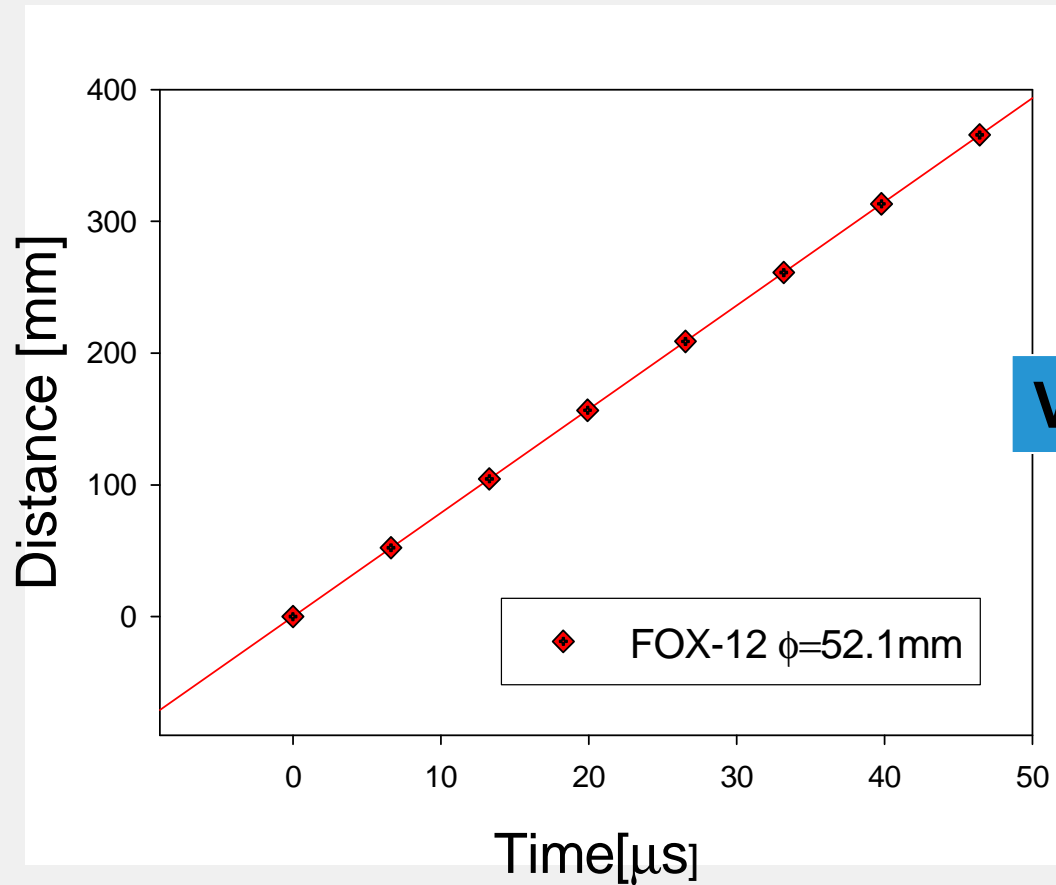
FOX-12 $\phi=52\text{mm}$
95% TMD

Detonation !

300g PETN/FO booster

VoD = 7870 m/s

FOX-12/GuDN Detonation velocity

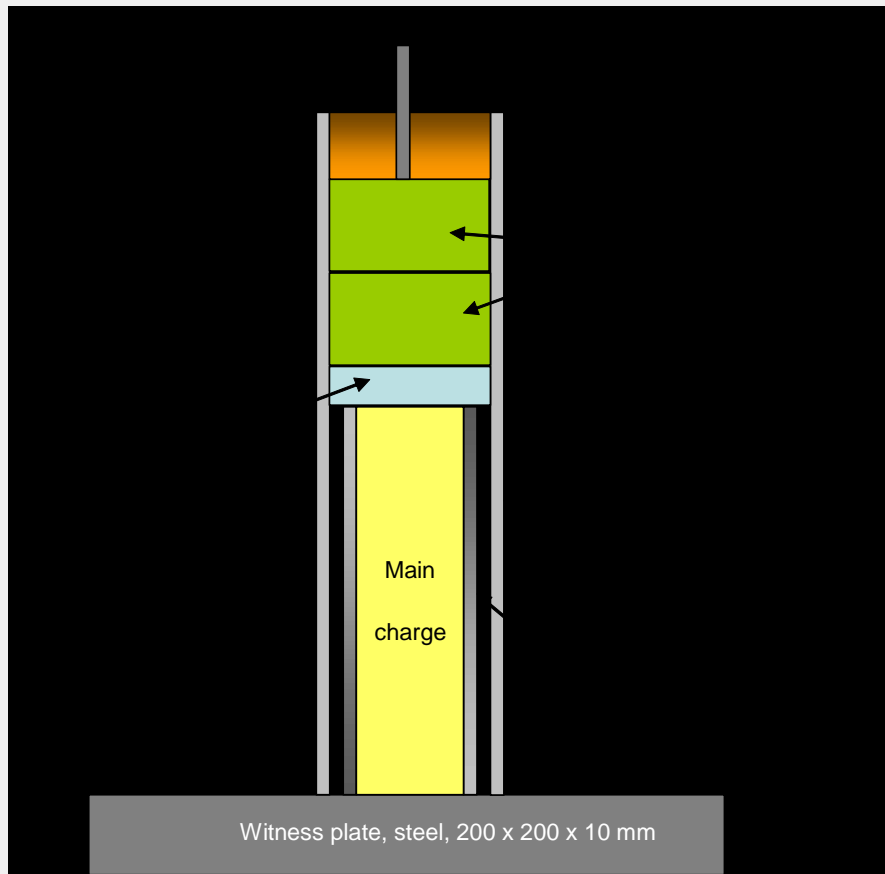


VoD = 7870 m/s

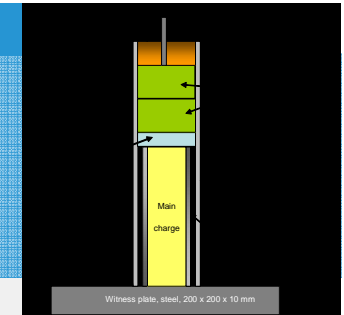
Detonation velocity measurements

Charge Diameter	Booster	Density (g/cm ³)	Detonation Velocity (m/s)	
			Measured	Calculated
22 mm	PBXN5 10g	1.67	No detonation	-
52.15 mm	PETN/FO 75g	1.66	No detonation	-
52.15 mm	PETN/FO 300g	1.66	7870	7810
60 mm (in copper tube shell thickness 6 mm)	Plan wave lens and 50 g Comp-B	1.666	7970	7835

Large Scale Gap Test



LSGT results



Name	Composition	No of cards (50% probability point)
FOX-12	FOX-12	72 - 90
<i>PBXW-115</i>	<i>AP/Al/HTPB/I-RDX^a</i>	<i>84</i>
<i>PBXN-109</i>	<i>RDX^a/Al/HTPB/DOA</i>	<i>130</i>
<i>Composition B</i>	<i>RDX^a/TNT</i>	<i>234</i>

Slow cook-off test setup

	Charge 1	Charge 2
Height (mm)	51.52	47.02
Diameter (mm)	49.89	49.87
Weight (g)	166.92	153.76
Density (g/cm ³)	1.66	1.67



Slow cook-off test results



Test setup after cook-off: cylinder (left), setup showing the opened side of the heating band (middle) and setup showing the back side of the heating band (right).

→ Type V

Melt Castable Formulations

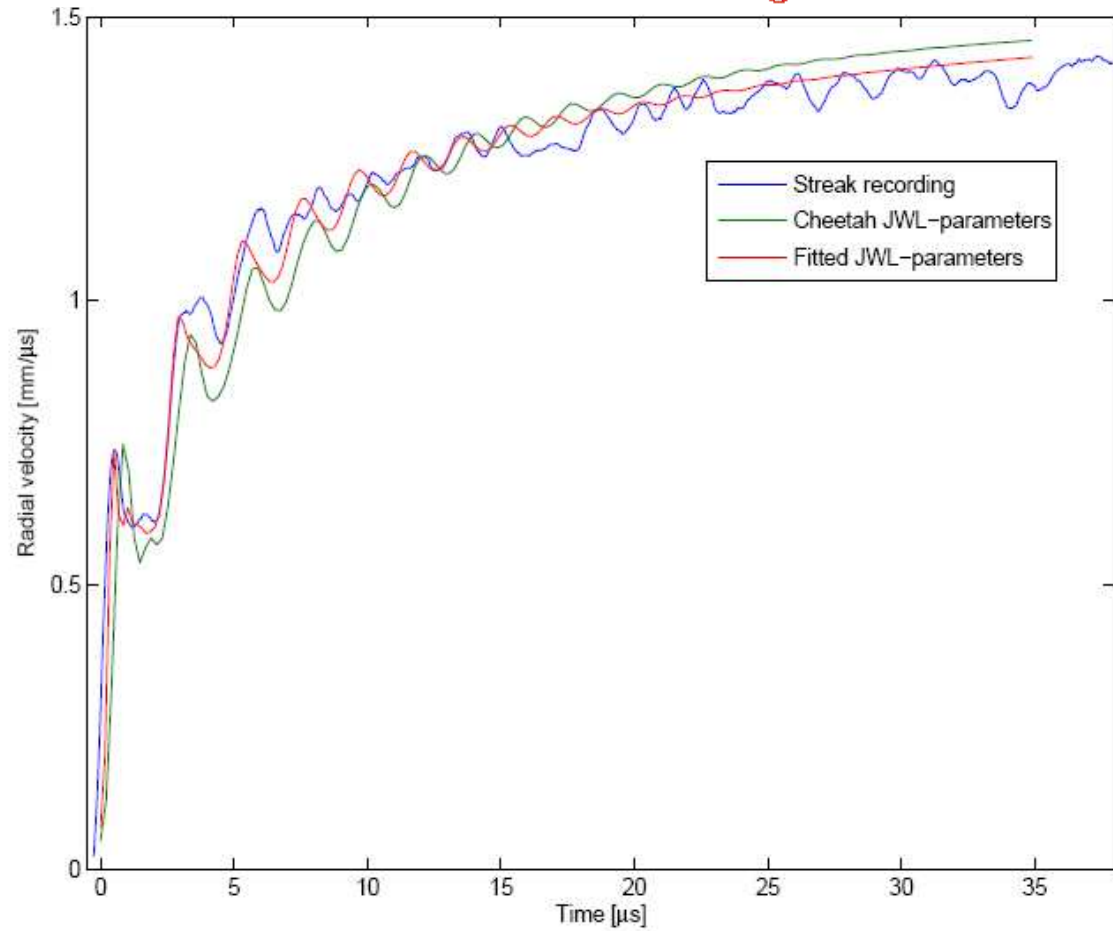
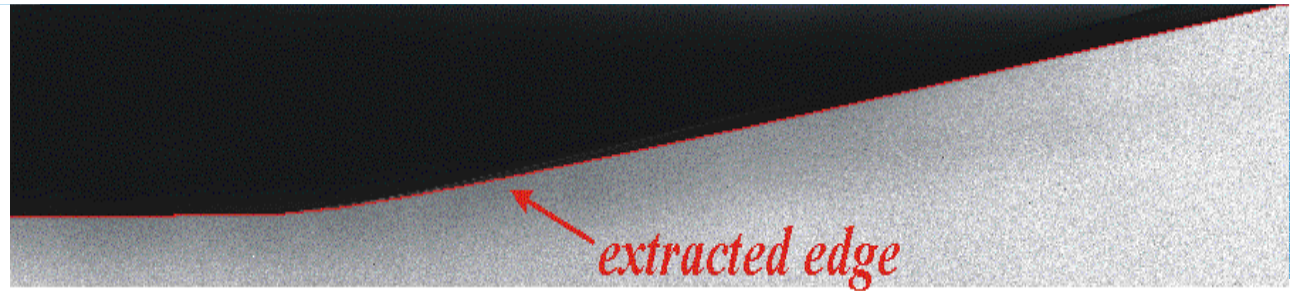
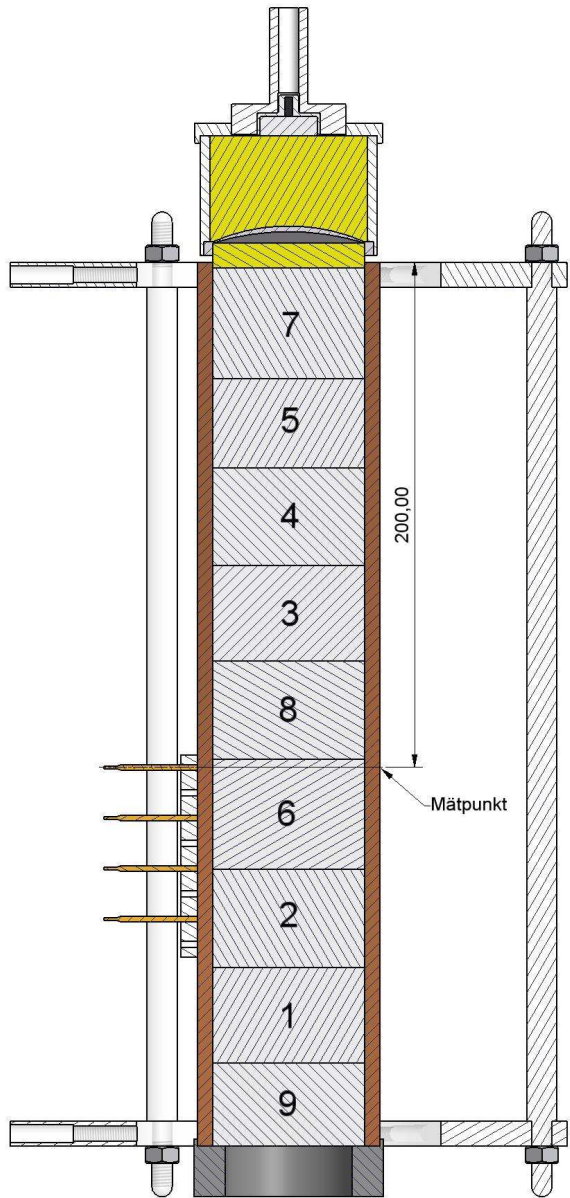
- Melt Cast Formulation FOX-12/TNT 60:40
- Performance

HE	VoD (km/s)	P _{CJ} (GPa)	V/V ₀ =2.2	Gurney velocity (2E) ^{1/2} =D/3
TNT	6.9	19.6	100	100
FOX-12	8.21	25.7	115	119
FOX-12/TNT 60:40	7.65	23.3	111	111

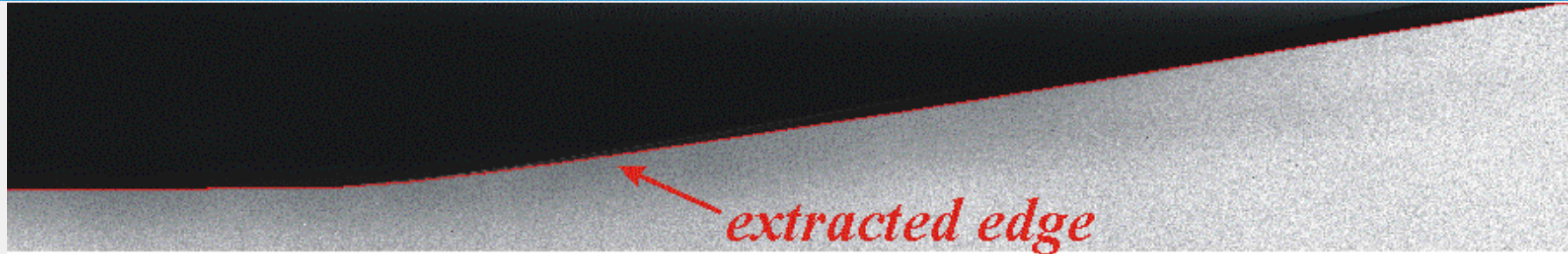
Melt-Cast Explosives

Explosive	Density (g/cm ³)	VoD (m/s)	Detonation Pressure (GPa)	Cylinder Expansion Energy for V/V ₀ =10 (Comp B=100)	Comments
FOX-12	1.75	8210	25.7	78	
TNT	1.65	6900	19.6	75	
RDX	1.81	8940	34.7	117	
FOX-12/TNT (60/40)	1.71	7650	23.3	79	Melt cast formulation
RDX/TNT (60/40) Comp B	1.74	8050	28.1	100	Melt cast formulation
FOX-12/GAP/Al 60/15/25	1.82	7940	23.4	103	Cast cure PBX
FOX-12/TNT/Al	1.86	7680	24.8	108	Melt cast formulation

Cheetah 2.0 BKWC



Cylinder test data



	D (m/s)	P_{CJ} (GPa)	A (GPa)	B (GPa)	R_1	R_2	w	E_0 (MPa)
Cheetah 2.0 BKWC	7 835	22.46	1061	7.048	5.178	1.064	0.385	6.796
Fit to exp. data	7 966	26.11	666.26	8.1308	4.55	1.46	0.385	6.800

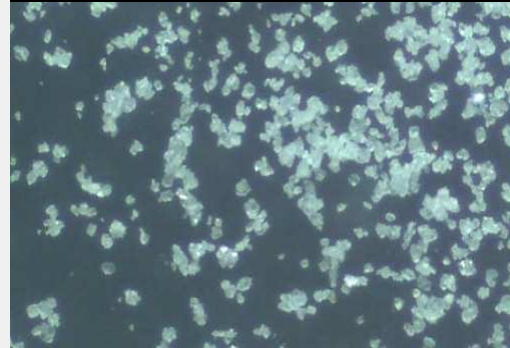
GuDN/FOX-12 particles

GuDN Gun propellant grade



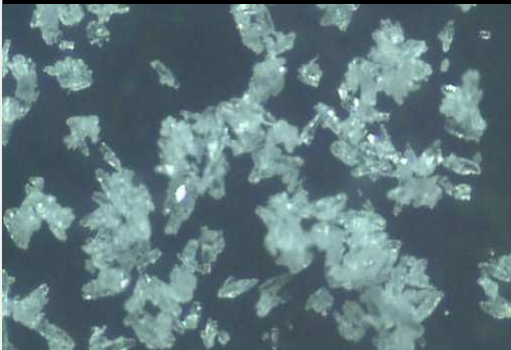
10-25 microns

GuDN class 1



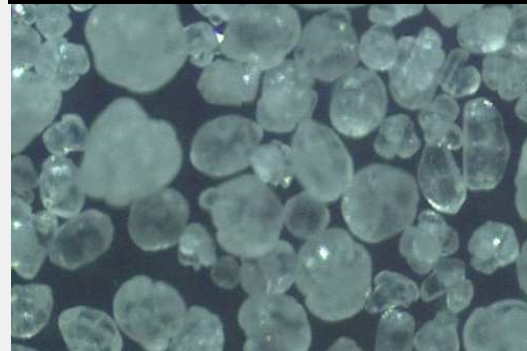
20-50 microns

GuDN class 2



80-150 microns

GuDN class 4

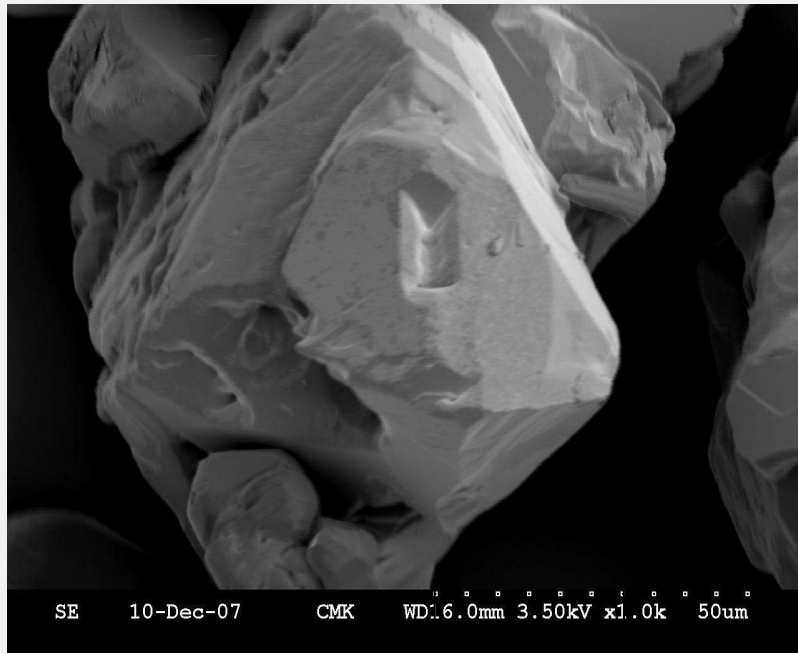


250 - 400 microns

GuDN/FOX-12 particles, class 1 vs propellant grade

GuDN class 1 NSG 110 art nr
34114

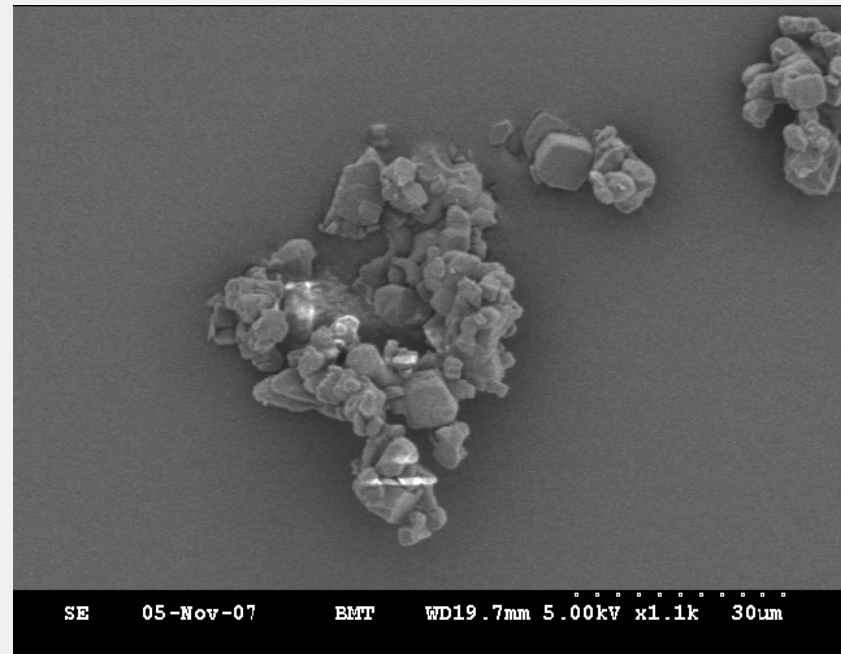
BET surface $\sim 0,1 \text{ m}^2/\text{g}$



30µm

GuDN, Gun propellant grade NSG 110 art nr 34100

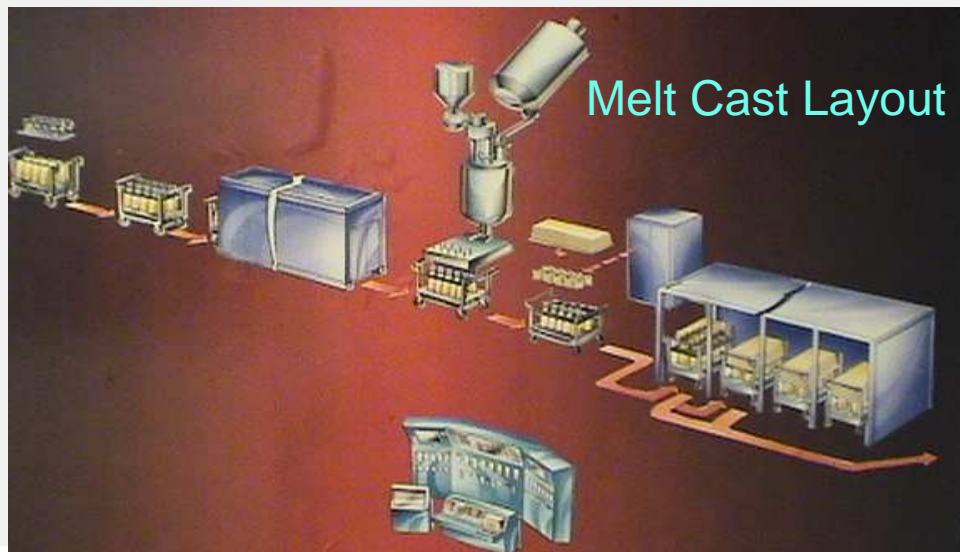
BET surface $\sim 0,4 \text{ m}^2/\text{g}$



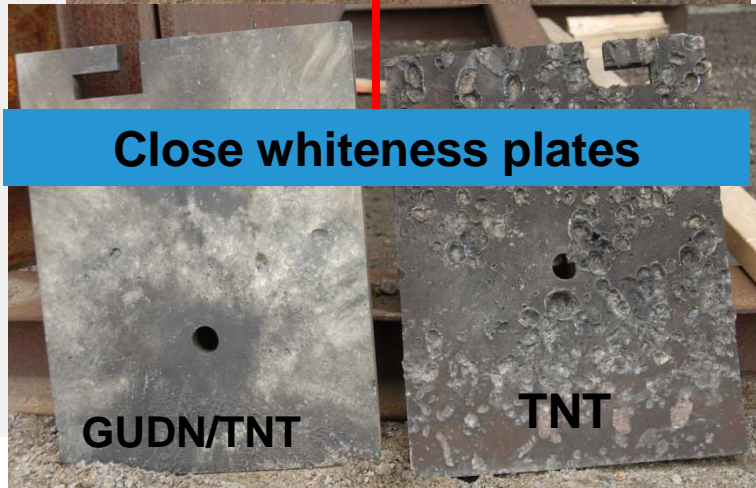
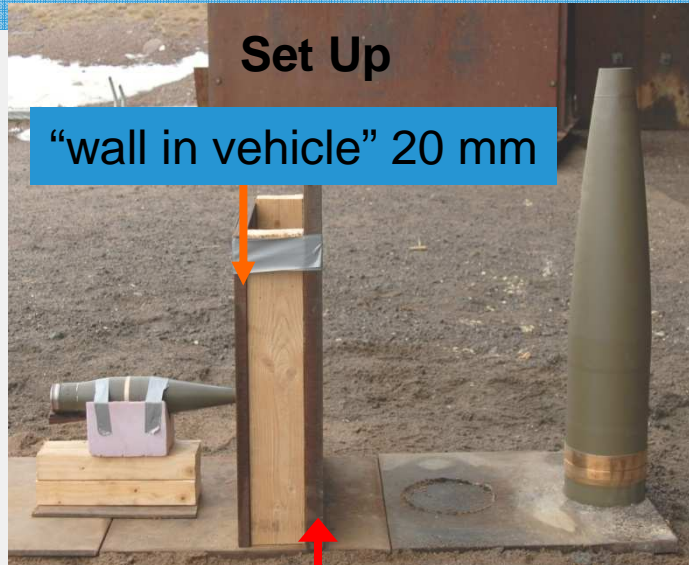
30µm

Casting 155 mm Artillery Shells

- Same casting process as for Comp B (RDX/TNT)
- Same surface treatment gave excellent adhesion
- No gaps
- X-ray showed no cracks or voids



Shaped Charge RPG-9 (73)



Conclusions

- GuDN/FOX-12 is extremely insensitive
- The thermal stability of GuDN/FOX-12 is comparable to RDX and superior to that of ADN
- The high molecular stability and low sensitivity of GuDN/FOX-12 is probably due to a layered crystal structure
- GuDN/FOX-12 has a higher performance than TNT
- GuDN/FOX-12 is melt castable with TNT
- GuDN/FOX-12 could be used as an ingredient in IM-composition for HE applications.

Acknowledgements

The authors would like to thank the following for support in this work:

The Swedish Armed Forces for funding this work

Andreas Helte for the cylinder test work

Carina Bergvall-Laitala for the work on particles