New Insensitive High Explosives

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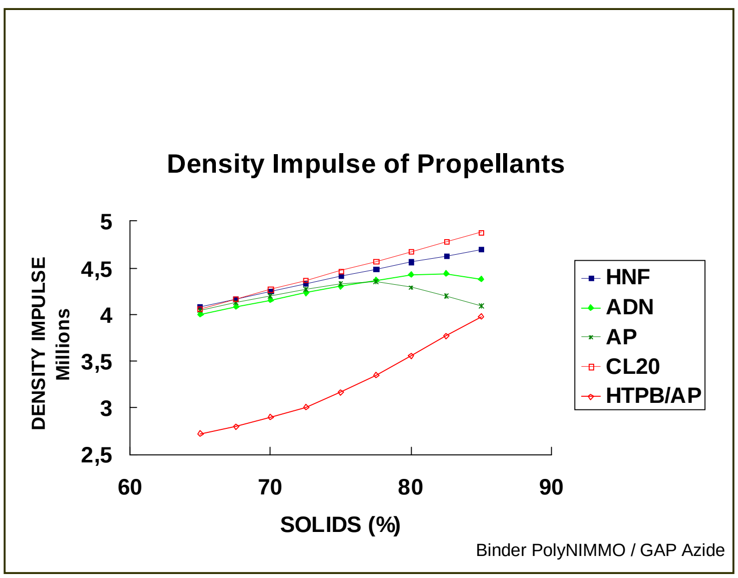
Ammonium dinitramide (ADN)

ADN is a strong oxidizer and an explosive. ADN has been produced for three years at NEXPLO Bofors AB using a method invented by FOA, Defense Research Establishment in Sweden. We are offering sample quantities as per request from our customers. Chemically ADN is a salt with the following formula: $NH_4^+ \ N_3O_4^-$

Low signature rocket propulsion.

Since ADN does not contain Chlorine it does not like AP-based formulations form HCl when it burns. Consequently no tail of condense is formed behind a missile or a rocket. This can be of great tactical importance. ADN-based propellants also give a higher specific impulse than AP-based propellants. Below is a diagram showing the calculated specific impulse in MNs/m^3 for ADN-based HTPB formulations compared with formulations based on HNF, CL 20 and AP. As can be seen in the diagram the ADN propellants have nearly the same performance as CL 20 and HNF. The maximum performance for an ADN propellant is obtained at rather low solid contents (around 80%). This is due to the high weight percentage of oxygen in ADN.



ADN in high performance underwater explosive compositions.

ADN is a high explosive with a detonation velocity of approximately 7000 m/s. It can therefore serve as both an oxidizer and a high explosive in depth charges. Therefore high explosives such as TNT or RDX can be left out from the composition, as they do not contribute with oxygen for burning the fuel. The result is higher bubble energy. Since ADN is meltable it is possible to use melt-casting filling technique.

ADN as main ingredient in liquid monopropellant.

Hydrazine has since the 1960's been the standard liquid monopropellant in space applications. Personnel safety and increased environmental awareness have become important issues in the context of propulsion system handling and operation. The cost of fuelling a spacecraft with hydrazine has therefore increased significantly along with the repeated lowering of the limit value of hydrazine exposure, which has been shown to be toxic, carcinogenic and volatile. Refueling in space has long been a target in the industry. The regulations prohibit hydrazine to ever be used in such operations.

A new composition based on ADN/Glycerol/water has been presented as a new non-toxic monopropellant with a better impulse than hydrazine[1]. Below is a table of performance (I_{sp} at an expansion ratio of 50) and toxicity (as LD50 orally) compared with hydrazine and HAN[2]. HAN (hydroxylammonium nitrate based monopropellant) has over the past five years emerged as a 'Green Propellant' candidate for space propulsion.

	I_{sp} (Ns/kg)	LD50 orally (mg/kg)
ADN/glycerol/water	2420	832 (pure ADN)
HAN/glycine/water	2001	325 (pure HAN)
Hydrazine	2325	59

General physical properties for ADN[2].

Appearance:	White or slightly yellow crystals
Heat of formation:	-137 kJ/mole
Density:	1.82 g/ml
Melting point:	92°C
Drop weight sensitivity:	31 cm (RDX 38 cm)
Friction sensitivity:	> 350 N
Autoignition temperature:	160°C
Transport classification:	1.1D

[1] 'Development and Testing of ADN-Based Monopropellants in Small Rocket Enfines', K. Anflo, T.A. Gronland, N. Wingborg, 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 17-19 July 2000, Huntsvilee, Alabama.
[2] Heat of Formation was measured at FOA.

Compatibility and stability for ADN based formulations

The compatibility studies on ADN presented so far show that the compatibility not only varies with the materials studied but also with the polymer system components but also with the manufacturer and the different lots of the components. ADN is somewhat incompatible with more reactive isocyanates. However, after curing the interactions disappear and the cured systems are stable. With a sensible choice of isocyanates and the right curing conditions we see a possibility to use ADN as an oxidant in polymeric binders cured with isocyanates. Below are tables of the measured compatibility[3] in 50/50 mixtures of ADN and some polymers and isocyanates that could be of interest in ADN work. This work was made by FOA.[4] The compatibility is best for DDI on the gram scale as can be seen below. On a mole scale HMDI is best since its mole weight is high.

Isocyanate	Manufacturer	Compatibility (J/g)
DDI	General Mills, USA	19
DNR	ICI, UK	> 112
HDI	Ventron, Germany	>386
IPDI	Huls, Germany	>137
X1004	ICI, UK	>189
HMDI (Desmodur W)	Bayer, Germany.	26
N-100	Bayer, Germany	>189

Polymer	Manufacturer	Compatibility (J/g)
Krasol LBH	Kaucuk a.s., Czech Republic	1
GAP	SNPE, France, 1996	0.7
PolyNIMMO	ICI, UK	7
Krasol LB	Kaucuk a.s., Czech Republic	13
HTPB (R-45 HT)	ARCO, USA	13

Plasticiser	Manufacturer	Compatibility (J/g)
Butyl-NENA	Dyno, Norway	>320
K-10	FOA	0.53

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[3] The compatibiliy is defined as the difference between the energy flow in the mixture and the energy flow for the pure components.

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Guanylurea Dinitramide (GUDN)

GUDN is a nitrogen rich dinitramide. The formula is $C(NH_2)_3N(NO_2)_2$. It is intended for use as the main feedstock for gas generating compositions in airbags and belt restrainer systems. The fact that it is rich in nitrogen and oxygen and not contains any atoms forming solid oxides means that it burns with a very high gas yield. The emission has a very low percentage of carbon monoxide due to the low content of carbon. This is important when it is used in automotive safety devices where there are strong restrictions regarding the toxicity for the gases.

The dinitramide burns with a moderate rate at a pressure coefficient approximately 0.5 – 0.7. However, when mixed with inorganic oxidizers, such as perchlorates or nitrates, they burn with a high rate and a pressure coefficient down to 0.3–0.4.

Another characteristic that makes this substance interesting for air-bag applications is its excellent thermal stability. It therefore meets the tough requirements on long-term stability that is required in the car industry.

The original idea with GUDN was to use it as a burning modifier in ADN-based rocket propellants. This application is not yet investigated. However, we assume that when continuing the work with ADN- based rocket formulations, the influence of this substance will be taken into consideration.

GUDN shows very low mechanical sensitivity. We therefore believe that the compounds could be of interest as energetic fillers in systems where IM- properties are required. A thinkable use for GUDN in this context is as an admixture to HMX. We have measured the detonation velocity to 7500 m/s for a 50:50 mixture. These mixtures will be more investigated and hopefully will more information be reported at the meeting.

The substance is a down-stream product in our production line for ADN. The availability for GUDN is practically not limited, as long as the requests are for sample quantities that could be up to several hundreds of kilograms.

Physical data.

Ignition temperature	200°C
Melting point	Decomposes before melting
Water solubility	5g/l (20°C)
Thermal stability	110°C/400 h
Pressure exponent	0.6 – 0.7
Burn rate as pure substance	5 mm/s (5 MPa), 50 mm/s (50 MPa)

Sensitivity data.

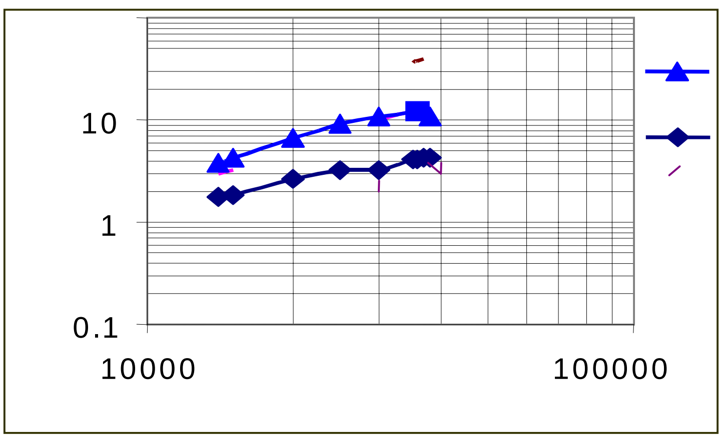
Impact (BAM)	> 49 J	(Maximum value according to the test method)
Friction (BAM)	> 353 N	(Maximum value according to the test method)
ESD	> 3125 mJ	(Maximum value according to the test method)

1,1-diamino, 2,2-dinitro ethene (FOX 7)

NEXPLO Bofors will now start a scaled up lab-production of FOX 7 using a synthetic route invented by FOA. Samples of 1 - 5 kg are now available. FOX 7 is a new high explosive with low sensitivity and a burn rate modifier in propellant.

FOX 7 as an explosive for IM warheads.

FOX 7 is considerably less sensitive than RDX but with similar performance. Therefore by changing from RDX to FOX 7 keeping everything constant could render IM qualities to most type of ammunition.



Today is NTO might be the most used low sensitive high explosive. We would like to present FOX 7 as an alternative to NTO with excellent thermal properties and good chemical stability including hydrolysis. The synthesis of FOX 7 is a two step path with high yields. Therefore we believe that the price of FOX 7 once its production is scaled up to industrial volumes will be very competitive.

FOX 7 as a burn rate modifier in LOVA propellant.

The diagram to the left shows the burn rate in in/sec vs. pressure in psi for an RDX based LOVA propellant (black legends (lower curve)) and after addition of 20 % Fox 7[5]

General physical properties[6].

Appearance	Orange crystals
Drop weight sensitivity	126 cm (RDX 38 cm)
Friction sensitivity	> 350 N (RDX 120 N)
Small Scale Gap Test at 1.63 g/ml	6.22 mm (RDX 9.33 mm, HMX 10.3 mm, TNT 6.4 mm)
ESD	> 8 J (HMX 0.2 J)
Detonation velocity	8500 m/s
Density	1.885
Calculated detonation pressure	34 GPa (RDX 35 GPa).

Solubility data for FOX 7

Solvent	Solubility, gr/100 ml at 20°C
acetone, aceticacid, buthanol	<0.1
ethyl acetate, nitromethane, water	<0.1
Acetonitrile	<0.5
Cyclohexanone	<0.5
dimethyl formamide	21
N-methyl pyrrolidone	32
dimethyl sulphoxide	approx. 45

FOX 7 has excellent compatibility with most materials used in energetic compositions such as: [7]

CAB (BF900), Estane, GAP (SNPE), HTPB (R-45 HT), HTPB (Krasol LBH), Viton, HMDI (isocyanate), Butyl, NENA, K-10.

[5] Christine Knott, Christine Walsh, Susan Peters, Ron Simmons, and Randall J. Cramer, 'Avdanced Gun Propellant Formulation & Technology', presented at 35Th Annual Guns & Ammunition Symposium and Exibition.
[6] All data obtained from FOA whith exception from detonation velocity.
[7] Compatibility data was obtained from FOA.