EURENCO
GROUPE SNPE

FOX-7 NEWS

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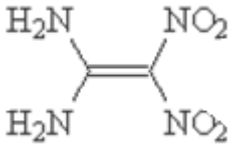
GENERAL

In this issue

The purpose with this paper is to update the readers on FOX-7. It is also an opportunity for us to inform you on our plans and ideas.



FOX-7 is a code name for 1,1-diamino-2,2 dinitroethylene, also called 1,1- diamino-2,2 dinitroethene, and its acronyms can be either DADE or DADNE. It is a high explosive with performance as RDX but with a significantly better stability to shock, friction, and heat. It has shown to be an inert substance with demonstrated compatibility to compounds commonly used in explosive formulations. FOI, the Swedish Defense Research Agency, invented a new synthetic route, which has made it possible for EURENCO Bofors to start pilot scale production. They also invented the name FOX-7. The availability and its interesting properties and ideas for applications published by FOI have sparked an interest for FOX-7. Several research establishments are today exploring its possibilities mostly for military applications. Today EURENCO Bofors produces FOX-7 in a pilot scale. For the moment, we can satisfy the need for samples for testing. A breakthrough for an application and procurement would give us the opportunity to scale up to industrial production.

Basic properties

Heat of Formation	-32 kcal/mole
Crystal density	1.885 g/cm3
Activation energy	58 kcal/mole (40 for RDX)
Drop-weight test	126 cm (38 cm for RDX)
SSGT (1.65 g/cm3)	6.22 mm (9.33 RDX)
Detonation velocity (1.5 % wax, 1.756 g/cm3)	8335 m/s
Calc. det. Velocity	8870 m/s (RDX 8930 m/s)
Calc. detonation pressure	34 GPa (RDX 34.6 GPa)
Koenen test (According to UN)	6 mm type F (RDX 8mm)
SCB BX formulation with 70% FOX-7	Bomb intact (Comp B exploded)

FOI has led the most of characterization work of FOX-7. The values are without exceptions collected from data published by them.

The well behaved explosive

It was quite recently, late nineties, when FOI started to publish experimental properties that FOX-7 became known as an available explosive. Now we know quit a lot of its potential for IM. Besides FOI the most important characterization of the sensitivity properties has been made at DSTO in Australia. They tested pressed cylindrical charges of FOX-7 and 5% poly(ethylene-co-vinyl acetate) (EVA) as the binder. The detonation velocity and pressure were respectively 8249 m/s and 26.4 GPa. Considering that the pressed charges had 6% porosity, these values are consistent with the Cheetah calculation by FOI 8870 m/s and 34 GPa. The Cheeta values for RDX are 8930 m/s and 35.64 GPa. A cylinder test with a composition of 1.5% wax pressed to the density 1.756 g/cm3 gave the value 8335 m/s. These results establish that FOX-7 has the performance of RDX.

FOX-7 seems to be the energetic substance that has been on the militaries "which list" since the systematic search for safer ammunition started around forty years ago. Difference from other explosive substances is the combination of sufficient performance and a low sensitivity. A number of published tests show sensitivity toward both mechanical and thermal stimuli drastically below RDX. Crystals, pressed formulations and cast cured PBX have been tested. In addition, the basic physical activation energy confirms the stability. The crystal structure maybe explains why FOX-7 is insensitive. FOI has discussed how the 'fish bone' like layered crystal structure contributes to its stability towards mechanical stimuli. The conclusion from published results is clearly that the performance and insensitivity for FOX-7 rest on a solid experimental and theoretical foundation.

It is relevant and interesting to compare TATB with FOX-7 for many reasons. Chemically, they have the same connectivity with amines and nitro-groups being substituted next to each other on olephines. Since both FOX-7 and TATB are more insensitive than other nitro aromatic and olephinic compounds it is tempting to believe that the alternation of electron withdrawing nitro groups and electron releasing amines should stabilize the bonds in the molecule. FOX-7 is chemically inert. No incompatibility has been seen with the plasticizers, polymers and isocyantates commonly used in explosive formulations. It is also quit insoluble compared to RDX, which also indicates its chemical inertness. Fortunately, it is not as insoluble as TATB, which sofar seems to be insoluble in anything except concentrated acids. In difference from TATB there are organic solvents in which FOX-7 can be efficiently re-crystallized. This is important since it is the best method to obtain high purity and optimized particle size distributions.

A relevant question is of course what price will be. The cost for making FOX-7 is quit reasonable. It is a onestep process. The starting material is more expensive than hexamine for RDX but still realistic. Today we charge a very high price compared to market price of RDX, NTO or HMX. The reason is we need to cover costs for scale up work and development we have had. It does not reflect the cost of production. If we would use the same pricing for FOX-7 as we do for RDX or HMX the price would be drastically lower. We have no illusions that we can continue to charge today's price once FOX-7 is used in larger scale. Of course, we need to have a competitive price with reference to other insensitive explosives, such as NTO and TATB. We do not see any large differences in the cost of producing NTO, which also is a one-step process explosives in only one step.

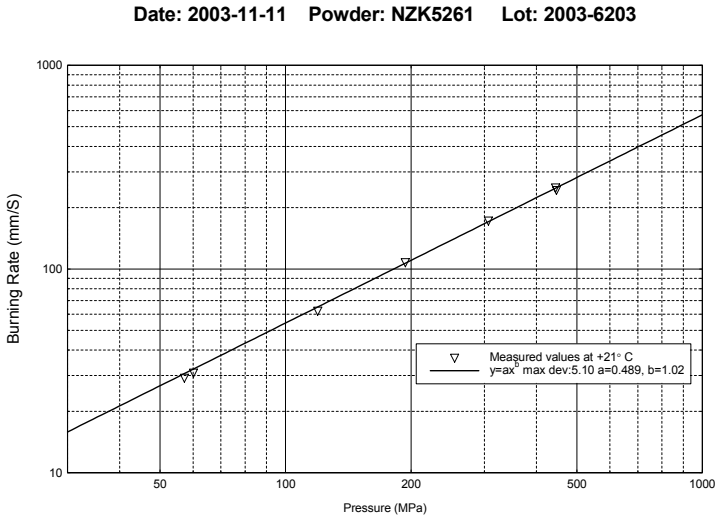
Compared to TATB, the price will most likely be lower considering the more complicated process for TATB. The VNS method developed by LLNL is a two-step process since the picramide is an explosive and therefore cannot be brought in as a raw material from a non-explosive manufacturer.

TATB is a potential booster explosive for IM. A pressed FOX-7 composition could also serve as an I.M. booster. DSTO have reported positive results for FOX-7 in the Bickfors Fuse and in the Train Test.

Insensitive High Performance Gun Propellant

The development of gun propellants at EURENCO Bofors took a new turn in 1999 when FOX-7 and FOX-12 became available for extensive testing in gun propellants.

The research on gun propellants based on new ingredients was initially included in a government funded research program. In 2002 preliminary tests with the new propellants led to a new research program aiming towards a more detailed study of insensitive gun propellants. A program funded by both government and industry and led to a production scale capability allowing for large scale testing.



The propellants that are under development at our company are mainly based on combinations of FOX-7, FOX-12 and RDX together with a binder system consisting of NENA and nitrocellulose. For comparative testing, we use a carrier composition in which RDX, FOX-7 and FOX-12 could be interchanged to screen possible performances. The most promising combinations where then further optimized.

Due to the different performance of FOX-7 and FOX-12 as energetic fillers in gun propellants, we can tailor compositions for a specific application without loosing the sensitivity aspect. FOX-7 is more energetic and delivers more gun performance to the propellant than FOX-12. FOX-12, on the other hand, contributes with a very low flame temperature and enough gun performance for artillery or machine gun applications where low barrel ware is important. At present, we test propellants containing FOX-7 in the kinetic round for BOFORS 40 mm gun, where as the FOX-12 propellants we test them in the modular charge system for BOFORS 155 mm gun.

Stability testing according to STANAG 4582 shows that the FOX-7 compositions are long term stable with some of the most common stabilizers. However, a new stabilizer is under development to strengthen the stability further. Preliminary testing shows good results.

1-perf FOX-7 propellant

A typical composition with 60% FOX-7 generates a burning-rate of approximately 55 mm/s at 100 MPa with a burning exponent around 1. Compared to a reference composition containing RDX as a replacement for FOX-7, the EMBLA burn rate curves are nearly identical. FOX-7 reduces the ignition start-up time significantly in comparison to the RDX reference composition. The gun performance equals that of a double-base propellant but the flame temperature as well as the temperature dependence is considerably lower.

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