CHARACTERIZATION OF 2,4-DINITROANISOLE (DNAN)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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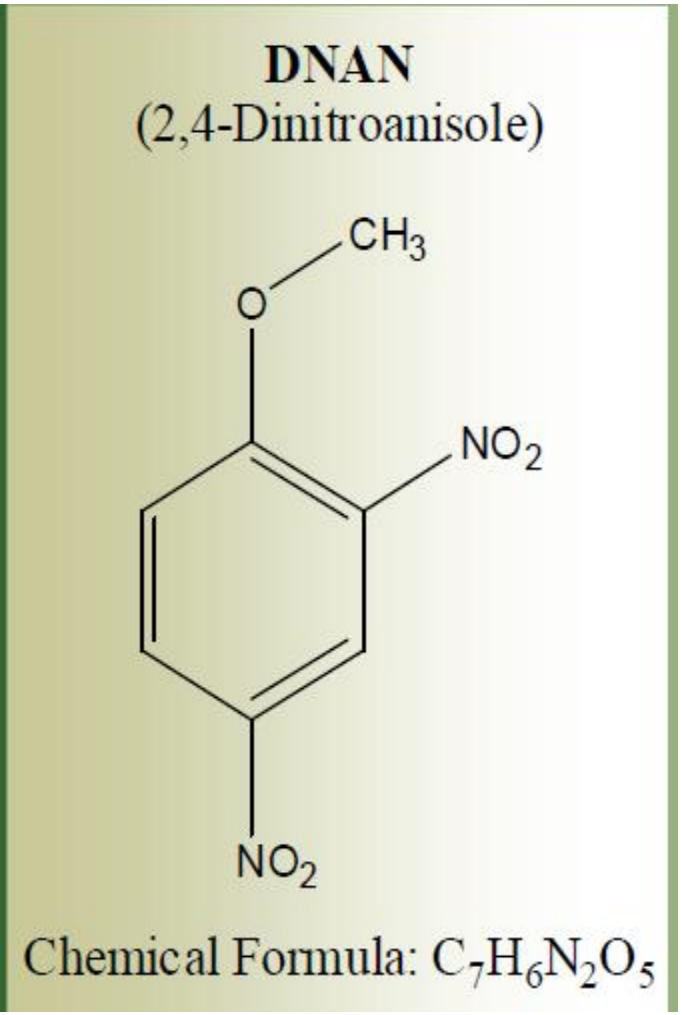
DoD / Industry Participants

Australian Government
Department of Defence
Defence Science and
Technology Organisation

Background

- DNAN based Explosives have been shown to have greatly improved IM characteristics, while still being able to meet performance requirements
- Army Qualified DNAN formulations are used in
  - PAX-21 (60mm M720A1/M768 Mortars)
  - PAX-41 (Spider Grenade)
  - PAX-48 (120mm HE-T)
  - IMX-101 (105mm & 155mm Artillery HE)
  - IMX-104 (60/81/120mm Mortar)

DNAN Properties



Application	General Purpose: A major ingredient for numerous extremely insensitive melt pour explosive formulations such as PAX-21, PAX-41, PAX-48, IMX-101, and IMX-104
Molecular Weight	198.13
Density	1.52 g/cc
Purity	>99%
Melting Point	92-96C
Peak Exotherm	>315C
Onset Exotherm	>330C
Vacuum Thermal Stability	<0.5mL/g sample (5.0 g sample/100C/48 hrs)
Color	Pale Yellow to Yellow
Water Content	20% Maximum
Batch Size	Full Production Scale (>3000 lb)
NOL LSGT	71 Cards* (Casted)
Detonation Velocity	5.59 km/s* (Casted)

*DSTO-TR-2256 The Formulation & Performance of DNAN Based Insensitive Explosives

Solubility

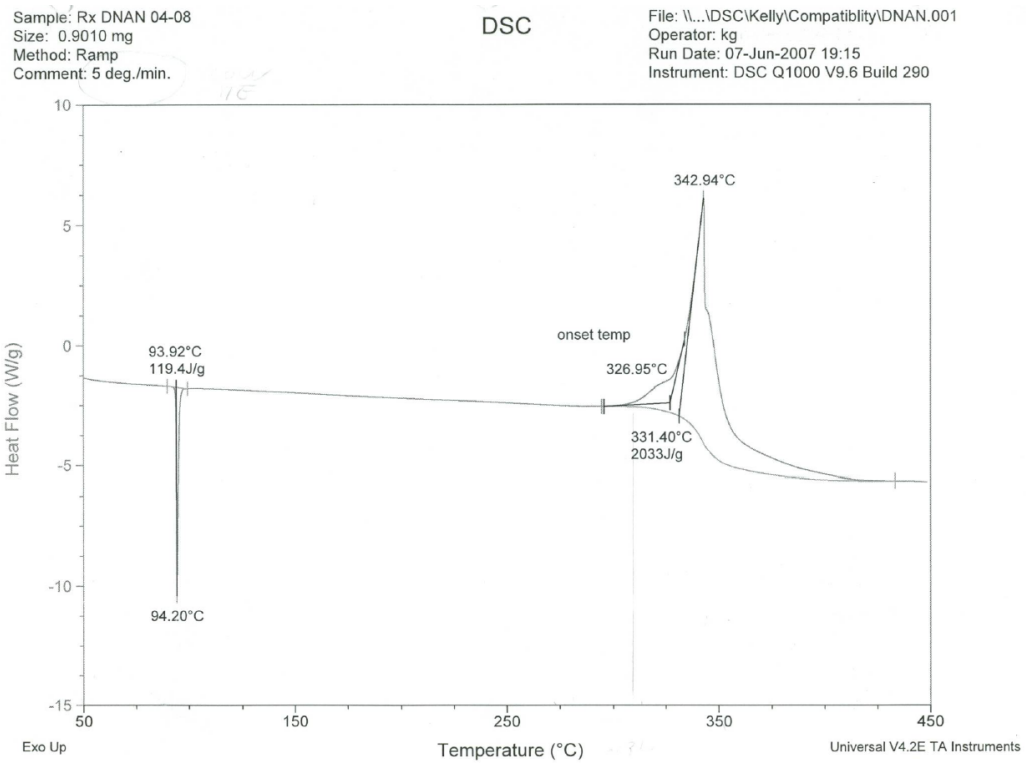
- Molten DNAN dissolves RDX as does molten TNT.
- Other ingredients are not very soluble.

SOLID SUBSTANCE	SOLUBILITY g/100g DNAN @ 100°C
RDX	14
HMX	3
NTO	0.2
NQ	0.45
AP	0.08

- RDX Solubility in TNT At 100ºC: 7.53
  - Reference TM 9-1300-214 “Military Explosives” with distribution DA Form 12-34-E, Sept. 1984, p. 8-33

Thermal

- 2,4 DNAN is more thermally stable than RDX.
- The DNAN sample was subjected to a 5°C /minute ramping rate up to 400°C
- The onset of decomposition occurred at a temperature of 226.13°C, the peak occurred at 244.44°C, indicating ignition and decomposition
- The DNAN sample did not exhibit any unusual DSC behavior
- The onset of melting was 93.92°C



Irreversible Growth Test Results per AOP-7

Formulation	Average % Volume Change
DNAN	15.01%
PAX-41	12.12%
Comp B	8.46%
IMX-101	8.00%
PAX-21	6.77%
IMX-104	5.26%
PAX-48	3.97%
Recovered TNT	3.52%
TNT	3.10%

- PAX-21: DNAN, RDX, AP
- PAX-41: DNAN, RDX
- PAX-48: DNAN, HMX, NTO
- IMX-101: DNAN, NTO, NQ
- IMX-104: DNAN, NTO, RDX

1” x 1” bare pellets subjected to 30 cycles -54ºC to +71ºC (AOP 7)

- AOP-7 states the advisory criteria is that the amount of growth be no more than 1%.

Exudation and Growth: No advisory criterion but data from tests performed per U.S. 202.01.010 (Exudation) and U.S. 202.01.011 (Growth) are required for TNT based explosives. Tests performed per U.S. 202.01.010 are required for explosives containing energetic plasticizers.

Exudation

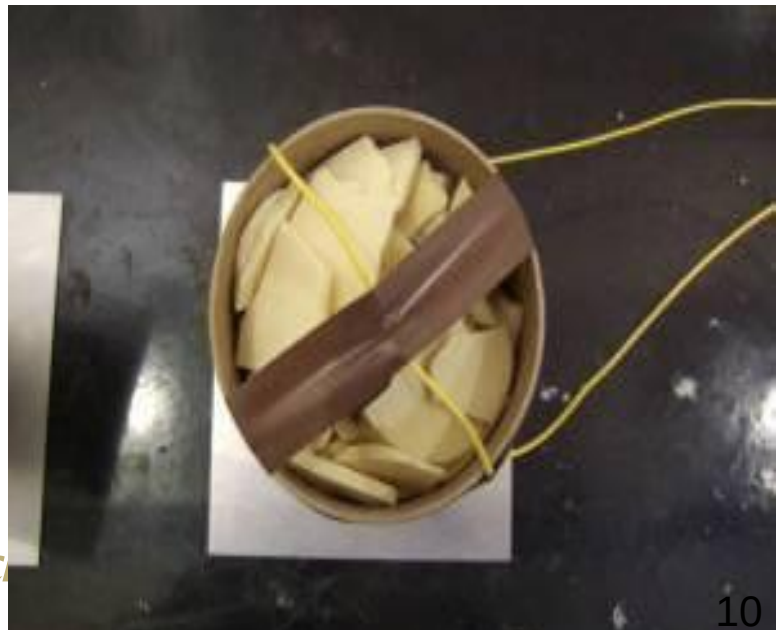
- Exudation testing was conducted following Method US 202.01.010 in AOP-7 (Edition 2) Rev. 1 qualification procedures for the United States.
- The test specifies pellets 1.000”-.001” diameter by a total of 4.950”-.002” long (three pellets were used per test fixture).
- The samples were melt cast, machined to length and set in a desiccator at room temperature for 4 days prior to the test.
- Testing at 160˚ F took place over 320 hours.
- Filter paper and all three samples were weighed and measured before and after the test to determine exudation.
- The exudation test does not have a pass/fail criterion; however it is suggested to use criteria of an exudation of 0.1% or less.

Formulation	Average % Exudation
DNAN	0.068
TNT	0.67
Comp B	0.69
PAX-21	0.29
PAX-41	0.28
PAX-48	0.03
IMX-101	0.05
IMX-104	0.044

Cap Sensitivity

- According to TB700-2 paragraph 5-6.a, this test is designed to determine the sensitivity of a substance to the shock from a standard detonator or blasting cap
- The test yields quantitative and unambiguous results for very insensitive explosive material
- The material is deemed “cap sensitive” if in at least one trial the witness plate shows clean penetration.
- DNAN is not “cap sensitive” and passes this test, consistent with its exceptional NOL LSGT value.

Formulation	Test result
DNAN	Pass
Comp B	Detonation
PAX-21	Detonation
PAX-41	Pass
PAX-48	Pass
IMX-101	Pass
IMX-104	Pass



ERL Impact

- The ARDEC ERL, Type 12 impact tester, utilizing a 2 ½ kg drop weight, was used to determine the impact sensitivity of the sample.
- The drop height corresponding to the 50% probability of initiation measures impact sensitivity (Test Method is described in STANAG 4489 Ed.1 "Explosives, Impact Sensitivity Tests“)

Formulation	Impact (cm)
DNAN	>100
TNT	88.3
Comp B	33.9
RDX Class I Type II	18
PAX-21	41.1
PAX-41	50.1
PAX-48	>100
IMX-101	>100
IMX-104	>100

BAM Friction

- The Large BAM Friction Test Method is described in AOP-7, 201.02.006, “BAM Friction Test”.
- Testing is begun at the maximum load of the apparatus (360 N) or lower if experience warrants it. If a reaction occurs in ten trials, the load is reduced until no reactions are observed in ten trials.
- All formulations with DNAN test higher than neat DNAN and many are better than Comp B.

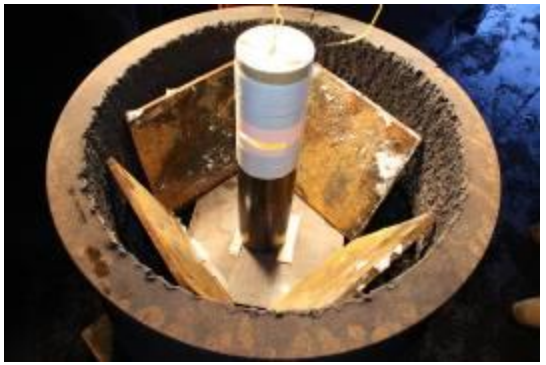
Formulation	Some Reactions (N)	No Reaction in 10 Trials (N)
DNAN	128	120
TNT	240	216
Comp B	192	168
RDX Class I Type II	192	168
PAX-21	168	144
PAX-41	205.8	188
PAX-48	216	192
IMX-101	252	240
IMX-104	168	160

ABL FRICTION on DNAN: 20 No Goes @ 8000 N

Shock Sensitivity

- Large Scale Gap Testing (LSGT) and Expanded Large Scale Gap Testing (ELSGT) was performed in accordance with AOP-7
- The test samples were cast into a 1.5” diameter by 5.0” long steel tubing which was supported on a 0.375” thick witness plate and 2.88” diameter by 11” for ELSGT
- A detonator sat on top of booster pellets that were separated from test sample by a series of card gaps
- The clear cut hole on the witness plate determines whether the test is a “go” or “no go”
- Dr. Arthur Provatas from DSTO, Australia determined DNAN to be (0.709”) 71 cards (70.2 kbars) during LSGT tests.

Formulation	LSGT	ELSGT
	(50% Card Gap)	(50% Card Gap)
DNAN	71	-
TNT	133	384.4
Comp B	200 - 219	596.4
PAX-21	163	-
PAX-41	204	-
PAX-48	110	-
IMX-101	35	165.1
IMX-104	106 - 120.5	-



Critical Diameter

- DNAN was found to have a critical diameter larger than 3.25”
- The large critical diameter of DNAN when combined with other insensitive ingredients has resulted in IM successes in passing Shaped Charge Jet and Sympathetic Detonation

Formulation	Critical Diameter (inches)
DNAN	>3.25
TNT	0.55 - 1.06
Comp B	0.169
PAX-21	0.45 - 0.5
PAX-41	<0.5
PAX-48	0.75 - 1
IMX-101	2.6
IMX-104	0.875

Detonation Velocity Results

- Due to the large critical diameter of pure DNAN, the Expanded Large Scale Gap Test Tube (ELSGT) was chosen as the test vehicle for detonation velocity
- The ELSGT Tube has an ID of 2.88”
- A 2.25” diameter Comp B donor charge was used after a standard sized pentolite pellet
- Piezo-electric pins were used to measure detonation velocity

Formulation	Detonation Velocity (Km/s)
DNAN[1]	5.67
TNT	6.9
Comp B	7.98
PAX-21	6.7
PAX-41	7.68
PAX-48[2]	7.18
IMX-101[3]	6.9
IMX-104[4]	7.4

All samples were tested at ¾” diameter except: 1) ELSGT Tube, 2) 1” diameter, 3) 4” Cylinder Expansion Tube, 4) 2” diameter

Comp B Type DNAN Based Explosives IM Test Results

IM Test:	FCO	SCO	BI	FI	SD	SCJI
PAX-41 Spider*	V	V	V	V	P	Not Tested
PAX-48 120mm HE-T*	V	V	V	Not Tested	P	50mm P
IMX-104 (120mm)*	Not Tested	(V)	(IV)	(V)	P	Not Tested
IMX-104 (81mm)	V	V	IV	I	P	81mm I

*All IM Tests were run to the old JROC Standards:

- 50F/hr, 6,000 ft/s, Single Bullet

- Engineering IM Tests in the M934A1 120mm Mortar and Formal IM Tests in the M821A2 81mm Mortar with IMX-104 show vast improvement over baseline Comp B

Results of IM Tests for IMX-101 in 155mm M795

Test	Engineering Test Scores	Formal IM Tests Scores	Notes on test results
Fast Cook-off	V	V	Single round and pallet configuration
Slow Cook-off	V (50° F / hr)	V	Heating rate is 6° F / hr
Bullet Impact into HE	V (single bullet)	IV	Triple bullet, Type V if scored to current criteria
Fragment Impact into HE	V	V	2,532 m/s
Sympathetic Reaction	Pass	Pass	Confined and unconfined
Shaped Charge Jet Impact	Pass (Comp B)	Pass	LX-14 conditioned jet

Toxicity

- The acute toxic level for DNAN for 50% of the population of Sprague-Dawley rats based on acute toxicity testing was established at >2933 mg/kg-day, based on extrapolation of results of PAX-21 oral toxicity study.

- The 90-day subchronic oral toxicity testing on 2,4, Dinitroanisole (DNAN) was completed in October 2011; results are pending.

- The USAPHC determined a Preliminary Occupational Exposure Level (Preliminary OEL) of 0.09 milligrams per cubic meter for DNAN, on 21 October 2011, based on the results of acute toxicity testing and the 90-day subchronic oral toxicity test.

- DNAN has also been tested for dermal sensitization on Rabbits, with a finding of Slight Skin Irritant, based on the Calculated Primary Irritation Index value of 0.25.

- DNAN was also tested for Primary Eye Irritation on Rabbits during the PAX-21 IM explosive development, and was determined to be a Moderate Eye Irritant.

2,4,6 Trinitrotoluene (TNT):

- The ACGIH determined an 8-hour TWA-PEL of 0.10 milligrams per cubic meter for TNT in March 2010

Future DNAN Uses

End Item	Explosive
105mm M1	IMX-101
155mm XM1128	IMX-101
Cluster Munition Replacement	IMX-104
High Explosive Mortars (Army/USMC)	IMX-104
M2A4	IMX-104
M3A1	IMX-104

Summary

- Characteristics of DNAN based explosives have been determined and engineering designs developed to utilize these to produce practical ammunition
- Processing of DNAN based formulations will require similar measures for safety and exposure as those taken for TNT and TNT based formulations
- DNAN based explosives have shown IM improvements over TNT based explosives by being just as effective and affordable
- The large critical diameter of DNAN based formulations has helped in passing Sympathetic Reaction and Shaped Charge Jet Impact
- Both IMX-101 and IMX-104 have shown vast IM improvement over their baseline formulations TNT and Comp B in both Artillery and Mortars
  - Lethality, Life Cycle Cost, and Production Readiness

QUESTIONS?

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