# TEGDN, Sensitivity reducing ingredient for nitrocellulose based Propellants

Jaana Suuronen, EURENCO Vihtavuori, Ruutitehtaantie 80, FI-41330 VIHTAVUORI,
+358 40 759 34 68, jaana.suuronen@eurenco.com

## 1. Background

Nitroglycerin is an important and widely used component of explosive materials. In double base propellants it is a main component in addition to nitrocellulose and stabilizers. However, Nitroglycerin is dangerous to handle. It is very sensitive to shock, temperature, and friction. Because of the safety aspects it is essential to find a substitute to Nitroglycerin. EURENCO Vihtavuori has nitrated ester manufacture. We also have capability to manufacture a more safe type of nitrate ester, TEGDN (Triethyleneglycol Dinitrate). One of the many advantages of TEGDN is its insensitiveness to detonation. TEGDN is also superior to Nitroglycerin being capable of withstanding cold temperature.

## 2. TEGDN manufacture

TEGDN was first prepared at 1863 by Leurenco. At World War II it was nitrated by Germans and Italians and used as plasticizer in double base propellants.[1] TEGDN is manufactured by nitrating TEG, Triethylene Glycol under controlled conditions with Mixed Acid. The critical point in production process is Spent Acid treatment. TEGDN is highly soluble in Spent Acid (~9 %)[2] and is relatively unstable. Safe Spent Acid treatment is important to ensure safe conditions for manufacture. Process at EURENCO Vihtavuori is continuous Biazzi process production capacity being 500 kg/h.

## 3. Properties

Chemical properties of TEGDN are listed in the Table 1. Nitrogen content is lower since there is one less nitrate group compared to Nitroglycerine. In Table 2 are listed the physical properties and in Table 3 Explosive properties.

[1] Development study for improvement of the manufacturing process for trietyhylene glycoldinitrate (TEGDN), Propellex Chemical Division, 1961, p. 6
[2] Meyer, R., Explosives, 6th Ed. 2007, p. 344

***Table 1*. Chemical properties of TEGDN compared to Nitroglycerine**

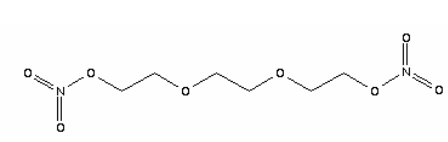
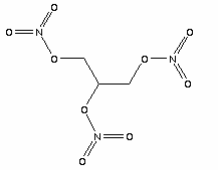
| Chemical Property | T E G D N | Nitroglycerine |
|---|---|---|
| **Chemical Structure** |  |  |
| **Chemical name** | Triethylene Glycol Dinitrate | Glycerol Trinitrate |
| **CAS number** | 111-22-3 | 55-63-0 |
| **Molecular weight** | 240 | 227 |
| **Nitrogen content** | 11,67 % | 18,50 % |
| **Oxygen balance** | -66,7 % | 3,5 % |

***Table 2.* Physical properties of TEGDN compared to Nitroglycerine**

| Physical Property | T E G D N | Nitroglycerine |
|---|---|---|
| **Appearance** | Light yellow oily liquid | Yellow oily liquid |
| **Specific Gravity** | 1,335 g/cm$^3$ | 1,591 g/cm$^3$ |
| **Solidification Point** | -19ºC | +13,2ºC stable modification<br>+2,2ºC unstable modification |
| **Boiling Point** | 327ºC (760 mmHg) | 145°C |
| **Decomposition temperature** | 228ºC (760 mmHg) | *50 – 60ºC*[3]<br>*180-200ºC*[4] |
| **Flash Point** | 146,9ºC | 12ºC |
| **Viscosity at 20ºC** | 13,2 cP | 37,8 cP |
| **Vapour pressure** | 0,001 mmHg | 0,00025 mmHg |

TEGDN has solidification point at -19ºC. This is remarkably lower than Nitroglycerine, which has its stable modification at +13.2ºC. In addition to low temperatures, TEGDN can also be used at higher temperatures than Nitroglycerine. Nitroglycerin starts to decompose at temperature 50-60ºC. TEGDN has decomposition temperature of 228ºC. TEGDN is less volatile than DEGDN (Diethyleneglycol Dinitrate).[5]

[3] TM 9-1300-214, Military Explosives, 1984, p. 8-9
[4] Bofors, Analytical methods for powders and explosives, 1960 p. 163
[5] Meyer, R., Explosives, 6th Ed, 2007, p. 344

***Table 3.*** **Explosive properties of TEGDN compared to Nitroglycerin**

| **Explosive Property** | **T E G D N** | **Nitroglycerine** |
|---|---|---|
| **Explosion Temperature (5 s)** | 225ºC | 222ºC |
| **Detonation gas volume** | 1 202 l/kg | 782 l/kg |
| **Detonation velocity** | 2 000 m/s | 7 600 m/s |
| **Heat of Explosion** | 725 kcal/kg | 1 616 kcal/kg |
| **Impact Sensitivity (2 kg)** | 100 cm+ (BM)<br>43 cm+ (PA)<br>65 cm+ (BAM) | 15 cm |
| **Lead Block Test** | 320 $cm^3$ /10 g | 520 $cm^3$ /10 g |
| **Vacuum stability 100ºC**<br>**120ºC** | 45 ml in 40 h<br>0.8 – 0.99 ml in 8 h | least stable of the standard military explosives |
| **Heat test, 100ºC first 48 h**<br>**second 48 h** | 1,8 %<br>1,6 % | 3,6 %<br>3,5 % |
| **Friction pendulum test**<br>**Steel shoe**<br>**Fibre shoe** | <br>Unaffected<br>Unaffected | <br>No reaction up to 353 N<br>- |
| **Critical diameter (steel sleeve test)** | 26,7 mm | 24 mm |
| **Card Gap test** | 0,48 cm (0.19 in) | 2,31 cm (0,91 in) |

Thermal stability at 100ºC indicates TEGDN is considerably much less sensitive to temperature than Nitroglycerin. TEGDN is insensitive to detonation. No detonation occurs in samples placed in relatively light steel tubing with diameter of 3.175 cm at a density of 1.33 $g/cm^3$. When heavily confined, the detonation velocity is less than 2000 m/s. TEGDN is unaffected in the pendulum friction test with the metal and fiber shoe. Impact resistance is much better than for Nitroglycerine. The Bureau of Mines impact test indicates a sensitivity of over 100 centimetres.[6]

## 4. Applications

TEGDN can be applied as a plasticizer in solid propellant formulations used in guns, rockets, air launched tactical motors, powering missiles, explosives, ground launched interceptors and space boosters. TEGDN very potential ingredient for IM Technology applications due to its insensitiveness to detonation, shock and temperature. EURENCO has tested TEGDN as a component in multi base propellant application, Modular Charge system. Results are promising.

[6] TM 9-1300-214, Military Explosives, 1984, p. 8-26

## 5. Toxicity

TEGDN is toxic as other nitrated explosive oils like Nitroglycerin and DEGDN. The toxicological properties of aliphatic nitrates are similar, differing only in intensity, onset and duration of effect.[7] In the Table 4 are listed toxicity values of TEGDN and Nitroglycerine.[8]

***Table 4.*** Toxicity values of TEGDN and Nitroglycerine.

| Toxicity | T E G D N | Nitroglycerine |
|---|---|---|
| **LD50, intraperitoneal, mouse** | 945 mg/kg[1] | 104 mg/kg[7] |
| **LD50, oral, mouse** | 1866 mg/kg[2] | 115 mg/kg[8] |
| **LD, skin, rabbit** | > 2000 mg/kg[3] | >280 mg/kg[9] |
| **LD50, intraperitoneal, rabbit** | 796 mg/kg[4] | 189 mg/kg[10] |
| **LD50, oral, rat** | 1000 mg/kg[5] | 105 mg/kg[11] |
| **LD50, subcutaneous, rat** | 2520 mg/kg[6] | 94 mg/kg[12] |


*1) American Industrial Hygiene Association Journal. Vol. 34, Pg. 526, 1973.*
*2) Acute Toxicity Data. Journal of the American College of Toxicology, Part B. Vol. 12, Pg. 606, 1993.*
*3) Acute Toxicity Data. Journal of the American College of Toxicology, Part B. Vol. 12, Pg. 604, 1993.*
*4) American Industrial Hygiene Association Journal. Vol. 34, P. 526, 1973.*
*5) American Industrial Hygiene Association Journal. Vol. 34, P. 526, 1973.*
*6) American Industrial Hygiene Association Journal. Vol. 34, P. 526, 1973*
*7) Iyakuhin Kenkyu. Study of Medical Supplies. Vol. 13, Pg. 90, 1982.*
*8) Yakuri to Chiryo. Pharmacology and Therapeutics. Vol. 13, Pg. 3649, 1985*
*9) Drugs in Japan Vol. -, Pg. 786, 1990.*
*10) Drugs in Japan Vol. -, Pg. 786, 1990*
*11) Yakuri to Chiryo. Pharmacology and Therapeutics. Vol. 13, Pg. 3649, 1985.*
12) *Yakuri to Chiryo. Pharmacology and Therapeutics. Vol. 13, Pg. 3649, 1985*


The Threshold Limit Value has not been established for TEGDN. A worker's exposure to TEGDN shall be minimized at all time. Exposure to TEGDN can occur through inhalation, ingestion, eye or skin contact, and absorption through the skin.

## 6. Summary

Because of its chemical and thermal stability, impact, shock and friction resistance, TEGDN is a promising ingredient to give reduced sensitivity for Nitrocellulose based propellants. The use of TEGDN can be applied to reach International Safety and IM-targets. TEGDN is applicable as an energetic plasticizer in propellants and in castable insensitive energetic compositions. Compared to Nitroglycerin, TEGDN is less sensitive to shock. In fact, TEGDN is characterized by a wholly insignificant sensitiveness to shock. Its chemical stability is better than that of Nitroglycerin or Nitrocellulose. TEGDN is also less sensitive to temperature than Nitroglycerin. TEGDN is relatively safely handled compared to Nitroglycerin. Detonation gas volume of TEGDN is higher than that of Nitroglycerin and heat of detonation smaller. Advantage is taken in the manufacture of flashless and non-erosive low calorific smokeless powder.

[7] HAZARDS OF CHEMICAL ROCKETS AND PROPELLANTS HANDBOOK, solid rocket propellant processing, handling, storage and transportation, Vol II, 1972, p. 3-22
[8] http://chem.sis.nlm.nih.gov/chemidplus/

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