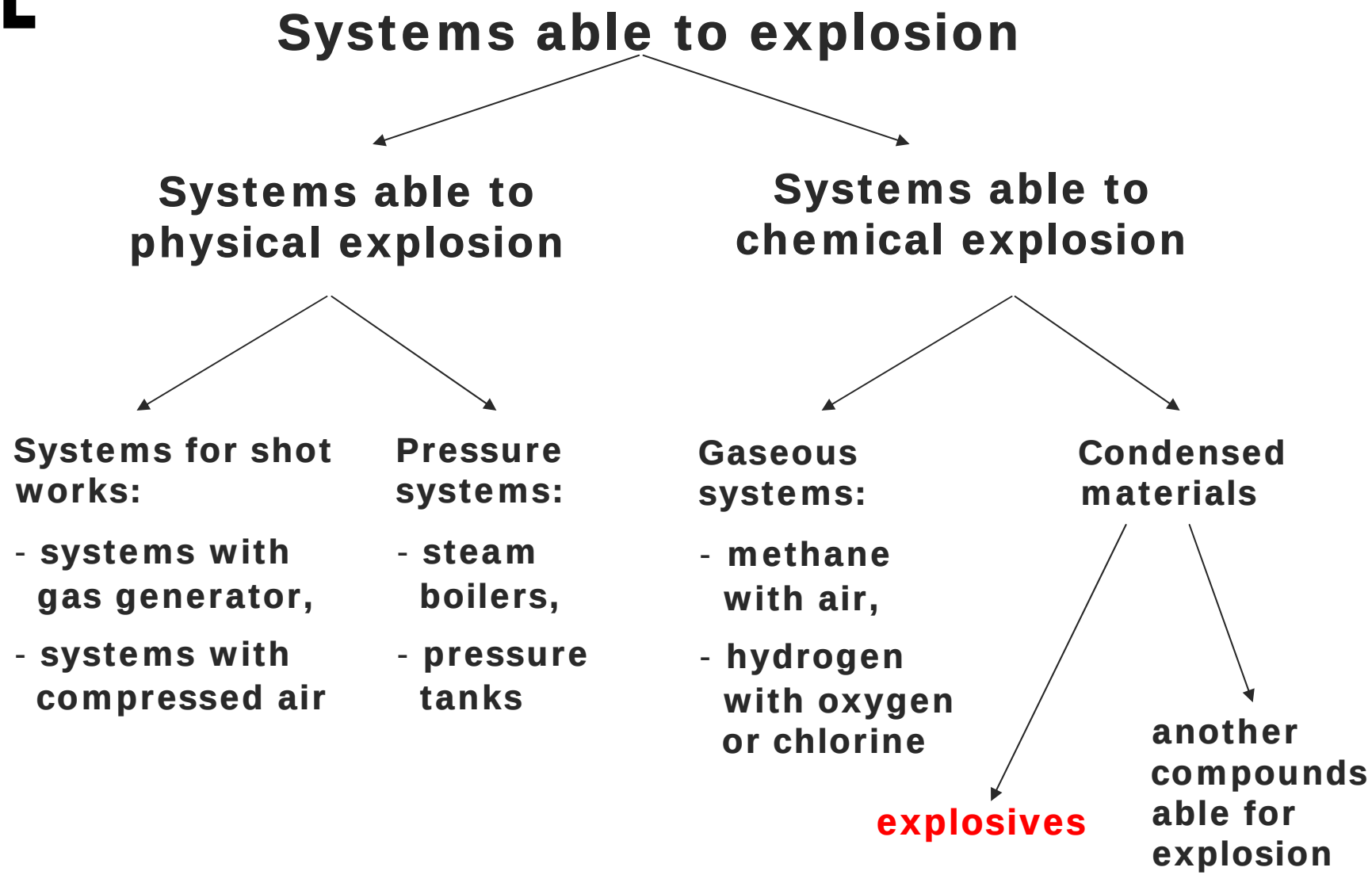
EXPLOSIVES

The idea, properties & application

Systems able to explosion



Definition of explosives

Explosive materials – chemical compounds or their mixtures, in solid or liquid form, which are in kinetically retreated state, able to fast chemical reaction without oxygen from air.

Explosive transformation of explosives
is characterized by:
- large exothermic effect;
- generation of gas products or their presence;
- large velocity of chemical reaction.

Explosive transformation of explosive materials can be initiated as a result of interaction: mechanical, thermic, electrical and detonation.

Equation of decomposition

$$C_{Y_1} H_{Y_2} O_{Y_3} N_{Y_4} Al_{Y_5} Ca_{Y_6} K_{Y_7} Na_{Y_8} Cl_{Y_9} S_{Y_{10}} Ba_{Y_{11}} \longrightarrow$$

$$n_1 CO_2 + n_2 CO + n_3 H_2O + n_4 N_2 + n_5 O_2 + n_6 Al_2O_3 +$$

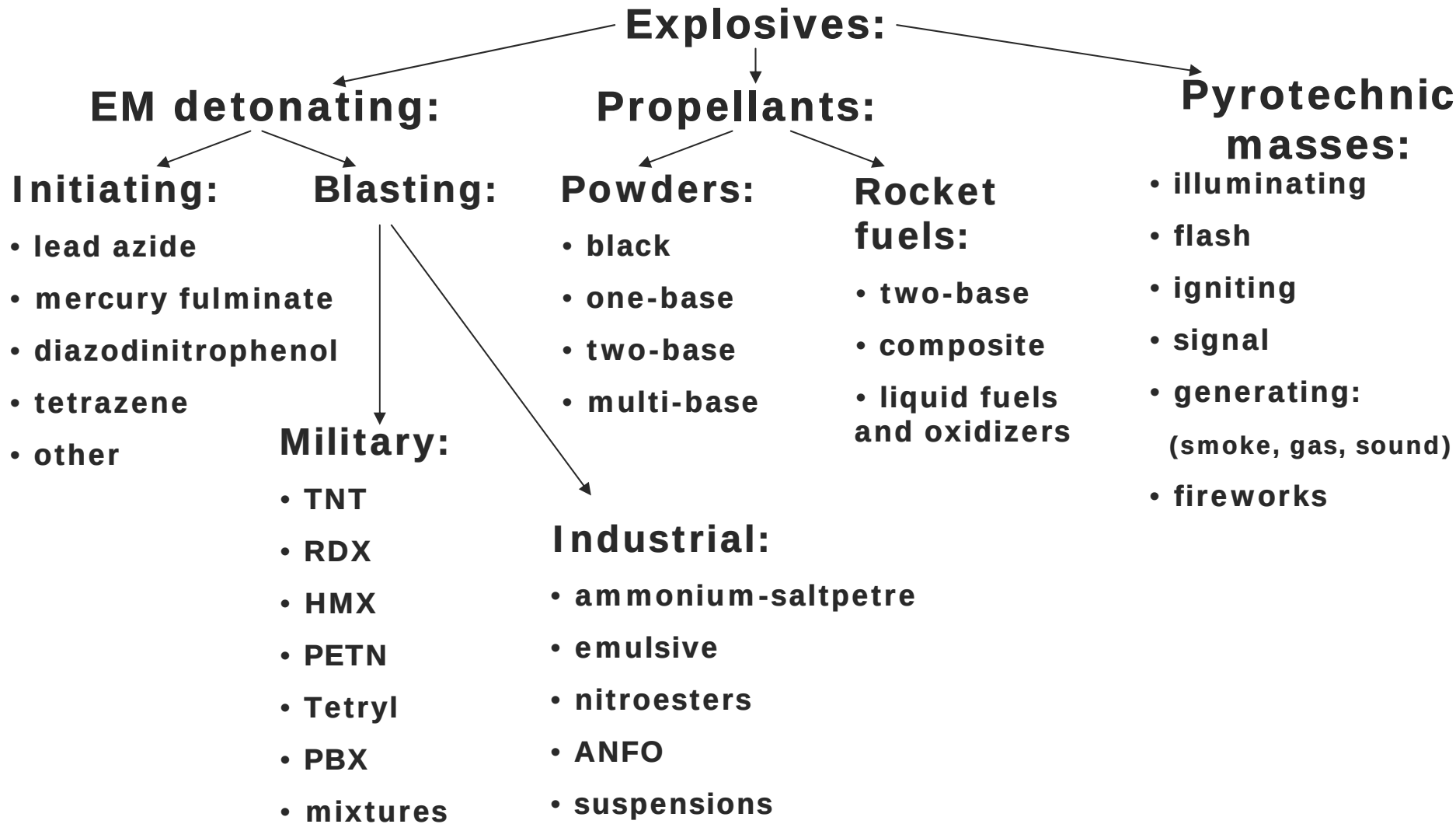
$$+ n_7 CaO + n_8 KCl + n_9 K_2CO_3 + n_{10} NaCl +$$

$$+ n_{11} Na_2CO_3 + n_{12} HCl + n_{13} SO_2 + n_{14} BaO$$

Y_i - fraction gram-atom of individual elements in explosive material

n_i - amount of moles of products formed in detonative transformation

Division of explosives regard on application



Division of explosives regard on chemical structure

Explosives:

Nitric acid esters:

- nitroglycol
- nitroglycerin
- PETN
- nitrocellulose
- nitrostarch
- nitrosugars
- polyvinyl nitrate

Nitro-compounds:

- TNT
- DNT
- nitrobenzene
- trinitrorezorcine
- picric acid

Aromatic nitroamines :

- Tetryl
- TATB

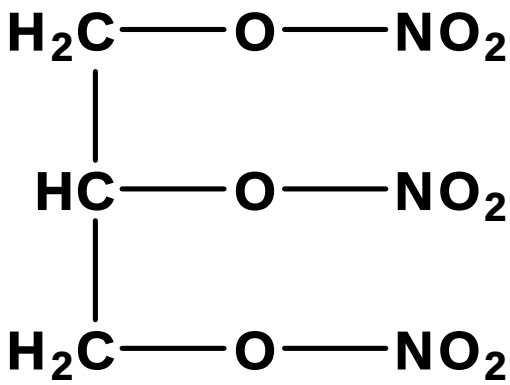
Aliphatic nitroamines:

- hexogen (RDX)
- oktogen (HMX)
- nitroguanidine
- dinitrourea

Explosive individuals:

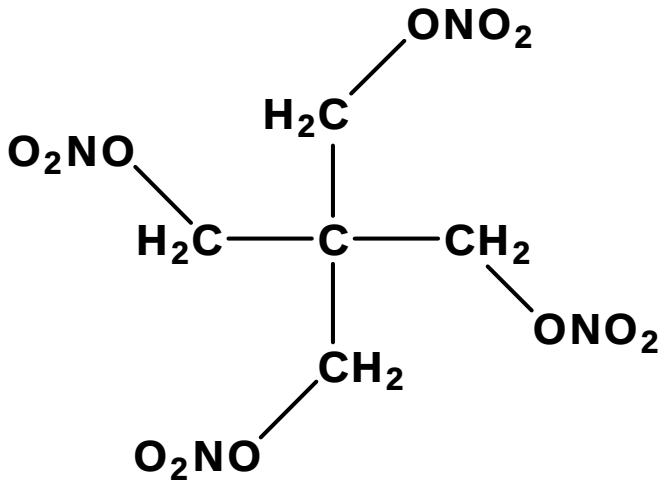
- fulminates
- azides
- peroxides
- other

Nitric acid esters



NITROGLYCERIN - NGl

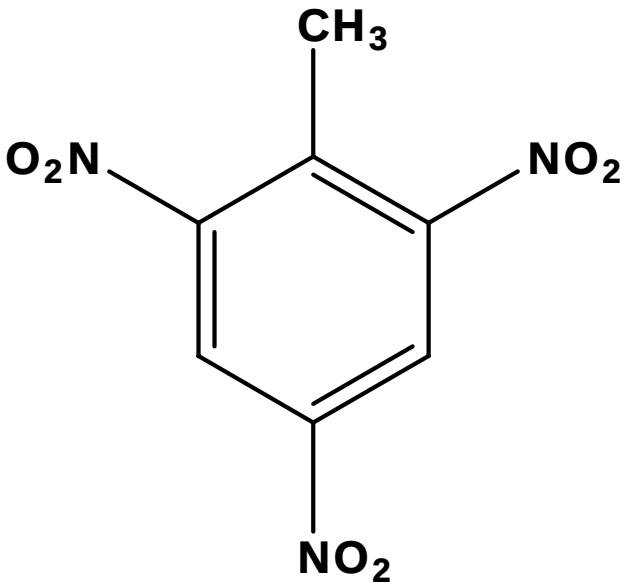
glycerin trinitrate(V)



PENTRYT - PETN

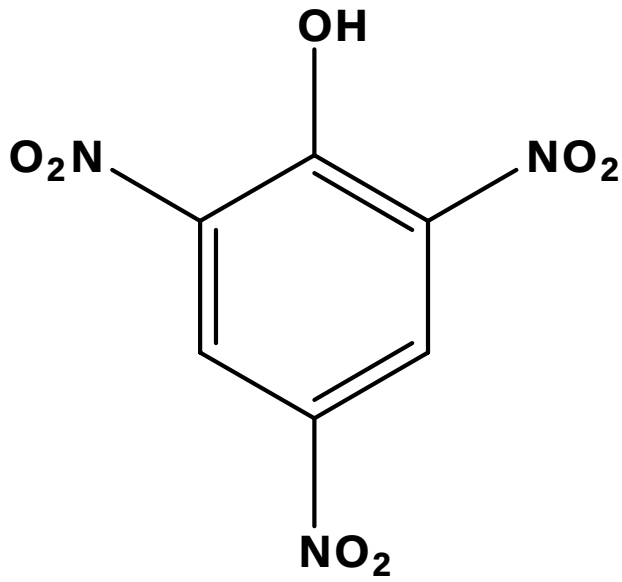
pentaerythryt tetranitrate(V)

Nitrocompouns



TROTYL - TNT

2,4,6-trinitrotoluene

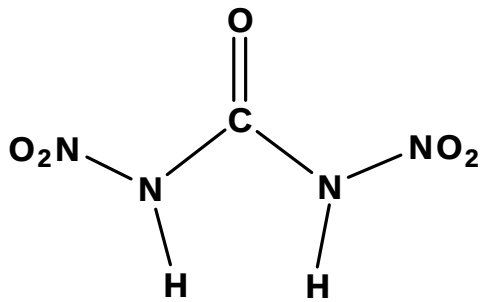


PICRIC ACID - TNP

2,4,6-trinitrophenol

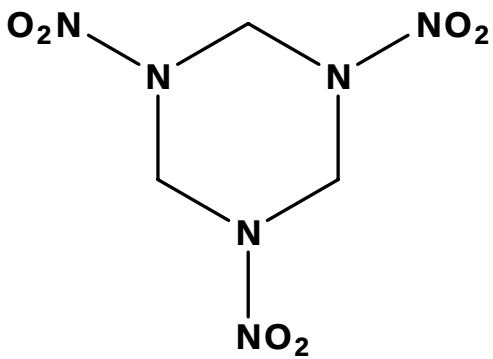
Nitroamines

a) aliphatic

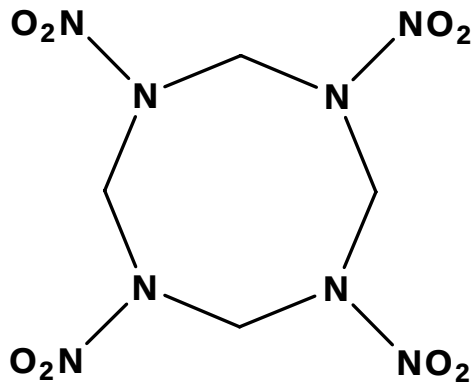


DNU

***N,N'*-dinitrourea**



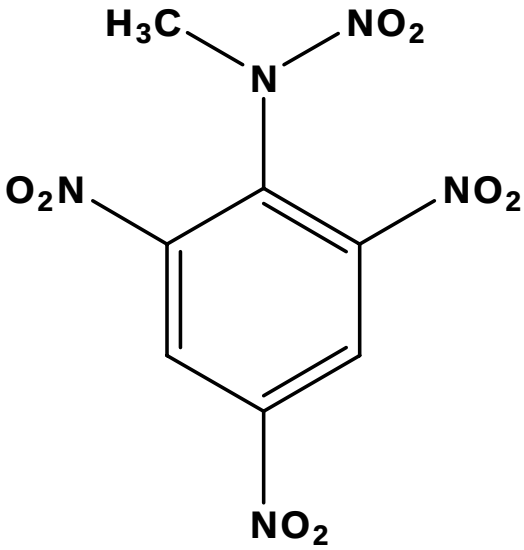
HEXOGEN - RDX, Hx
1,3,5-trinitro-1,3,5-triazine



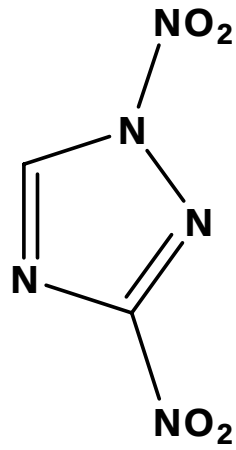
OKTOGEN - HMX
1,3,5,7-tetranitro-
1,3,5,7-teraazacyclooctane

Nitroamines

b) aromatic

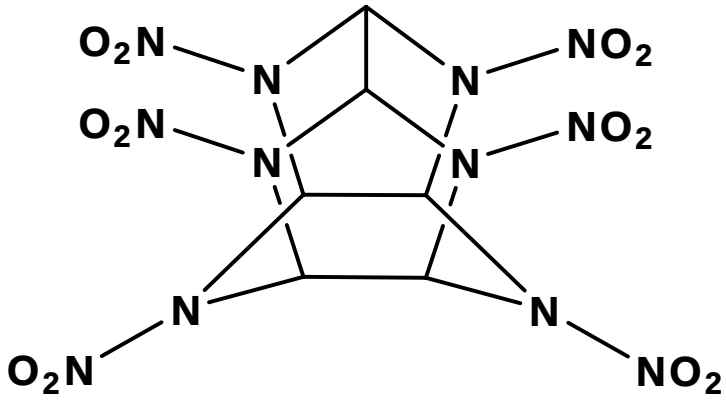


TETRYL
***N*-metyl-*N*,2,4,6-tetranitroaniline**

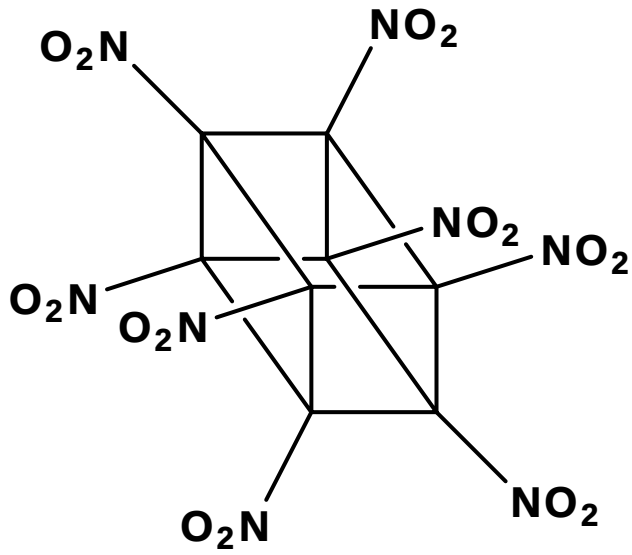


DNTr
1,3-dinitrotriazole

Polycyclic polynitric compounds



CL 20, HNIW
hexanitroheksaazaisowurtzitane



25, ONC
octanitrocubane

Explosive individuals

mercury fulminate

lead azide

Characteristic indices of two types of explosive transformations

Characteristic indices	Explosive transformation	
	Deflagration	Detonation
Conversion time to transformation products	ms	μs
Burning velocity	up to a dozen or so cm/s	1,5 ÷ 10 km/s
Pressure	up to about 400 MPa	300 ÷ 30000 MPa
Dependence of transformation velocity on pressure	very strong	practically independent
Propagation velocity of burning wave front	0,5 ÷ 1,5 km/s	1,5 ÷ 10 km/s

Characteristic indices of nitroglycol transformation

Characteristic indices	Symbol Unit	Deflagration	Detonation
Burning velocity	**D** [m/s]	$3 \cdot 10^{-4}$	$7{,}3 \cdot 10^{3}$
Flux density of mass transformation	ρ_0**D** [kg/m^{2}s]	$4{,}5 \cdot 10^{-1}$	$1{,}1 \cdot 10^{7}$
Proper transformation energy	**Q** [kJ/kg]	$1{,}93 \cdot 10^{3}$	$6{,}7 \cdot 10^{3}$
Energy flux density	ρ_0**QD** [kW/m^2]	$8{,}7 \cdot 10^{2}$	$7{,}4 \cdot 10^{10}$
Ratio of energy flux density related to deflagration	-	1	ok. 10^{8}
Width of transformation area	**a** [m]	$1 \cdot 10^{-2}$	$1 \cdot 10^{-3}$
Energetic load of transformation area	ρ_0**QD / a** [kJ/m^{3}s]	$8{,}7 \cdot 10^{4}$	$7{,}4 \cdot 10^{13}$

Ammonium nitrate as a main EM component

Ammonium nitrate, is one of the most popular chamical compounds used as a component of explosive materials since XIX century. This substance is the main component of majority of currently produced EM.

Ammonium nitrate (M = 80,04 g/mol), molecular formula NH_4NO_3, is white crystallic substance with density d=1,73 g/cm^3, which is obtained by neutralization of nitric acid (V) with gaseous ammonia according to the reaction equation:

$$NH_{3\ (g)} + HNO_{3\ (l)} \rightleftharpoons NH_4NO_{3\ (s)}$$

Equation of the ammonium nitrate decomposition reaction

At the temperature of 169,6 ºC ammonium nitrate melts, at the slightly higher temperature it decomposes to water and dinitro oxide, however above temperature of 250 ºC it burns with yellow flame according to the reaction:

$$NH_4NO_3 \rightarrow \frac{1}{2}N_2 + NO + 2H_2O$$

After stronger heating decomposition of ammonium nitrate proceeds in explosive way according to the following equation:

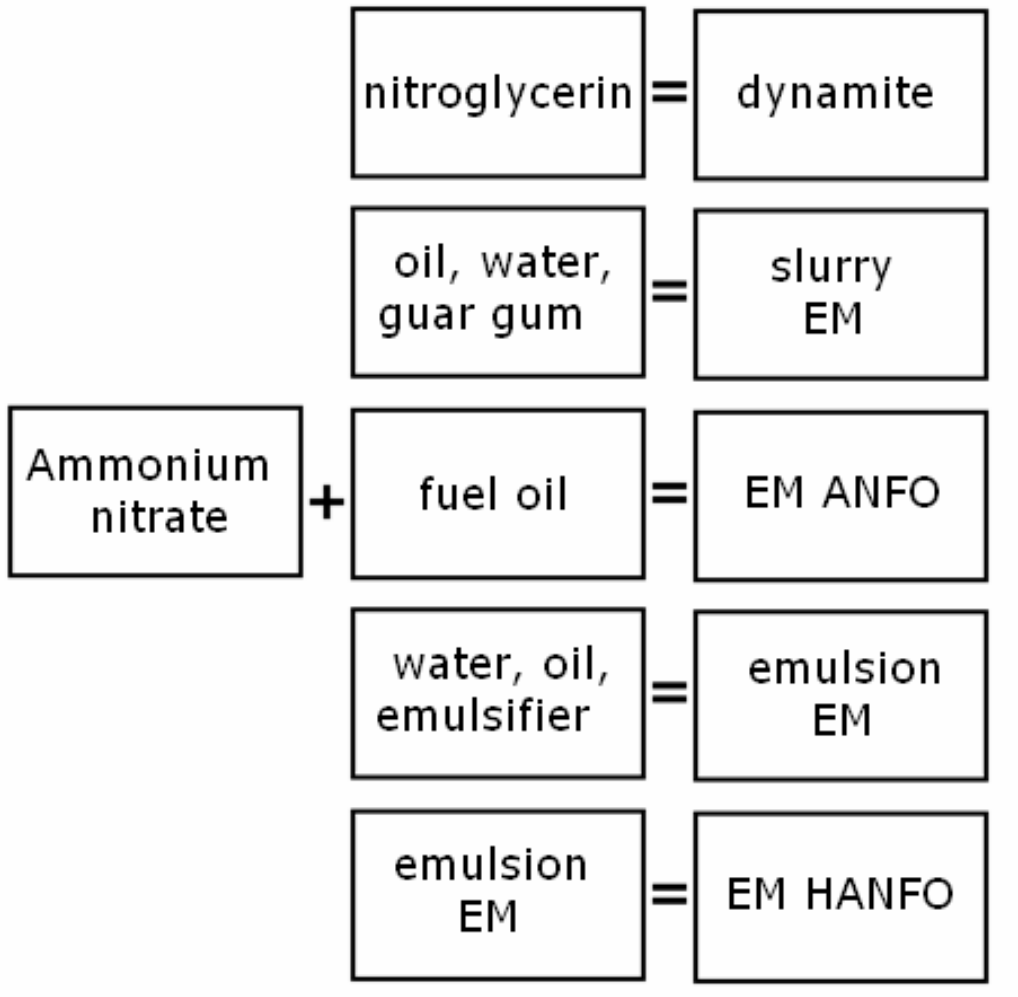
$$NH_4NO_3 \rightarrow N_2 + \frac{1}{2}O_2 + 2H_2O$$

General equation of explosive transformation of EM ANFO type

$$(3x+1)NH_4NO_3 + C_xH_{(2x+2)} \longrightarrow$$

$$\longrightarrow (3x+1)N_2 + (7x+3)H_2O + xCO_2$$

Application of ammonium nitrate in EM technology



EM parameters

Table. Basic parameters of EM

Parameter		EM ANFO	EME	Dynamite (30 % of nitroesters)
Density (g/cm^3)		0,7 ÷ 0,85	1,1 ÷ 1,2	1,4 ÷ 1,5
Gas volume (dm^3/kg)		980	894	864
Explosion heat (kJ/kg)		3800	3400	4800
Energy concentration (kJ/dm^3)		2900	3900	7000
Detonation velocity (m/s)	Hole diameter < 25 mm	2300	4500	2700
	Hole diameter > 25 mm	4000	5500	5800

Fraction of individual EM on the market

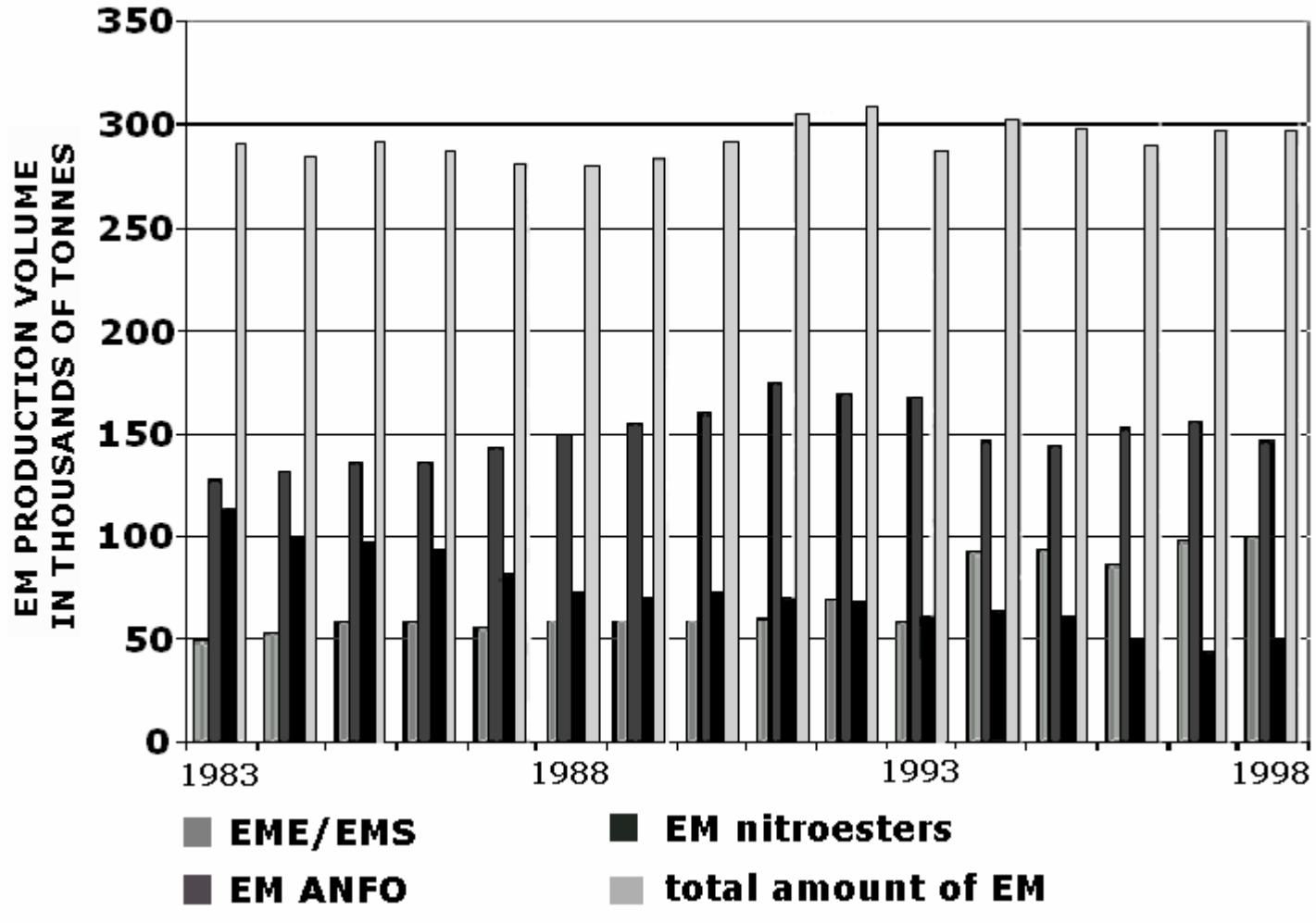


Fig. 1 EM production volume in UE countries in years 1983-1998

Consumers of EM industrial products

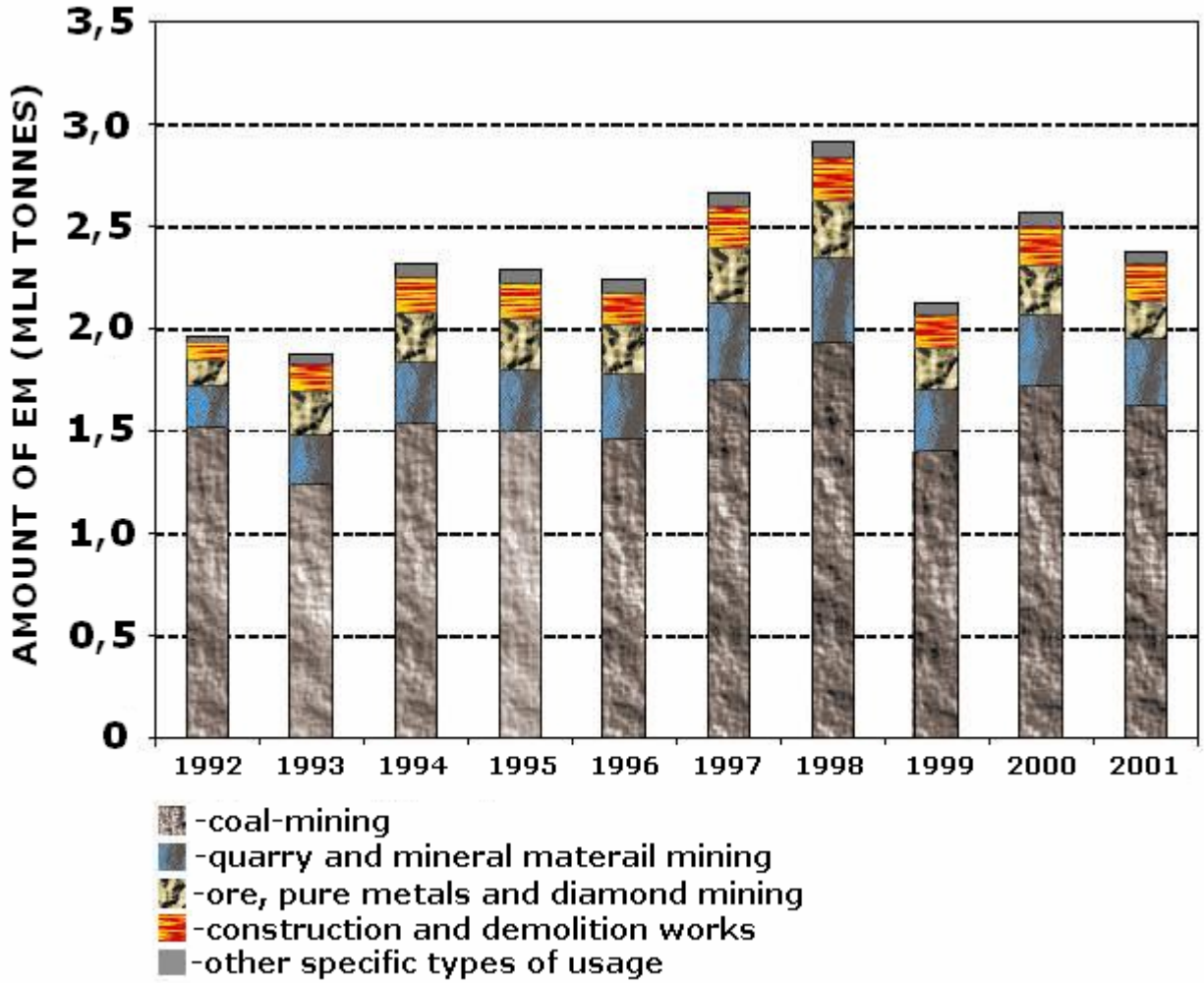


Fig. 2 Fraction of consumers in the sale volume of industrial EM in the last decade