13.3 Explosives Detonation

13.3.1 General[1-5]

This section deals mainly with pollutants resulting from the detonation of industrial explosives and firing of small arms. Military applications are excluded from this discussion. Emissions associated with the manufacture of explosives are treated in Section 6.3, "Explosives".

An explosive is a chemical material that is capable of extremely rapid combustion resulting in an explosion or detonation. Since an adequate supply of oxygen cannot be drawn from the air, a source of oxygen must be incorporated into the explosive mixture. Some explosives, such as trinitrotoluene (TNT), are single chemical species, but most explosives are mixtures of several ingredients. "Low explosive" and "high explosive" classifications are based on the velocity of explosion, which is directly related to the type of work the explosive can perform. There appears to be no direct relationship between the velocity of explosions and the end products of explosive reactions. These end products are determined primarily by the oxygen balance of the explosive. As in other combustion reactions, a deficiency of oxygen favors the formation of carbon monoxide and unburned organic compounds and produces little, if any, nitrogen oxides. An excess of oxygen causes more nitrogen oxides and less carbon monoxide and other unburned organics. For ammonium nitrate and fuel oil (ANFO) mixtures, a fuel oil content of more than 5.5 percent creates a deficiency of oxygen.

There are hundreds of different explosives, with no universally accepted system for classifying them. The classification used in Table 13.3-1 is based on the chemical composition of the explosives, without regard to other properties, such as rate of detonation, which relate to the applications of explosives but not to their specific end products. Most explosives are used in 2-, 3-, or 4-step trains that are shown schematically in Figure 13.3-1. The simple removal of a tree stump might be done with a 2-step train made up of an electric blasting cap and a stick of dynamite. The detonation wave from the blasting cap would cause detonation of the dynamite. To make a large hole in the earth, an inexpensive explosive such as ANFO might be used. In this case, the detonation wave from the blasting cap is not powerful enough to cause detonation, so a booster must be used in a 3- or 4-step train. Emissions from the blasting caps and safety fuses used in these trains are usually small compared to those from the main charge, because the emissions are roughly proportional to the weight of explosive used, and the main charge makes up most of the total weight. No factors are given for computing emissions from blasting caps or fuses, because these have not been measured, and because the uncertainties are so great in estimating emissions from the main and booster charges that a precise estimate of all emissions is not practical.

13.3.2 Emissions And Controls[2,4-6]

Carbon monoxide is the pollutant produced in greatest quantity from explosives detonation. TNT, an oxygen-deficient explosive, produces more CO than most dynamites, which are oxygen-balanced. But all explosives produce measurable amounts of CO. Particulates are produced as well, but such large quantities of particulate are generated in the shattering of the rock and earth by the explosive that the quantity of particulates from the explosive charge cannot be distinguished. Nitrogen oxides (both nitric oxide [NO] and nitrogen dioxide [NO_2]) are formed, but only limited data are available on these emissions. Oxygen-deficient explosives are said to produce little or no

Table 13.3-1 (Metric And English Units). EMISSION FACTORS FOR DETONATION OF EXPLOSIVES

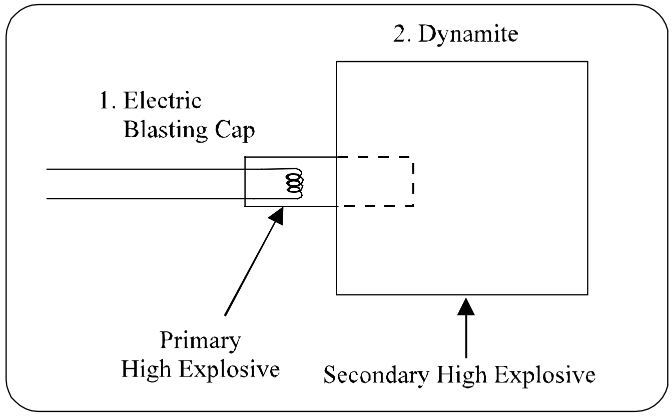
EMISSION FACTOR RATING: D

Explosive	Composition	Uses	Carbon Monoxide[a]		Nitrogen Oxides[a]		Methane[b]		Other		
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	Pollutant	kg/Mg	lb/ton
Black powder[2]	75/15/10; Potassium (sodium) nitrate/ charcoal sulfur	Delay fuses	85 (38-120)	170 (76-240)	ND	ND	2.1 (0.3-4.9)	4.2 (0.6-9.7)	H_2S	12 (0-37)	24 (0-73)
Smokeless powder[2]	Nitrocellulose (sometimes with other materials)	Small arms, propellant	38 (34-42)	77 (68-84)	ND	ND	0.6 (0.4-0.6)	1.1 (0.7-1.5)	H_2S Pb	10 (10-11) —[c]	21 (20-21) —[c]
Dynamite, straight[2]	20-60% Nitroglycerine/ sodium nitrate/ wood pulp/ calcium carbonate	Rarely used	141 (44-262)	281 (87-524)	ND	ND	1.3 (0.3-2.8)	2.5 (0.6-5.6)	H_2S	3 (0-7)	6 (0-15)
Dynamite, ammonia[2]	20-60% Nitroglycerine/ ammonium nitrate/sodium nitrate/wood pulp	Quarry work, stump blasting	32 (23-64)	63 (46-128)	ND	ND	0.7 (0.3-1.1)	1.3 (0.6-2.1)	H_2S	16 (9-19)	31 (19-37)
Dynamite, gelatin[2]	20-100% Nitroglycerine	Demolition, construction work, blasting in mines	52 (13-110)	104 (26-220)	26 (4-59)	53 (8-119)	0.3 (0.1-0.8)	0.7 (0.3-1.7)	H_2S SO_2	2 (0-3) 1 (0-8)	4 (0-6) 1 (1-16)

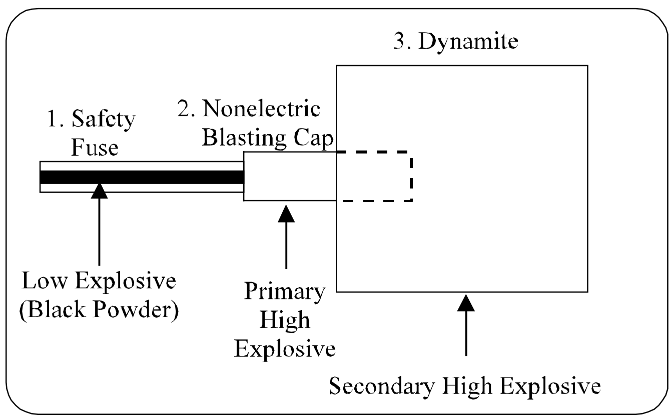
Table 13.3-1 (cont.).

Explosive	Composition	Uses	Carbon Monoxide[a]		Nitrogen Oxides[a]		Methane[b]		Other		
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	Pollutant	kg/Mg	lb/ton
ANFO[4,5]	Ammonium nitrate with 5.8-8% fuel oil	Construction work, blasting in mines	34	67	8	17	ND	ND	SO_2	1 (0-2)	2 (1-3)
TNT[2]	Trinitrotoluene	Main charge in artillery projectiles, mortar rounds, etc.	398 (324-472)	796 (647-944)	ND	ND	7.2 (6.6-7.7)	14.3 (13.2-15.4)	NH_3 HCN C_2H_2 C_2H_6	14 (14-15) 13 (11-16) 61 0.5	29 (27-30) 27 (22-32) 121 1.1
RDX[3]	$(CH_2)_3N_3(NO_2)_3$ Cyclotrimethylene-trinitroamine	Booster	98[d] (2.8-277)	196[d] (5.6-554)	ND	ND	ND	ND	NH_3	22[d] (12-61)	44[d] (24-122)
PETN[2]	$C(CH_2ONO_2)_4$ Pentaerythritol tetranitrate	Booster	149 (138-160)	297 (276-319)	ND	ND	ND	ND	NH_3	1.3 (0-25)	2.5 (0-5)

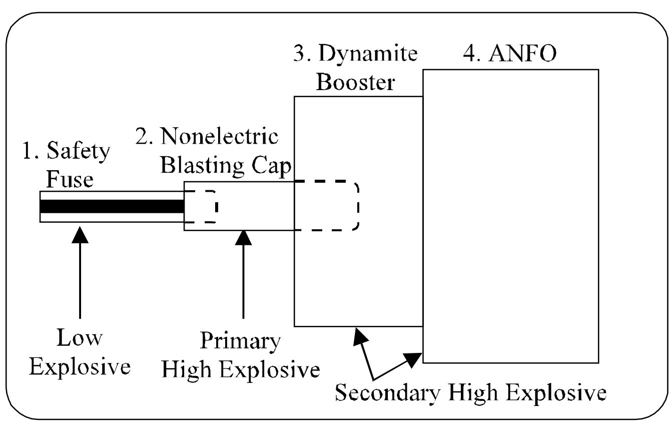
[a] Based on experiments carried out prior to 1930 except in the case of ANFO, TNT, and PETN. ND = no data.
[b] The factors apply to the chemical species, methane. They do not represent total volatile organic compounds (VOC) expressed as methane. Studies were carried out more than 40 years ago.
[c] Greater than 6 mg per 158 grain projectile (0.6 kg/Mg, 1.2 lb/ton).
[d] These factors are derived from theoretical calculations, not from experimental data.



a. Two-step explosive train



b. Three-step explosive train



c. Four-step explosive train

Figure 13.3-1. Two-, three-, and four-step explosive trains.

nitrogen oxides, but there is only a small body of data to confirm this. Unburned hydrocarbons also result from explosions, but in most instances, methane is the only species that has been reported.

Hydrogen sulfide, hydrogen cyanide, and ammonia all have been reported as products of explosives use. Lead is emitted from the firing of small arms ammunition with lead projectiles and/or lead primers, but the explosive charge does not contribute to the lead emissions.

The emissions from explosives detonation are influenced by many factors such as explosive composition, product expansion, method of priming, length of charge, and confinement. These factors are difficult to measure and control in the field and are almost impossible to duplicate in a laboratory test facility. With the exception of a few studies in underground mines, most studies have been performed in laboratory test chambers that differ substantially from the actual environment. Any estimates of emissions from explosives use must be regarded as approximations that cannot be made more precise because explosives are not used in a precise, reproducible manner.

To a certain extent, emissions can be altered by changing the composition of the explosive mixture. This has been practiced for many years to safeguard miners who must use explosives. The U. S. Bureau of Mines has a continuing program to study the products from explosives and to identify explosives that can be used safely underground. Lead emissions from small arms use can be controlled by using jacketed soft-point projectiles and special leadfree primers.

Emission factors are given in Table 13.3-1. Factors are expressed in units of kilograms per megagram (kg/Mg) and pounds per ton (lb/ton).

References For Section 13.3

1. C. R. Newhouser, *Introduction To Explosives*, National Bomb Data Center, International Association Of Chiefs Of Police, Gaithersburg, MD (undated).

2. Roy V. Carter, "Emissions From The Open Burning Or Detonation Of Explosives", Presented at the 71st Annual Meeting of the Air Pollution Control AssociatIon, Houston, TX, June 1978.

3. Melvin A. Cook, *The Science Of High Explosives*, Reinhold Publishing Corporation, New York, 1958.

4. R. F. Chaiken, et. al., *Toxic Fumes From Explosives: Ammonium Nitrate Fuel Oil Mixtures*, Bureau Of Mines Report Of Investigations 7867, U. S. Department Of Interior, Washington, DC, 1974.

5. Sheridan J. Rogers, *Analysis Of Noncoal Mine Atmospheres: Toxic Fumes From Explosives*, Bureau Of Mines, U. S. Department Of Interior, Washington, DC, May 1976.

6. A. A. Juhasz, "A Reduction Of Airborne Lead In Indoor Firing Ranges By Using Modified Ammunition", Special Publication 480-26, Bureau Of Standards, U. S. Department Of Commerce, Washington, DC, November 1977.