CHAPTER 28

Gas and Fume Generation At the Blast Site

Gases and fumes are generated as a result of explosives detonation at a blast site. This chapter discusses only those gases produced by the detonation of commercial explosives. Since fracturing of the rock has potential to allow these detonation gases to either (1) accumulate in the muckpile or (2) migrate out of the blasted area, they should be ventilated as soon as possible.

Underground operations install ventilation systems to exchange the air, but surface operations rely on natural ventilation to the open air. To facilitate the ventilation, the blaster-in-charge should encourage early muckpile excavation to avoid any potential of accumulation of detonation gases.

DETONATION GASES

The heaving action of an explosive is a result of the large quantities of rapidly expanding hot gases produced as it detonates. Ideally, a detonation produces only steam (H_2O), carbon dioxide (CO_2), and nitrogen (N_2) as a result of the reaction. However, in the real world the detonation of explosives in a blasting operation also produces the three toxic gases: (1) nitrogen dioxide (NO_2), (2) nitric oxide (NO), and (3) carbon monoxide (CO) (ISEE, 1998). The quantities of CO, NO, and NO_2 released by the explosive varies according to conditions of use and its formulation by the manufacturer.

Anything that tends to cool the detonation process increases the formation of oxides of nitrogen. Some of the factors that increase toxic fumes are poor product formulation, improper use, inadequate priming, insufficient water resistance, degree of confinement, reactivity of the explosive ingredients with the rock or other material being blasted, and incomplete product reaction. In general, poor performance of an explosive in a blast tends to increase the production of toxic fumes. Fumes should not be confused with smoke, which is composed mainly of steam and the solid products of combustion or detonation. Excessive exposure to smoke, especially that produced by dynamite, can cause severe headaches and should be avoided. The headache may be the result of small particles of unreacted or partially reacted explosive ingredients in the smoke. Explosives manufacturers are able to provide products that minimize toxic fumes production and should be consulted when blasting in locations where sufficient natural or forced ventilation may not be sufficient to dissipate the fumes.

In an effort to protect workers, extensive research has been done on the toxic fumes generated by the detonation of explosives. Many countries have test procedures and formal or informal requirements in place for the maximum permitted fumes production by a given amount of explosives (Streng, 1971, Karmakar and Banerjee, 1984, and International Society of Explosives Engineers, 1998). In the U.S., the system used for quantifying the toxic gases produced by an explosive is the Institute of Makers of Explosives (IME) fume class. The IME fume classification is based on the toxic gases produced by the detonation of a 32 millimeter by 200 millimeter (1¼ inch x 8 inch) cartridge of explosive in the Bichel Gauge (*See* figure 28.1).

Explosives producing less than 4.53 liters (0.16 ft^3) toxic fumes are rated IME fume class 1. IME fume classes 2 and 3 produce larger quantities of toxic fumes. Blasters who wish to shoot blasting agents underground in a state requiring IME fume class 1 explosive are faced with a dilemma. Blasting agents will not reliably detonate at full order when initiated by a blasting cap as a 32 millimeter by 200 millimeter (1¼ inch x 8 inch) cartridge so it is not possible to determine IME fume class using the Bichel Gauge. Therefore, explosive manufacturers calculate fumes quantities based on thermodynamics to assign fume classes for those products. Internationally, measurements of the toxic fumes produced by blasting agents in large scale mining operations have been conducted but these have been carried on as research and no standardized test procedure has been developed. (Streng, 1971) (Mainiero, 1997).

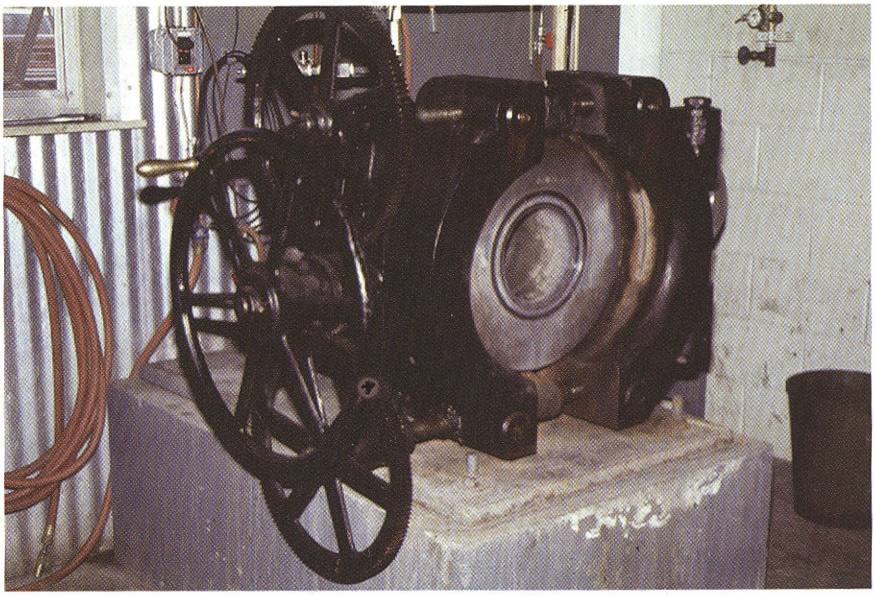

Figure 28.1 - Bichel Gauge used for determining the quantities of toxic gases released by a cartridge of explosive. (Courtesy: R. Mainiero)

In the U.S., the U.S. Mines Safety and Health Administration has placed limits on the toxic fumes that may be produced by permissible explosives for blasting in underground coal mines. These are detailed in the U.S. Code of Federal Regulations Title 30, Part 15 and are based on measurements made in the Large Chamber Test (*See* figure 28.2). In this test, 0.454 kilogram (1 pound) of explosive is loaded unstemmed in a cannon at one end of the chamber. Following detonation of the explosive, the fumes in the chamber are sampled and analyzed. Based on the quantity and types of toxic gases produced, the explosive is approved or rejected as a permissible explosive (Santis, 1995).

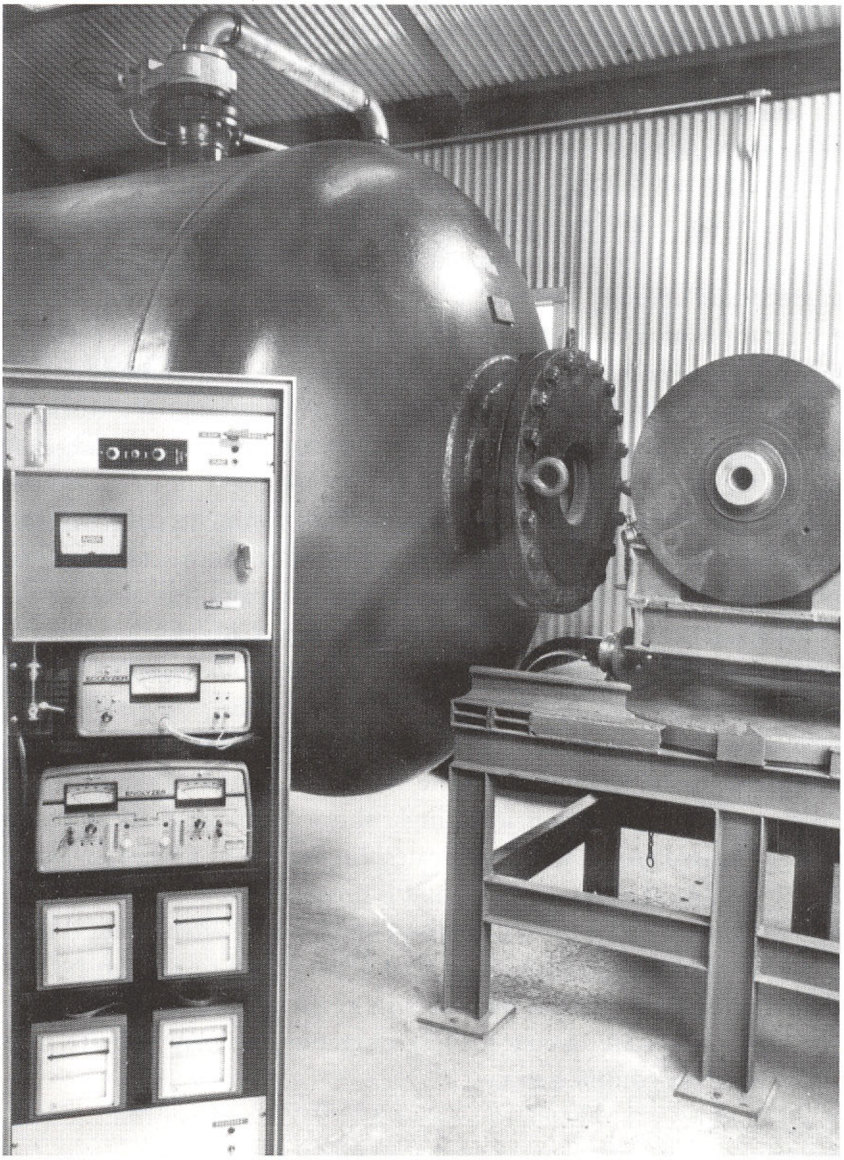

Figure 28.2 - Large Chamber used for determining the toxic fumes produced by permissible explosives. (Courtesy: R. Mainiero)

TOXIC HAZARDS OF CO, NO, AND NO_2

CO is an odorless, colorless gas that can cause illness and death by asphyxiation. In general, the first symptoms include headache, fatigue and lightheadedness. At high exposures to CO, skin flushing, rapid heart rate, and lowered blood pressure occur. At even higher exposure levels, decreased attention span is followed by nausea, vomiting, impaired coordination, fainting, coma, convulsions, and, finally death.

NO is a colorless gas. Symptoms of exposure include redness of the eyes, abdominal pain, coughing, headache, dizziness, blue skin, lips, or fingernails, shortness of breath, and convulsions. Exposure to NO will always include simultaneous exposure to NO_2 since NO is continuously converted to NO_2 in the atmosphere.

NO_2 is a brown gas with a pungent odor. It is very corrosive and will cause severe burns to the skin, eyes, and lungs in sufficiently high concentrations. Symptoms include a burning sensation to skin, eyes, or lungs, sore throat, cough, dizziness, headache, sweating, labored breathing, nausea, shortness of breath, and vomiting. The symptoms for NO_2 poisoning may be delayed. A person exposed to NO_2 may feel only minor symptoms at first. The actual damage to the lungs may not show up until several hours later, at which time the lungs become congested with fluid and breathing becomes labored.

The symptoms of CO, NO, and NO_2 exposure are similar to those of the flu and other illnesses. People exposed to these toxic gases may think they are coming down with a cold, the flu, or are suffering from food poisoning. If a worker becomes ill on the worksite, it is a good idea to stay on the side of caution and seek medical attention.

Blasters working in underground or confined environments have long been aware of the hazards of these gases and know that they must ensure adequate ventilation to quickly dilute them below harmful levels before returning to their work stations. Blasters at surface mines and construction operations have not been as concerned about blasting fumes as their counterparts in underground mines, believing that fumes would be adequately dispersed in the open air (ISEE, 1998).

Surface blasters, however, must be aware that toxic fumes have the potential to create hazards in their operations. Some large surface mines detonate up to two million pounds of blasting agent in a single shot. Some of these shots produce a red or orange colored cloud, which indicates the presence of NO_2 (Barnhart, 2004), (Barnhart, 2003), and (Lawrence, 1995) and is unsafe to breathe.

The CO in the gaseous products released immediately after a blast is not as much of a concern as the NO and NO_2 since CO is much less toxic than NO and NO_2. The CO danger lies with the gas that remains in the ground after the blast which is released to the atmosphere during loading operations or may migrate through the ground and collect in confined spaces.

TOXICITY LEVELS

As previously mentioned, the toxic gases of primary concern for blasting operations are NO, NO_2, and CO. One common way to express the toxicity of these gases is the OSHA Permissible Exposure Limit or PEL. The PEL is the time weighted average concentration, usually expressed as parts per million (ppm), that must not be exceeded during an 8 hour work day. The PEL for NO_2, NO, and CO are 5, 25, and 50 ppm, respectively (NIOSH, 1994). Toxicity of gases may also be expressed as the concentration Immediately Dangerous to Life and Health, or IDLH. Workers should never be exposed to concentrations above the IDLH without specialized respiratory protection. The IDLH levels have been set based on the belief that a worker would be able to escape to fresh air without loss of life or irreversible health effects. The IDLH for NO_2, NO, and CO are 20, 100, and 1,200 ppm, respectively (NIOSH, 1994).

The only reliable way to detect the presence of toxic gases following a blast is with an instrument designed to detect these gases. These instruments may be used to monitor the gases being released by a muck pile or determine whether the air in a confined space near a blast is safe to breathe.

CONFINED SPACE

The National Institute for Occupational Safety and Health (NIOSH) defines a confined space as "a space which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy" (*See* NIOSH web site). An example of a confined space near a construction blast might be a manhole or an excavation for utility lines. The Occupational Safety and Health Administration (OSHA) guidelines for confined space safety should always be followed since a dangerous atmosphere may result from many sources in additions to blasting (*See* OSHA web site). Figure 28.3 shows a worker using a multi-gas monitor to measure blasting fumes in a manhole. on a trenching project.

Figure 28.3 - Worker using a multi-gas monitor to measure blasting fumes in a manhole. on a trenching project. (Courtesy: R. Mainiero)

CO MIGRATION

In rare cases blasting fumes may travel hundreds of feet through the ground and collect in the basement of a structure adjacent to a blasting site. In these cases the culprit is likely CO. NO and NO_2 do not travel far through the ground due to soil and ground water absorption (Mainiero, 2007). CO, being odorless and colorless, may build up in a basement or other confined space without any warning or telltale odor. Since 1988, there have been eighteen documented incidents of CO migration in the United States and Canada; the confined space typically being a home and in one case a sewer manhole vault (NIOSH, 1998), (Eltschlager, Schuss, Kovalchuk, 2001), (NIOSH, 2001), and (Santis, 2001). There have been thirty-nine suspected or medically verified carbon monoxide poisonings caused by blasting-generated CO, with one fatality. In one incident in Kittanning, Pennsylvania, blasting fumes traveled 450 feet from a coal strip mine into a home, poisoning a couple and their baby. Fortunately, all three recovered following treatment in a hyperbaric chamber (Eltschlager et al. 2001) and (NIOSH, 2001).

The only way to detect the CO is with an instrument. Fortunately many homeowners have installed monitors to detect CO that may be produced by a faulty furnace or space heater. These monitors work just as well in detecting CO that may come from a blast. If a home near a blast does not have CO monitors, a blaster should consider giving or loaning the homeowner one for the duration of the blasting.

REFERENCES

Barnhart, C. R. 2004. Analytical measurements in cast blasting to identify the cause and cure for "orange smoke." International Society of Explosives Engineers (ISEE) Proceedings of the 30th Annual Conference on Explosives and Blasting Technique, February 1 - 4 pp. 1 – 15, New Orleans, LA. ISEE, Cleveland, OH.

Barnhart, C. R. 2003. Understanding the "orange smoke" problem in cast blasting. International Society of Explosives Engineers (ISEE) Proceedings of the 29th Annual Conference on Explosives and Blasting Technique, pp. 1 – 11, February 2 – 5, Nashville, TN. ISEE, Cleveland, OH.

Mine Safety and Health Administration (MSHA). Code of Federal Regulations (CFR), Title 30, Section 15.20(g). MSHA , Washington, D.C.

Eltschlager, K. K., Schuss, W., Kovalchuk, T. E. 2001. Carbon monoxide poisoning at a surface coal mine....A case study. International Society of Explosives Engineers (ISEE) Proceedings of the 27th Annual Conference on Explosives and Blasting Technique, January 28 – 31, Orlando, FL. ISEE, Cleveland, OH.

International Society of Explosives Engineers (ISEE). 1998. ISEE Blasters' HandbookTM, 17th Edition, p. 48. ISEE, Cleveland, OH.

Karmakar, N. C. and Banerjee, S. P. 984. A review of laboratory and field test methods for studying fume characteristic of explosives. Journal of Mines, Metals and Fuels, Vol. 32, No. 1/2, January - February pp. 398-402.

Lawrence, D. L. 1995. A study of post blast generation of nitrogen dioxide. International Society of Explosives Engineers (ISEE) Proceedings of the 22nd Annual Conference on Explosives and Blasting Technique, February 2 – 5, pp. 1 – 12, Nashville, TN. ISEE, Cleveland, OH.

Mainiero, R. 1997. A technique for measuring toxic gases produced by blasting agents. International Society of Explosives Engineers (ISEE) Proceedings of the 23rd Annual Conference on Explosives and Blasting Technique, pp. 595-604, February 2 - 5, Las Vegas, NV. ISEE, Cleveland, OH

Mainiero, R.J., Harris, M.L., and Rowland, J.H. 2007. Dangers of toxic fumes from blasting. International Society of Explosives Engineers (ISEE) Proceedings of the 33rd Annual Conference on Explosives and Blasting Technique, January 28 – 31, Nashville, TN. ISEE, Cleveland, OH.

National Institute for Occupational Safety and Health (NIOSH). 2001. Technology News 488 - Migration of blasting fumes into a western Pennsylvania Home, Pittsburgh, PA. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

National Institute for Occupational Safety and Health (NIOSH). 1998. NIOSH HETA 98-0020. Hazard evaluation and technical assistance report: Carbon monoxide intoxication and death in a newly constructed sewer manhole, Cincinnati, OH. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health.

National Institute for Occupational Safety and Health (NIOSH). 1994. Pocket guide to chemical hazards. DHHS (NIOSH) Publication No. 94-116. Cincinnati, OH. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health.

Santis, L. D., J. H. Rowland, III, D. J. Viscusi, and M. H. Weslowski. 1995. The large chamber test for toxic fumes analysis for permissible explosives, International Society of Explosives Engineers (ISEE) Proceedings of the 21st Annual Conference on Explosives and Blasting Technique, February 5 – 9, Nashville, TN, ISEE, Cleveland, OH.

Santis, L. D. 2001. A summary of subsurface carbon monoxide migration incidents, International Society of Explosives Engineers (ISEE) Proceedings of the 27th Annual Conference on Explosives and Blasting Technique, January 28 – 31, Orlando, Fl. ISEE, Cleveland, OH.

Streng, A.G. Evaluation of Toxic After Detonation Gases Formed By Industrial Explosives, Explosivstoffe, 1971, vol. 34, pp. 58–64.