






## EXPLOSIVE CHEMICAL HAZARDS & RISK MINIMIZATION

### Background

The United State Occupational Safety and Health Administration (OSHA) defines an explosive material as follows: a solid or liquid chemical which is in itself capable by chemical reaction of producing gas at such temperature and pressure and at such speed as to cause damage to the surroundings.

There are seven divisions for explosives.

- Unstable explosives
- Division 1.1 – mass explosion hazards (i.e., nearly instant detonation of the entire quantity of explosive present)
- Division 1.2 – projection hazards but not mass explosion hazards
- Division 1.3 – present a fire hazard and minor blast or projection hazard
- Divisions 1.4 through 1.6 – very insensitive substances; negligible probability of accidental initiation or propagation

Division	Pictogram	Signal Word	Hazard Statement
Unstable explosive		Danger	Unstable explosive
1.1		Danger	Explosive; mass explosion hazard
1.2		Danger	Explosive; severe projection hazard
1.3		Danger	Explosive; fire, blast or projection
1.4		Warning	Fire or projection hazard

1.5	NONE	Danger	May mass explode in fire
1.6	NONE	NONE	NONE

Typical Precautionary Statements for Unstable through Div. 1.5 (Div 1.6 has none):

- In case of explosion risk evacuate area.
- Obtain special instruction before use.
- Keep only in original packaging.
- Keep away from heat, hot surfaces, open flames and other ignition sources.

## Scope

This SOP is limited in scope to those chemicals that meet OSHA's definition of an explosive. However, it is important to understand that explosions can occur with chemicals that are not classified by OSHA as explosives. For example, an explosion can occur with large-scale polymerization of a monomer. The reaction of monomers forming polymers is exothermic. In a small-scale reaction, most of the heat is lost to the environment, thereby preventing an explosion.

Sodium azide ( $\text{NaN}_3$ ) is another example of chemical that can explode but which is not classified as explosive. Only in the presence of the proper initiator will it violently decompose to nitrogen gas and sodium ions, which is why it was once used in vehicle air bags.

An explosive reaction may occur when two chemicals are mixed, with one being an organic and the other a strong oxidizer, and neither being individually classified as explosive. For example, mixing of ammonium nitrate fertilizer (an oxidizer) and fuel oil (a combustible liquid) will cause an explosion.

## Deflagration and Detonation

There are two classifications of explosions that describe something about their hazards. These are deflagration and detonation.

- Deflagration is a very rapid combustion of particles of an explosive. The combustion begins at one or more points or on a surface and 'burns' at a very rapid rate through the material. The rate of reaction is subsonic or in other words below the speed of sound.

This rate, when expressed in terms of feet per second, is less than 1,125 feet per second (343 meters per second).

- Detonation, on the other hand, is an almost instantaneous combustion of an explosive accompanied by high temperature-pressure wave formation. The rate of a detonation is supersonic and can reach speeds of 29,000 fps (8,839 mps). This is 20,300 miles per hour! Detonation will produce a true shock wave as the result of the explosion, while deflagration will not.

The important difference between these two is that some chemicals that deflagrate burn slow enough that they need confinement in order to be explosive. Black powder is an example of this. Lit as a ribbon on the ground it can be out walked. Chemicals that detonate are dangerous without confinement.

## Explosion Effects

Once an explosion has occurred there is a series of effects it will produce. These effects are broken into two major categories, primary and secondary effects. Primary effects will always accompany an explosion, while secondary effects may or may not occur.

### Primary Effects

Primary effects are almost always the most destructive explosive effects. There are three types of primary effects: blast pressure, fragmentation, and thermal.

- **Blast Pressure.** In general, blast pressures are the most destructive force involved in any explosion. The blast pressure of any given explosion may be as high as 700 tons per square inch, depending on the particular explosive involved. This pressure travels out from the source of the explosion in a circular pattern at speeds up to 13,000 miles per hour and can be produced in as short a period of time as 1/10,000 of a second.
- **Fragmentation.** Fragmentation includes that of the explosive container as well as materials in the same vicinity. During fragmentation, objects are literally broken into small parts by the energy imparted by the blast pressure. These fragments will be propelled away from the origin of the explosion at speeds up to 2700 feet per second (faster than many conventional bullets).
- **Thermal.** In explosions, intense temperatures are generated for very short periods of time. Theoretical temperatures can reach 27,000° F, which can cause severe

skin burns even though the temperature will likely drop rapidly (i.e., in thousandths of seconds). It is characterized by the flash and fireball associated with the explosion.

### Secondary Effects

Secondary effects are also divided into three types: shock wave modification, fire, and shock wave transfer. It is important to remember that all or none of the secondary effects may be present with any given explosion. Of these three, fire is the only one generally of concern in a laboratory.

## Residual Hazards After an Explosion

After an explosion bits and pieces of unexploded material are likely to litter the area. Any of the remaining pieces of explosive material can be dangerous. Due to the explosion, the remnants may be extremely sensitive and require very little force to initiate another explosion. Usually secondary explosions are small; however, any personnel in the immediate area would be in danger. Again, it is important to assess an area where an explosion has occurred before moving containers, cleanup, etc.

## Mitigating the Risks from Explosives

A written, comprehensive project-specific risk assessment with additional oversight is required for any experiment involving an explosive classified as unstable or Division 1.1 through 1.3. See the companion EHS SOP, ***Chemical Hazard Assessment and Risk Minimization***. A specific risk assessment with additional oversight may also be required for other classes of explosives depending on the specific hazards of an experiment or protocol, as described in the companion EHS SOP referenced above.

General risk mitigation measures are as follows:

- Follow general safe chemical handling practices as described in the EHS SOP, ***General Guidance for Chemical Ordering, Receipt, Distribution, Use and Storage***.
- Conduct a thorough literature search, including review of Safety Data Sheets, to establish a thorough understanding of the properties of the explosives to be handled with particular consideration given to the procedures and tasks to be conducted. See also the Laboratory Safety Colloquium archive presentation titled ***Safe Handling: Unstable, Reactive, and Energetic Compounds***.
- Observe all specific safety procedures established for the laboratory/procedure.

- A chemical fume hood and permanent or portable blast shields and remote operations should be used to isolate as much as possible the researcher from the chemical. Minimize the time any part of the body, including hands, is unshielded. Note, any distance between a researcher and an explosion can be significant. Blast pressure decrease by about the cube as the blast wave moves away from the source. Thus, a hand holding a flask that explodes might be severely damaged or lost while a hand just a foot (30 cm) distant is only lacerated. With explosives, inches count.
- Wear appropriate PPE. See EHS SOP, ***Personal Protective Equipment for Chemical Exposures***. In addition to standard personal protective equipment, consideration should be given to hearing protection, face shields and heavier than standard lab coats, leather outer garments, or garments and gear specifically designed to provide protection from arc blasts. Outer garments rated for high temperature arc blasts are available from safety suppliers for electricians.
- Using non-explosive chemicals is one way to mitigate the risk. In a lab setting, it is also an unlikely option because the chemicals are either being used because they are explosive or because they possess properties important to the research and these properties include the capacity to explode. Using chemicals that are less likely to explode is another way to reduce the risk. Explosives are not equally sensitive to shock. Some are so sensitive that they will explode with no apparent outside influence. Others are so insensitive that only other explosives will set them off. If possible, choose the least sensitive explosive available for research. Sensitivity is not related to whether a chemical will deflagrate or detonate. Some chemicals that deflagrate are much more sensitive to shock than those that detonate.
- The scale of work is critical. It should be done at the smallest scale possible (e.g., mmole) and scaled up only with the input and authorization of the Principle Investigator/Supervisor.
- For those chemicals that deflagrate, eliminate, as much as possible, sources of confinement.
- Only those chemicals involved in the operation should be in the vicinity of the work being done. Bottles/containers from which they were dispensed and other chemicals need to be put away. Containers near the work could be broken by the blast wave and, if the contents are combustible, set on fire by the intense heat of the fireball or vaporized and spread throughout the work area.

- Identify and eliminate sources of static discharge since this can be an initiating force for some explosives. Sources of static include clothing, use of plastic, and transfer of materials between containers. Low humidity environments also increase the potential for static.
- Conduct transfers and other operations with compatible tools and equipment. For example, some explosives can form more sensitive compounds when exposed to metal and especially heavy metals. For those chemicals, non-metal tools and equipment should be used.
- Keep the work area, tools and equipment scrupulously clean. Do not allow explosives to build up. Use non-static wipes or brushes or use appropriate wet methods to clean handling areas. Do not scrape explosives from surfaces.
- Do not attempt to crush or grind an explosive or apply other pressure to it unless it is explicitly known that the explosive is not sensitive to it with consideration given also to the amount or scale. Keep the threads of containers clean for the same reason.
- Where possible dilute explosive wastes in a safe solvent. Most explosives are more stable when dilute. Some, when wetted, lose the ability to explode.
- Keep explosive wastes separate from other wastes to prevent contamination that might cause the explosive to become more sensitive.
- Know what actions to take in the event of an emergency. Ensure that an appropriate fire extinguisher and properly functioning safety shower are readily available.
- See the EHS SOP, ***Fire Safety – General Prevention and Extinguishing*** and the EHS web-based training program titled ***Fire Extinguisher Training***.

## Other Resources

United States Department of Energy, Explosives Safety Manual (DOE M 440.1-1A). Section 21.0 covers Laboratory Operations. It is available on the DOE web site.

Prudent Practices in the Laboratory, Updated Version (2011), National Research Council Committee on Prudent Practices in the Laboratory. Section 6.G has a good discussion of explosives. It is available on the National Academies Press web site.