FEATURE

The cardinal rule of explosives safety

The US Military and its contractors work safely with energetic materials on both an industrial scale and a laboratory scale. Practices and procedures used with these materials will benefit academic and research laboratories that work with reactive, energetic, and explosive materials. The most effective practice may be one of the simplest and least expensive to implement. This is especially useful for laboratories beginning new projects with inexperienced laboratory workers. Though not a substitute for a detailed chemical hazard analysis with strictly enforced standard laboratory procedures, the cardinal rule of explosives safety must be adhered to at all times: "Expose the minimum number of people to the minimum amount of explosive for the minimum amount of time"

This information was originally presented at the 246th ACS National Meeting in Indianapolis, Indiana September 9, 2013 for the ACS Division of Chemical Health and Safety symposium "Managing reactive chemistry".

By J. Keith Butler

Some materials are intrinsically hazardous, that is they are hazardous in and of themselves regardless of how they are manipulated. These materials require special consideration by workers. The DOD Contractors Safety Manual for Ammunition and Explosives addresses this challenge with one simple rule known as the cardinal principle of explosive safety:

> "Expose the minimum number of people to the minimum amount of explosive for the minimum amount of time."[1]

The goal of all safety programs is to prevent accidents. However, even the most effective safety program suffers from the weaknesses brought into the workplace by the individual. Accidents still occur. The cardinal principle addresses being prepared for the moment preventive efforts fail. The aim is to minimize the negative impact. With explosives that may include property damage, severe injury and multiple deaths.

The Laboratory Safety Institute has prepared a memorial of laboratory workers who have died from work related injuries. There are numerous examples of accidental deaths involving explosives.[2] The impact of improved safety policies and procedures is evident in the observation that the most recent explosive death listed was in 1979. However there have been non-fatal accidents involving explosives reported more recently.[3,4]

An evaluation of each of these incidents reveals that adherence to the cardinal principle would have lessened the negative impacts including preventing some deaths. Again, while this simple principle does not address the many complex issues involved in preventing these accidents it serves a very beneficial role, a role that should not be limited to explosives and ammunition workers. Following the cardinal principle of explosive safety should be applied to any situation that involves hazardous materials. There have been numerous accidents involving a variety of "non-explosive" chemistry that would have been less costly had the cardinal principle been followed.[5,6]

There are a number of laboratories currently involved in reactive chemistry research. Work is being performed directly, within collaborative projects, and through grant funded university research by the U.S. Department of Defense, U.S. Department of Homeland Security, the National Bureau of Mines, NASA, the U.S. Department of Energy, and numerous industrial commercial activities.

A number of lessons can be learned from these experts. The US Military and its contractors work safely with energetic materials on both an industrial scale and on a laboratory scale. Practices and procedures developed for use with these materials should also be followed by academic, industrial and research laboratories that work with reactive, energetic, and explosive materials. The effectiveness of these practices is reflected in the observation that most accidents in the explosives industry are normal industrial accidents: slips, trips, falls, back strain, cuts and abrasions, etc. This industry is highly regulated; managers and operators are keenly aware of the hazards and always utilize top-down verified policies and procedures. Worksites with less regulatory oversight, such as academic research laboratories will benefit from learning these lessons.

The Cardinal Rule of Explosives Safety must be adhered to at all times. A detailed chemical hazard analysis for all procedures should be performed.[7] Strictly enforced standard laboratory procedures should be in place. The cardinal principle should be implemented in a manner that is consistent with safe and efficient operations. Overly restrictive policies invite non-compliant short-cuts. A zero tolerance for violation of safety policies should be maintained. Violations should always result in disciplinary action.

Effective application of this principle begins with the effective use of

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1871-5532/$36.00
http://dx.doi.org/10.1016/j.jchas.2014.01.001

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MAXIMUM PERSONNEL

Operators 6
Casuals 5

MAXIMUM QUANTITY OF EXPLOSIVES

5 LBS

Figure 1. Personnel limits and explosive limits for specific work areas or operations should be determined and clearly posted and strictly enforced.

administrative and engineering tools to reduce the number of people exposed, the time of exposure, and the quantity of material subject to a single incident. A proper hazard analysis will result in defined explosive limits for each operation and personnel limits for the area used for each operation. These explosive limits and personnel limits should be clearly posted (Figure 1) so there are no opportunities to deny awareness of a limit and no challenges when the limits are being enforced. Again, there are no exceptions. If a laboratory or other work area is at capacity and the principle investigator (PI) enters the laboratory, the PI should exit the laboratory upon realization that the limit has been exceeded. Returning to the laboratory only after arrangements can be made for an exchange of personnel. An entry-level operator is fully justified in asking a supervisor or manager to step outside until the personnel levels in the area can be met. Such employees should be acknowledged in a positive manner. This is not an exercise in setting an example for researchers; it is a positive action to reduce the negative impact of an unexpected detonation by minimizing the number of possible victims.

"EXPOSE THE MINIMUM NUMBER OF PEOPLE . . ."

There are a number of considerations required to minimize the number of people exposed to severe hazards. The people at highest risk are the operators due to their proximity to the hazard and because they are actually manipulating the hazardous energetic material. At the second highest risk are bystanders who are working nearby or who may be observers or causal visitors. Both operators and bystanders need protection from flying debris as well as the pressure pulse generated by a blast. The blast hazard may be minor in comparison with that from flying debris.

Operators face an individual risk. They should be aware of this risk and accept it as part of the job. Bystanders and casual observers face a group risk. It is possible that bystanders may be unaware of any hazard present. They may assume the operators are following safe practices. Operators are assumed to be fully aware of the risk and of how to control that risk; therefore, operators are responsible to protect bystanders.

Flying debris is composed of primary and secondary fragments. Primary fragments are generated from the container in direct contact with the explosive. Primary fragments are commonly small and initially travel at thousands of feet per second. They can be lethal at long distances from the parent explosion. Secondary fragments are composed of debris from items in close proximity to the explosion. Secondary fragments are larger in size, initially travel at hundreds of feet per second and do not travel as far as primary fragments. A hazardous fragment, primary or secondary is one having an impact energy of 58 ft-lb (79 J) or greater.[1]

Shielding or remote operation technology should be used to protect people from fragmentation hazards. Consideration should also be given to public traffic routes and other occupied areas. This applies whether the use is occasional or frequent.

Personnel limits for each work area or even for each task should be established using information generated during a hazard analysis.[7] These will include the maximum number of operators and the maximum number of transients which includes supervisors, other workers, and visitors. A complete hazard analysis will also determine the need for dividing walls, firewalls and operational shielding to protect others in the same room. Transient workers can have diverse responsibilities and work experiences. Protecting these important workers requires special care.

Maintenance Workers

To protect maintenance workers, operators should be diligent to decontaminate work areas and equipment before maintenance or repair technicians begin work. When complete removal of explosives is not possible, operators should identify areas and parts of the equipment that could not be cleaned and provide maintenance personnel with specific instructions for safe handling.

Housekeepers

Precautions that should be taken to protect housekeepers begin with maintaining a clean and orderly work station – this has a number of benefits in addition to enhanced safety for all. Work will proceed more efficiently and will better accommodate housekeepers if a regular cleaning schedule is established. More specific work practices include:

- Do not perform general cleaning concurrently with hazardous operations.
- Promptly remove spilled explosives and hazardous materials following proper established procedures.
- Use cleaning methods that do not create ignition hazards.
- Flammable compounds should not be used. If there is a detonation these will magnify the negative impact of the incident.
- Do not use cleaning agents containing alkalis. They can form sensitive explosive compounds with nitrated organic explosives.
- Use natural rather than synthetic fiber brooms to reduce generation of static charge.
- At the end of the workday, personnel should remove all energetic material from laboratory apparatus and store it in an appropriate magazine or designated storage location.