CHAPTER 8

HEMs: Concerns of Safety

8.1 Introduction

Do you know a strange fact? Although explosives are dangerous and feared substances, the explosives industry does not figure in the top ten among the most accident-prone industries or professions in the world (coal mining and steel industries are at the top of the list). This is obvious because those who deal with the explosives know that they deal with the explosives! A whole range of precautions are taken, Standard Operating Procedures (SOPs) are followed, and clearly written-down DO's and DON'Ts are observed at every stage of explosives processing all over the world. Nevertheless, accidents, some of them disastrous, still keep occurring sporadically, indicating that some lapses must have occurred either due to ignorance or negligence. Remember, in the field of HEMs, it is safety and safety alone that is the priority, and the rest of the objectives, like project success, cost, etc., come later. The intention of this chapter is to give the readers a gist of the vital and salient points concerning various aspects of HEM safety.

8.2 Nature of Hazards

In the earlier chapters we have seen that HEMs can result either in detonation (creating destructive shock waves) accompanied by blast or deflagration, depending on the circumstances that they are subjected to, particularly the degree of their confinement. The synergistic effect of shock waves plus blast creates disastrous structural damage and also missile effects of the debris, whereas high temperatures encountered during deflagration practically incinerate everything it comes into contact with. The damages that HEMs can cause can be classified into:

- Formation of highly destructive shock wave and blast pressure in case of high explosives.
- Huge quantities of product gases at high pressures (sometime even up to hundreds of atmospheric pressures) and high temperatures (the flame temperatures of certain propellants can be as high as 3000 K) with enormous heat output when propellants burn.
- Phenomenally high amounts of heat radiation when pyrotechnics burn.

It is, therefore, mandatory that the technical personnel dealing with the HEMs have some fundamental scientific knowledge about their chemical nature, thermal behavior, aspects of

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sensitivity with respect to friction, impact, and static electricity, and problems of compatibility between ingredients that go to make a formulation.

Thermochemical and molecular structural factors and factors like crystal defects, which easily lead to "hot spot" initiation, make quite a few HEMs sensitive to initiation by impact or friction, or heat or discharge of static electricity. This basic knowledge of these aspects is an essential prerequisite for any person who is involved in the synthesis/processing/handling/transportation/storage of HEMs. He/she should be thoroughly aware of these hidden hazards of HEMs.

8.3 Hazard Classification of HEMs

The United Nations have classified different dangerous goods like explosives, toxic chemicals, inflammable chemicals, radioactive materials, etc. under nine categories. Explosives/HEMs are categorized under "**1**". They are further subclassified (1.1−1.6) into six Hazard Divisions (HDs) depending on their sensitivity, as well as the terminal damages they can inflict in case of an accident. Table 8.1 gives a summary of the same. Of these HD 1.1, HD 1.2 and HD 1.3 are highly important.

1. **HD 1.1**: HD 1.1 refers to explosives that undergo mass detonation that creates and propagates shock wave and blast pressure. The destruction is caused mainly by blast and high velocity fragments like shell fragments, boulders, etc. Craters are formed.
2. **HD 1.2**: When there is an accident involving HEMs in cased units (e.g., a rocket motor with nozzle), the major risk is that of propulsion of such a unit and materials of this nature are classified under HD 1.2.

Table 8.1: UN classification of HEMs.

Hazard Division	Effect	Example
HD 1.1	Mass detonation creating shock waves with major blast effects, high blast pressure, & crater.	Initiatories, high explosives
HD 1.2	Projectile and fragmentation hazard	Rocket motor with nozzle, grenades
HD 1.3	Mass fire and radiant heat	Propellants and pyrotechnics
HD 1.4	No significant hazard	Small arms ammunition and caps.
HD 1.5	Very little probability of initiation	No military explosives
HD 1.6	Highly insensitive detonating substance	No military explosives

Table 8.2: Effects of air blast overpressure on human beings.

Probable Effect	Blast Pressure, Psi (kPa)
Ear Drum Rupture	
Threshold	7 (48)
50% Probability	15 (103)
Lung Damage	
Threshold	30—40 (207—276)
Severe	80 (552)
Fatal	
Threshold	100—120 (690—828)
50% Probability	120—180 (828—1242)
100% Probability	200—250 (1380—1725)

3. **HD 1.3**: This includes HEMs like propellants, which undergo mass deflagration (burning). The major risk here is that of **mass fire** and rarely, minor blasts.

The effects of air blast overpressure on human beings have been studied in great detail, and the results are given at Table 8.2.

Out of the three major hazards of HEMs viz. (1) mass detonation, (2) mass fire, (3) thermal radiation, the first two are reversible depending on the conditions like degree of confinement. For example, if we want to burn about 50 kg of gun propellant (like it is done during waste disposal), we should spread it into a thin layer so that the entire surface undergoes only deflagration (burning) safely. If, on the other hand, we make a heap of it, what will start as deflagration in the beginning will transform itself into a detonation because of the confinement. We must understand that confinement refuses to allow the gaseous products to escape, resulting in higher pressures that enormously increase the burning rate of HEMs to such a level that a shock wave is formed. Waste explosive/propellant/pyrotechnic disposal is an extremely hazardous process that has caused many fatal accidents all over the world and, therefore, all precautions/safety norms should be religiously followed during this process.

8.4 The Damages

Many tragic accidents are avoidable by scrupulously following the SOPs/precautionary measures. Before we discuss these procedures/DO's and DONT's, let us remind ourselves that the following are the damages of any major accidents, including HEM—related ones.

1. Personal: Major injuries & Death
2. Property: Buildings/Structures, Facilities, & Materials

3. Morale of Workers
4. Downtime
5. Reputation (of the establishment)

8.5 General Safety Directives

If you are working in the field of HEMs, please pay attention to **EACH and EVERY** point given below.

8.5.1 Assume the Hazard

"Expect the unexpected," particularly while you will work with new materials/ compositions.

8.5.2 Never Work Alone!

Work as a group, even if it is a small one.

8.5.3 Start with the Smallest Possible Quantities

Particularly while the compound/composition is expected to be sensitive, e.g., initiatory composition. What should be that "smallest possible quantity" can be decided after thorough discussion with the Safety Division of the establishment.

8.5.4 Safety Shields

Use safety shields—wherever needed.

8.5.5 Fire Hazards: Expect and be Ready

Expect fire hazards and keep your Fire Fighting equipments in readiness.

8.5.6 Ground (Earth) Your Facilities

Grounding/earthing the personnel and equipments is an inescapable requirement when one deals with sensitive HEMs like initiatories and pyrotechnics. In fact, handling propellants (for guns, rockets, etc.) during dry weather also strictly calls for grounding both the working personnel and equipments.

The static electricity discharge pits connected to the equipments should be periodically inspected for their reliability as also the reliability of other static electricity discharge/ conducting mats, gloves, and garments.

8.5.7 Wear Protective Garments/Equipments (Including Antistatic Ones)

These include gas masks/goggles/helmets/aprons/safety shoes/antistatic shoes, etc., depending on the type of operation involved.

8.5.8 Practice Relative Humidity Control

When processing/handling explosives, propellants, and pyrotechnics, which are sensitive to static discharge, the Relative Humidity in the process room/laboratory should not be less than 60%. The process rooms should be equipped with humidifiers for this purpose.

8.5.9 Housekeeping

Good housekeeping greatly helps to avoid accidents. Ensure that the labs/process rooms are not cluttered with too many equipments/hardware/materials. Avoid storing incompatible materials together. Ensure before the commencement of operation that the exit pathway is clear.

8.5.10 Know about the Material Hazards

The hazardous nature of materials should be well understood by all the concerned workers/operators. Do thorough literature survey to know such hazards before new processes are tried. (Examples):

1. Chlorates are highly incompatible with carbonaceous matter, ammonium compounds, sulphur, red phosphorus, etc.
2. Water is dangerous with mixtures containing powdered Zr/Ti/Mg/Zn/Al.
3. Very fine ammonium perchlorate/ammonium nitrate can be dangerously sensitive to impact in presence of carbonaceous impurities.

8.5.11 Toxic Hazards

It should be realized that many HEMs and their related chemicals possess not only explosion and fire risks but also toxic hazards. For example, prolonged contact with RDX and trinitrotoluene (TNT) is known to cause skin-related ailments. Isocyanates (like toluene di-isocyanate (TDI) used in composite propellant processing) can cause lungs-related problems like bronchitis. Prolonged ingestion of solvents like benzene might cause cancer while heavy metal ions of barium, and lead might severely impair the functioning of liver and kidneys. Therefore, the following preventive measures have to be taken:

- Compulsory use of personnel protective equipments like gas masks, gloves, aprons, etc., as required

- Periodic workplace monitoring for toxic fumes with reference to the Threshold Limiting Values (TLV)/Short Term Exposure Limit values for the particular chemical
- Effluent treatment if needed

8.5.12 Prepare a Work Plan

- In case of an established process, ensure that Standard Operating Procedure (SOP) has been prepared, taking care of all safety aspects including Man Limit, Explosive Limit, Fire-fighting facilities, Housekeeping, Earthing, etc.
- In case of a new process/synthesis of new HEM, do a thorough literature survey to gauge the hazards involved and then make a step-by-step procedure with precautions to be observed to prevent any runaway reactions/fire/explosion.

8.5.13 Hazard Evaluation

While preparing/processing new explosives/formulations:

1. Start with the smallest quantity.
2. Soon after the initial preparation, evaluate its sensitivity/stability by various tests like Impact sensitivity, Friction sensitivity, Spark sensitivity, differential thermal analysis (DTA), Vacuum stability, etc.
3. In case of new mixtures, first evaluate the compatibility between various ingredients using techniques like DTA.

The results of these tests will adequately caution you before you do further processing/ scaling up.

8.5.14 Storage/Transport

During storage/transport of explosives, due care should be taken to observe the statutory explosive regulations very meticulously. While planning an explosives process building or magazine, various safety distances like Storage Inside Quantity Distance (SIQD), Process Inside Quantity Distance (PIQD), and Outside Quantity Distance (OQD) should be strictly followed apart from the type of protection necessary like the requirement of a particular type of traverse, blast wall, etc. Both during storage and transport of explosives, care should be taken to ensure that:

- only the approved type of package and transport like explosive van should be used.
- no incompatible groups of explosives are transported together.

Note: Extensive studies and trials have been carried out to decide upon the Quantity—Distance relation in the field of explosives. For instance, when one wants to construct a magazine, an Explosive Storage House (ESH) for storing 2 tons of RDX (categorized under HD 1.1), what should be the minimum safety distance (D) from the ESH to another similar ESH as well as to a residential colony? Naturally, the value of D cannot be same for both, and in the latter case, it should be far greater than the first one. We are guided by an empirical formula given below to determine the minimum safety distance, D required in such as case:

$$D = K \times Q^{1/3} \tag{8.1}$$

where D = minimum distance required between the ESH (sometimes referred as Potential Explosion Site) and the building/installation/infrastructure under consideration (measured in meters).

Q = Net Explosive Quantity in kilogram at ESH
K = Protection level, the value of which depends on what you want to protect.

Figure 8.1 explains this concept.

In this example (where NEQ is 2000 kg), the values of K for another ESH (magazine) and residential colony are 2.4 and 22.2, respectively. Accordingly:

$$(\text{SIQD}) : D = 2.4(2000)^{1/3} \sim 31\,\text{m} \quad (\text{minimum})$$
$$(\text{OQD}) : D = 22.2(2000)^{1/3} \sim 280\,\text{m} \quad (\text{minimum})$$

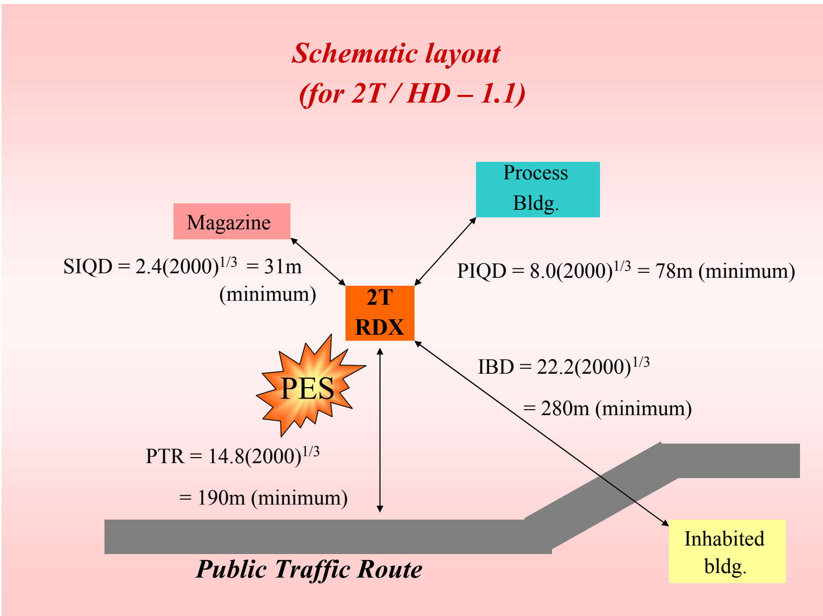

Figure 8.1
Typical Representation of Quantity Distance Relation.

It means that there is a nine-fold increase in the minimum (safety) distance when we compare a residential colony with another ESH.

8.5.15 Waste Disposal

Although it may appear innocuous and routine, waste disposal of explosives, propellants, and pyrotechnics is probably one of the most hazardous operations in the field of explosives. As already mentioned earlier, many fatal accidents have been well-reported during the waste disposal of explosives and ammunitions. Their disposal should be well planned and carried out strictly as per the laid down norms available in the literature.

8.6 Conclusion

As it is normally described about fire and electricity, explosives are our "best friend but also our worst enemy." Remember that when we talk about safety:

- Ignorance cannot be excused
- Negligence cannot be tolerated
- Overconfidence cannot be pardoned

Suggested Reading

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Questions

1. What are the different hazard classifications of HEMs?
2. What is SOP? How it is important for new processes?
3. What are the different classes of fire extinguishers available?
4. How are thermal techniques useful towards explosives safety?
5. What are the steps necessary to prevent electrostatic initiation of HEMs?
6. Why are waste propellants disposed by spreading them as a thin layer?