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Basics of Hazard Management

K.L. and B.J. Kosanke, and C. Jennings-White

The consequences of accidents can be devastating to those immediately involved and their relatives. However, the ramifications of accidents can extend much further. This is illustrated in what Richard Green (Idaho National Engineering Laboratory)[1] has described as "The Four Horsemen of Our Own Apocalypse", specifically:

ACCIDENTS, INJURIES, LITIGATION, and LEGISLATION.

In effect, this is a chain in which Accidents produce Injuries, which often result in Litigation, the notoriety from which helps generate pressure for more restrictive regulation (Legislation). With this view, it is accidents involving individuals that produce increased regulation, or at least provide an excuse for increased regulation. Because regulations not only affect those individuals having accidents, but also the fireworks community as a whole, the whole community has a stake in eliminating fireworks accidents. It is the hope of the authors that this article will contribute by stimulating thought and discussion of some basic Hazard Management concepts.

Obviously there are potential hazards associated with the manufacture and use of fireworks. It is through the techniques of "Hazard Management" that the goal of "Safety" is achieved. Thus, perhaps the place to begin is to look at the definition of safety. The dictionary will generally say *something is <u>safe</u> if it involves <u>no risk</u> of mishap, error, etc*. However, by this definition, there is no activity engaged in by people that is safe, because there is always <u>some risk</u> of mishap or error in literally every activity undertaken by people. For example:

Activity	Possible Mishap
Eating	Choking on food
Walking	Stumbling and spraining ankle
Sitting in a chair	Being struck by a meteor from outer space

Thus perhaps a better definition for safety is that *"something is safe when the (attendant) risks are below an acceptable level."*[2] This is the definition used in Hazard Management and is the one used in this article.

There are three elements in the Hazard Management Process:

RECOGNITION, EVALUATION, and CONTROL.

Recognition is simply the identification of possible or potential hazards. In pyrotechnic manufacturing, in addition to all of the normal industrial hazards, there are those hazards related to accidental ignition and to chemical toxicity. For displays there are the hazards associated with malfunctioning fireworks and people doing foolish things (e.g., body parts over loaded mortars; spectator encroachment, etc.). For consumer fireworks there are the hazards from misuse of fireworks and from defective items. In a formalized Hazard Management Process, in the Recognition phase, one would simply make a list of all potential hazards.

Having identified potential hazards, the next step is to evaluate each hazard for its "Attendant Risk". For each potential hazard, risk evaluation involves two factors "Consequences" and "Probability". To illustrate the way in which consequence and probability combine to determine risk, consider the following examples:

- Activity – Jumping off a roof to see if you can fly.
- Consequence – Severe (personal crash landing).
- Probability – High.

➡ Risk — Unacceptable (Unsafe)

Because the consequence of a negative result to the activity is severe and the probability of that outcome is high, most people correctly conclude the activity has an unacceptable risk. As another example, consider:

- Activity – Swimming in the ocean.
- Consequence – Severe (being eaten by a shark).
- Probability – Very low.
  - ➡ Risk — Acceptable (Safe)

While the consequence of a negative result is at least as severe as in the first example, the probability of that happening is quite low. Thus, most people correctly conclude that swimming in the ocean has an acceptable risk and is reasonably safe. As a final example, consider:

- Activity – Flipping a coin to decide which movie to see.
- Consequence – Trivial (watching the poorer movie).
- Probability – Relatively high (50%).
  - ➡ Risk — Acceptable (Safe)

Here, even though the probability of a negative result is high, most people would decide this activity is acceptable because the associated consequence is trivial. The risk associated with an activity can be acceptable if either the consequence of a negative result is sufficiently trivial or if the probability of getting the negative result is sufficiently low. Of course, the safest activities are those for which both the consequences are trivial and the probability is low.

Having made a list of potential hazards, in the evaluation phase, the severity of potential consequences and their probabilities of occurring must be established. In the most cursory hazard management program this could simply be to highlight those activities having either at least a moderately severe consequence OR at least a modest probability of occurrence. These activities would be candidates for attention. Certainly any hazard having both at least a moderately severe consequence AND at least a modest probability of occurrence will necessarily need to be controlled.

It is possible to take a more quantitative approach to evaluating and ranking hazards. This might be done by defining relative hazard consequence and probability scales. Each of these scales could range from zero to five. Here zero on the consequence scale might correspond to accidents that produce no injury or economic loss (trivial consequence). On the probability scale, accidents that could essentially never happen (near zero probability) might be assigned a zero. On the other end of the scales, five's would be accidents that produce life-threatening injuries (consequence scale) and accidents that happen frequently (probability scale). With such a methodology, each potential hazard would be assigned an appropriate consequence scale value and probability scale value. Then a relative attendant risk value could be calculated by multiplying the consequence and probability scale values together. After this has been done for each identifiable potential hazard, one would have attendant risk values that range from 0 to 25. Hazards with risk values of zero (and perhaps one and two) might be mostly ignored. However, all hazards with high attendant risk values would require serious attention, with the activities producing the highest risk values given the highest priority for immediate control measures.

Control of hazards with unacceptable risks can either take the form of severity of consequence reduction, probability of occurrence reduction, or preferably both consequence and probability reduction.

In pyrotechnic manufacturing, to reduce the consequences of an accidental ignition:

- Expose as few people (or as little property as possible) to any accident.
  - = Separate individual hazardous work areas using barriers or distance.
  - = Use the minimum number of people in each hazardous work area.
  - = Do not mix hazardous and non-hazardous work (workers) in any area.
- Minimize the amount of exposed pyrotechnic material in each work area.
  - = Draw relatively small quantities of raw materials from bulk storage areas.
  - = Remove completed items frequently.
  - = Keep pyrotechnic materials covered.
  - = Store excess materials in day boxes.

- Employ personnel protection strategies.
  - = Use safety shields and operate remotely.
  - = Provide easy, short and direct exits from work areas.
  - = Use personal safety equipment.
  - = Never work completely alone.

To reduce the probability of an accidental ignition:

- Avoid the input of energy to pyrotechnic materials.
  - = No smoking, open flames or high temperature surfaces.
  - = Never scrape dried composition.
  - = Press slowly, do not ram with hammer blows.
  - = Pick up, do not slide, containers to move them.
  - = Eliminate, or cover, hard or sparking tools and surfaces.
  - = Control electrostatic buildup and discharge.
- Consider the potential for problems with the chemistry of pyrotechnic materials.
  - = Learn and avoid sensitive chemical combinations.
  - = Keep work areas and tools clean to avoid chemical contamination.
  - = Monitor for signs of heating or chemical reactions.
  - = When appropriate, use non-aqueous binders.
- Address personnel issues relating to accidents.
  - = Do not work when tired or distracted.
  - = Think and plan activities in advance.
  - = Do not improvise.

In pyrotechnic manufacturing, the importance of minimizing the risk of accidental ignition is obvious. However, the risk of toxic hazards is sometimes given too little attention. For a chemical agent to produce a harmful effect, it must enter the body through ingestion, inhalation, or absorption into or through the skin. The response to toxic hazards typically fall into one of two categories: acute or chronic. An acute response is generally a relatively immediate reaction to exposure to a chemical toxin; and, assuming survival, the response is normally of limited duration. For example, the diarrhea produced by barium poisoning will occur within a few hours of exposure and will persist for a couple of days at most. This is in strong contrast to a chronic response, which may only manifest itself after a prolonged delay and persists indefinitely. For example, the cancer that may result from the use of some smoke dyes may not develop until decades after the initial exposure and may progress with fatal consequences. The control of toxic hazards should follow the same basic strategy described above. Efforts should be made to minimize probability and consequences of exposure. We have prepared a Safety Rating System for Pyro-Chemicals, based on the J.T. Baker, Inc. system. Anyone may obtain a copy of this list of chemicals with Health, Flammability, Reactivity and Contact Hazard Ratings by sending a self-addressed, stamped envelope to K. L. Kosanke, 1775 Blair Road, Whitewater, CO 81527. [A copy is included at the end of this article.]

The hazard management process discussed above for fireworks manufacturing can be applied to fireworks displays and even to the use of consumer fireworks. These will not be discussed in detail here; however, a few examples are given below as illustrations:

Fireworks Displays:

- Consequence minimization:
  - = The crew's use of personal safety equipment.
  - = Spectators kept at NFPA separation distances.
- Probability minimization:
  - = Performing shell inspections shortly before use.
  - = Keep ready box covered and up wind.

Consumer Fireworks:

- Consequence minimization:
  - = Provide complete user directions like "Do not light with body over fireworks."
  - = Do not store inventory in massive amounts at one location.
- Probability minimization:
  - = Do not sell items that have a history of malfunction or misuse.
  - = Use only low temperature sealing methods for assortment packs.

It is difficult to over estimate the human and economic cost of a serious accident. Many hazard management measures are cheap and easy to implement; obviously these should be applied immediately. Others may be expensive to implement, especially if modification of an existing facility is required. For these, a cost benefit analysis may be necessary, and these may require more time before being fully implemented.

References

1) R. Green, "Booms, Bangs and Debris: A Rocketeer's Primer on Safety", Idaho PGI Convention, 1992.

2) W.W. Lowrance, *Of Acceptable Risk*, William Kaufmann, Inc., 1976.

SAFETY RATING SYSTEM FOR PYRO-CHEMICALS

0 = None,
1 = Slight,
2 = Moderate,
3 = Severe, and
4 = Extreme.

The safety ratings are given for four areas of hazard concern:

H = Health is danger or toxic effect a substance presents if inhaled, ingested, or absorbed,

F = Flammability is the tendency of the substance to burn,

R = Reactivity is the potential of a substance to explode or react violently with air, water or other substances, and

C = Contact is the danger a substance presents when exposed to skin, eyes, and mucous membranes.

Description	H	F	R	C
Accroides Resin (red gum)	1	2	0	1
Acetone (nitrocellulose solvent)	1	3	2	1
Aluminum (400 mesh flake)	1	4	2	1
Aluminum (325 mesh, granular)	1	3	2	1
Ammonium Dichromate	4	1	3	3
Ammonium Nitrate	1	0	3	2
Ammonium Perchlorate	1	0	3	2
Anthracene	1	1	0	1
Antimony Trisulfide (325 mesh)	3	3	2	1
Barium Carbonate	1	0	0	1
Barium Chlorate	3	0	3	1
Barium Nitrate	3	0	3	1
Barium Sulfate	1	0	0	0
Benzene	4	3	2	1
Boric Acid	2	0	0	2
Cab-o-sil (colloidal silica)	2	0	0	1
Calcium Carbonate	0	0	0	1
Calcium Sulfate	1	0	0	1
Charcoal (80 mesh)	0	1	0	1
Charcoal (air float)	0	2	0	1
Chlorowax	2	1	1	1
Clay (bentonite, very fine powder)	1	0	0	0
CMC (sodium carboxymethyl-cellulose)	1	1	1	1
Copper (II) Carbonate (basic)	2	0	0	1
Copper (II) Oxide (black, cupric)	2	0	0	1
Copper Oxychloride	2	0	0	1
Copper (II) Sulfate (cupric)	2	0	0	2
Cryolite	1	0	0	1
Dechlorane	2	1	1	2
Dextrin (yellow)	0	1	0	0

Description	H	F	R	C
Gallic Acid, Monohydrate	1	1	0	1
Graphite (325 mesh)	1	2	0	0
Hexachlorobenzene (HCB)	2	1	1	1
Hexachloroethane (HCE)	2	1	1	1
Hexamine (hexamethylenetetraamine)	1	1	1	1
Hydrochloric Acid (Concentrated)	3	0	2	3
Iodine, Sublimed	3	0	2	3
Iron (II) Oxide (black)	1	0	1	1
Iron (III) Oxide (red)	1	0	1	1
Isopropanol (isopropyl alcohol)	1	3	1	1
Lactose	0	1	1	0
Lampblack (oil free)	1	2	0	1
Lead, Granular	3	0	0	1
Lead Dioxide	3	0	3	1
Lead Nitrate	3	0	3	1
Lead Oxide (red, minium)	3	0	1	1
Magnesium (200 mesh)	1	3	2	0
Magnesium (325 mesh)	1	4	2	0
Magnesium Alum. 50/50 (gran., 100–200 m.)	1	3	2	1
Magnesium Alum. 50/50 (gran., 200–400 m.)	1	4	2	1
Magnesium Carbonate	1	0	1	0
Manganese Dioxide	1	0	1	1
Methanol (methyl alcohol)	3	3	1	1
Methylene Chloride	3	1	1	2
Mineral Oil	1	1	0	1
Nitric Acid (Concentrated)	3	0	3	4
Nitrocellulose (lacquer 10% solution)	1	3	2	1
Paraffin Oil	1	1	0	1

Description	H	F	R	C
Parlon (chlorinated natural rubber)	2	1	1	1
Phosphorous, Red	0	2	2	2
Picric Acid, Crystal	2	2	2	2
Polyvinyl Chloride (PVC)	2	1	1	1
Potassium, Lump	3	3	3	4
Potassium Bicarbonate	1	0	1	0
Potassium Chlorate	1	0	3	2
Potassium Dichromate (fine granular)	4	0	3	3
Potassium Hydroxide, Pellets	3	0	2	4
Potassium Nitrate	1	0	3	2
Potassium Perchlorate	1	0	3	2
Potassium Permanganate	2	0	3	2
Potassium Sulfate	1	0	0	0
PVC (polyvinyl chloride)	2	1	1	1
Red Gum (accaroides resin)	1	2	0	1
Shellac (–120 mesh, orange)	1	2	0	1
Silica (fumed-colloidal, Cabosil)	2	0	0	1
Silica Gel (60–200 mesh)	2	0	0	1
Silicon Metal Powder (325 mesh)	2	3	1	1
Silver Nitrate, Crystal	3	0	3	3
Smoke Dye	1	1	1	2
Sodium, Lump	3	3	3	4
Sodium Azide	3	2	3	2
Sodium Benzoate	1	1	0	1
Sodium Bicarbonate	0	0	1	1
Sodium Carboxymethylcellulose (CMC)	1	1	1	1
Sodium Chlorate, Crystal	1	0	3	1

Description	H	F	R	C
Sodium Cyanide, Granular	3	0	2	3
Sodium Hydroxide, Pellets	3	0	2	4
Sodium Nitrate	1	0	3	1
Sodium Oxalate	3	0	1	2
Sodium Salicylate	1	1	0	1
Sodium Silicate (water glass, liquid)	1	0	0	2
Sodium Sulfate	0	0	0	1
Starch, Soluble Potato	0	1	0	1
Stearic Acid	1	1	1	1
Strontium Carbonate	1	0	0	1
Strontium Nitrate	1	0	3	1
Strontium Sulfate	1	0	0	1
Sulfur (flour)	1	1	0	1
Sulfuric Acid (Concentrated)	3	0	3	4
Talc, Powder	1	0	0	1
Tetrachloroethane	3	0	1	2
Tin, Granular (20 mesh)	0	0	0	1
Titanium Metal Powder (100 mesh)	1	3	2	1
Titanium Metal Powder (300 mesh)	1	4	2	1
Titanium Tetrachloride	3	0	2	3
Trichloroethylene (Stabilized)	3	1	2	2
Water	0	0	1	0
Zinc Metal Powder (dust)	1	3	2	1
Zinc Oxide	4	0	3	3