

# **HAZARD ASSEMENT AND ACCIDENT PREVENTION AT UNUSUAL SHOOTING SITES FOR DISPLAY FIREWORKS**

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Author's note: Some of the comments herein imply that there are laws governing some of the items I have written about. OSHA and various State Labor and Industries laws and "Work Rules" vary widely. Readers are cautioned to be responsible enough to know the laws and work rules of the area in which they are operating. Nothing in this document should be construed as being in opposition to NFPA 1123. It is strongly recommended that the precepts of 1123 should be followed with any fireworks display.

In the last several years there have been a number of incidents/accidents in which technicians working on fireworks displays have been injured or killed. Perhaps the guidelines contained here will help reduce these incidents. This document is written primarily for the "pyrotechnician in charge", but should be useful to management and all those who work on display fireworks.

## GENERAL GUIDES PERTAINING TO ALL SITES

Hazard assessment and safety evaluations generally include:

- Reduction of exposure
- Reduction of mass
- Evaluation of the number of persons
- Exposure time
- Distance.

A good communications interface between the pyrotechnician and management and/or the person who designed/sold the display is essential to the safe completion of a display. This is especially important in unusual shooting sites. Preview the site if possible before the day of the show. Arrive early, hours before the crew. Walk the site and note possible hazards. Make written notes of hazards so you can relate them to your crew. Layout the show as you walk and watch for hazards created by your layout. Develop some kind of safety plan for the show/site with hazards listed. Hold a safety meeting before work starts, of sufficient length to cover the hazards present. Hold another brief meeting just before the display to be sure all that will be present understand their job and the hazards present.

## BARGES

Start here when you get out of the truck. Look at the barge. Where is it docked and how is it situated. Sometimes it is located at the end of a system of docks, ramps, other barges, or may be anchored offshore. Look at the dock, will it support your vehicle? If there isn't a load limit sign, and you are unable to definitively determine the limit, never assume. If there is to be a crane used for the loading of material on your barge, let the Crane Company or its operator direct the placement and operations of the crane. Caution: in many areas cranes used in marine service must be certified for that use.

Examine any ramps or gangways. Are they load-worthy? Or does the board nearly break when you cross it with no load? Is it tied down so that it can't move with use, or fall in the water? Dropping a man between two vessels, or barge and dock can be very dangerous. Even small barges or other vessels only have to move a few inches to crush a person.

Other problems with ramps or gangways can happen in tidal waters. If not properly secured, the ramp can drop with the tide and fall at one end or the other. As the tide rises, the ramp can catch on the dock or barge and "pop" loose. Even moving only a few inches it has more than enough force to crush a foot, ankle or leg.

Before boarding the barge, look around you, note power lines or "working" lines that may present problems. Some docks can have as much as 480 volts or more for "shore supply power" for ships or other marine equipment. There may be radar left running on a vessel that may interfere with your communications. Some very powerful military radar may be able to cause problems with electrical igniters. If you are not sure about what you see, ask. If information is unavailable get the barge moved before working on igniters and electrical firing systems. "Working" lines or docking lines can look harmless until a vessel of some sort ties up next to your barge. Be aware of what may be going on around you.

As you board the barge note what the surface looks like. Is it flat to the edge? Does it have a rail of some kind? Or, does the edge of the barge slope off to the vertical? Is the surface of the barge steel, wood, or asphalt? Are there "pad eyes" (rings for tying down cargo) or other tripping hazards? Some barges may have round or square holes about a foot deep with a pad eye in the bottom. These can be ankle-breakers. Wood decks can be very rough and provide tripping hazards. Steel decks with sand or petroleum product spills can cause slipping/falling hazards that can result in sprains or broken bones. Falls happening with shells with igniters attached can provide additional hazard.

If there is no railing on the barge, "work rules" generally say persons working within 3 to 6 feet of the edge must have a PFD (personal floatation device) and/or a harness and tether on and secured. If you rig some kind of safety rope railing, be sure it meets the requirements of the "work rules" in your area. When the barge is in motion and not tied

to a dock it is likely “work rules” may say that all persons aboard must be wearing a PFD. Common sense, Coast Guard Regulations, and/or local laws, require that during firing of the display all persons aboard the barge MUST be wearing a PFD, period. Many local “work rules” may also require a “throw ring” with 100 feet of rope attached to be present on the barge during all work activity. Workers should be cautioned that when close to the edge of any vessel it is “one hand for the job and one hand for your safety”. It is not “chicken” to hold on.

As you look over the barge, note if there is a ramp at either end. If others haven’t already decided it, you decide where the tug will be during towing and firing. If possible, discuss it with the tug captain, or the Port Captain for the tug company. The most common way seems to be, to tight-line the barge on a couple hundred feet of tow wire. Depending on the size of the barge and the display configuration, the tug may stay tied to the stern or one side. The best is to be tied to two anchors so that the barge is held in position. Next would be 2 tugs on tight-line at opposite ends. Some displays can be fired over the bow with the tug at the stern, backing into the wind with only enough turns of the propeller to maintain steerage. Thus the display is fired downwind and away from the tug. The important thing is to know how the tug will work before you set up the display.

As you walk over the deck of the barge, look for hatches and manholes and be sure they are secure. If there is a hatch or manhole open, it must be covered. Do what you have to do, but get it covered. Aside from one of your crew falling in, you cannot take a chance in letting fire fall into the bilges, cargo tanks, or, floatation tanks. You have no way of knowing what has been in those recesses. It may be flammable or explosive. If the barge has been hauling any flammable substances in cargo tanks, there should be a “Marine Inspection Certificate” issued by a “Licensed Marine Engineer” that certifies the barge is safe for your use. There may also be construction, or other equipment on the barge. There may be materials left on board. This is not uncommon, particularly with small construction company barges. This material and equipment must be carefully inspected for hazards. These hazards must be dealt with, or compensated for.

If your barge is small or has very little freeboard (distance from the deck to the water) you may have to plan for some kind of protection to keep the water from washing over the pyro materials. If the water is going to be rough be sure to leave the dock in plenty of time to go slow enough to keep waves from washing over the bow and drowning the display.

Now that you are thoroughly familiar with the vessel and its hazards, that you are going to use as a platform to set off explosives, you can lay out your display. Is your display going to be hand fired? Reload? (reloading on barges or floating platforms is now forbidden by the US Coast Guard and NFPA 1123). Electrically fired? If hand fired the display must be laid out with safety routes for escape from a pyro related incident. Remember that depending on the barge and the show configuration, there are a limited number of places to shelter and/or to get away. You must provide for the safety of your

crew, they are your responsibility. Hand fired displays should be laid out so the shooter works down the length of the barge.

He/she should not have to walk between rows that place him in a position with loaded mortars pointed at him. At the same time he/she has to have an escape route. Do not place him/her in a position where there is no place to go if something goes wrong. Crew and audience safety is foremost.

If your display is electrically fired, a shelter should be provided for the persons firing the display. This shelter should provide reasonable protection in case of a detonation. While a fire pump is probably not necessary (except perhaps on old wooden barges) there should be several pressurized water extinguishers available to the firing crew. It is strongly recommended that all persons except the required minimum crew be taken off the barge during the firing of the display. Generally, 3 persons should be enough to fire any display. One is the shooter, the second is his/her assistant and the third is a safety person with a fire extinguisher. If there is an exception for very large barges needing two shooters, then it is recommended both have a safety person with a fire extinguisher.

When loading equipment aboard the barge use wheelbarrows and hand trucks as much as possible. This is not only easier on the workers but is generally safer as there is less tripping and stumbling. If any items are being put aboard with a crane, all persons aboard the barge or in the proximity of the hook-up/pick-up point must wear hard hats during crane operation. Only experienced persons should be handling, or setting “chokers” or load bearing chains or slings. Work rules in some areas may be very strict in this matter.

In some instances where there is a high dock and a low barge, and the dock will support the weight of the truck or semi-trailer, a chute may be used to slide equipment down to the barge deck. The chute must be securely fastened to prevent movement or dropping. Persons working on the barge deck at the lower end of the chute are to work at the side of the chute, NOT at the bottom. The angle of the chute should be kept at the minimum necessary to allow equipment to slide down slowly. Boxes of pyrotechnic materials SHOULD NOT be allowed to slide down any chute.

All pyrotechnic materials must be loaded onto the barge carefully and protected from harm. It will reduce your exposure if you can stack the pyro materials in small, well-separated stacks on the barge. If machinery is running on the barge, such as a loader for moving sand, care must be taken to avoid running into the pyro materials, and to avoid getting into a position where sparks or flames from the exhaust can in anyway endanger them. In keeping with good safety habits, carry boxes or use a hand truck. Do not “scoot” them as this may generate friction, which should be avoided. Do not carry more than can be safely handled by an individual. Avoid trying to carry several shells piled in your hands. Dropping one can be very dangerous. One shell in each hand should be the rule. There should be NO SMOKING anywhere on the barge. BBQ grills are not a good idea on a fireworks barge. Large bore mortars, (8 through 24 inch) should be located at the furthest point from the firing position. All large bore mortars must be fired electrically.

With so many things going on around an average waterfront area it is even more important to be sure to keep igniter leg wires shunted until actual hook-up to the firing system. Remember that on many barges there is no place to hide or duck behind and with some having high sides there may be no place to run. The pyrotechnician in charge, and all onboard need to be ever vigilant for safety. The pyro in charge needs to be constantly moving about the barge carefully watching every phase of the display and on the lookout for existing hazards, and those generated by the set-up activity.

One important feature of barge displays is not on the barge. It is the patrol craft in the water. No matter how small your display or how few the spectators, some kind of patrol craft is essential. It is nearly impossible to get a reluctant or confused boater to move out of the safety zone by yelling to him from the barge. You can also use the radar on the tug to help correctly position the barge for the display. As in all displays, wind direction as well as size and kinds of pyro products must determine the size of the safety zone. If your display is in navigable waters be sure to notify the Coast Guard of your show time. The Coast Guard may require a "Marine Event Permit". All permits and licenses should have been handled prior to the show date.

Displays fired from small floating docks and swimming platforms require special consideration. Just the size of the platform can tremendously exacerbate any and all hazards. The numbers and sizes of any pyrotechnic materials must be reduced to that which can be fired safely. Use the formula from NFPA 1123 for safe results.

Again, the number of accidents/incidents causing injuries and fatalities are the primary cause of the present discussions that may result in severer restrictions on all displays fired from any floating platforms. The pyros in charge of displays fired from any floating platform should heed this and be sure their safety standards will be sufficient for the situation.

## BUILDINGS

Display fireworks fired from buildings require careful consideration of not only the building you are on but any other buildings in what might be the safety zone. Many of the hazards mentioned here may apply to all of the buildings in the safety zone or down wind.

In assessing the shooting site buildings plan for a big enough safety zone to allow for the often-changing winds that can be encountered in cities. Even light breezes can swirl around neighboring buildings and suddenly change direction. Direction of the winds can change as you move up the side of a building depending on the weather and the shape and height of the surrounding structures. On very tall buildings of 300 to 500 feet or more, wind at the top can be blowing several times more severe than at the ground level.

While spectators always seem to want to be as close as possible, the best view of a display fired from a building is often several blocks away. A good advertising program stressing that can relieve the crowd pressure at the base of the building. Some displays are designed to attract spectators to the building. In that instance the prudent Display Company will hire a fence to be installed around the base for a safety zone. This zone can be cleared before actual firing time.

Even with such a safety zone at the base the prudent Display Company will carefully consider what product to fire overhead. Items such as mines, candles, comets, fountains, strobes, and illuminations may be a wise choice for this kind of display. If shells are to be fired in this kind of display setting a safety zone 3 to 5 time the normal distance or more may be prudent. A shell falling several hundred feet more than its original design can move a long way in the wind, and if defective may strike the ground or other surfaces at a comparatively higher velocity than normal.

As you survey the building from the outside, make note of surfaces that may have to be protected from the possibility of being showered with burning material. This can include decks, balconies, roofs of lower floors, as well as the primary roof you are firing from. Additionally there may be surfaces that should be protected from the blast effects of the mortars and certainly from possible detonation. Some building roofs are complicated sets of stairs and platforms and the actual surface of the roof may be hard to get to. These areas especially must be protected from fire. Perhaps leaving a sprinkler running during the display will suffice. The prudent display planner and the pyro in charge will confer with the building engineer, and fire inspection on how to best avoid problems.

As you get into the elevators to go up to the top of the building make note of the location of the freight elevators and their access areas. Discuss with the building engineer the load capacity and availability of the freight elevators. While equipment may be moved any time the freight elevators are free for that use, pyrotechnic materials should only be moved in the early hours of the morning when the building is essentially unoccupied. If you are moving pyro materials with igniters attached, double check that the leg wires are securely shunted. There can be a considerable numbers of electric cables in a shaft of several elevators. Voltages of 480 volts are not uncommon.

Many freight elevators do not go all the way to the roof. Equipment must be carried or hand trucked to the firing position. Make careful note of this passage and how much room you may have to move equipment. Under some conditions some equipment may have to be modified or even new equipment may have to be specially designed. With buildings of only a few stories equipment may be hoisted to the roof or set up with a high-reach forklift. Any hoisting equipment should strictly comply with the requirements of prevailing work rules. Only experience persons should be setting chokers or load slings. All persons in the proximity of the hoisting operation must wear hard hats.

As you walk out on the actual roof of the building note whether there is a parapet wall around the roof. If there is not a parapet wall is there a safety rail? Note what the surface of the roof is made of. The roofs of some buildings are a virtual maze of ladders, stairs, grates, walkways, and machinery. Use caution around intake and exhaust fans as this equipment can start automatically. If a window washer track is present, consult the building engineer about the schedule of its use. The moving hoist and travel machinery can provide additional hazards.

Moving about the roof of a building requires a constant awareness of safety. The many tripping, falling and bumping hazards are everywhere. Many ladders are steep and cannot be used carelessly. Additionally there are many sharp edges that will cut or puncture not only pyrotechnic materials, but also skin. Handling pyrotechnic materials under these conditions requires experienced, careful, technicians that have been thoroughly briefed on the set-up and safety.

In planning for the firing of display fireworks from the roof of a building careful note should be made of all of the equipment and electrical wiring on the roof. Care must be taken that to the extent possible smoke should be kept away from the intake of the air handling system. Large quantities of smoke can cause real problems in the interior of a building. Not the least of which is tripping the smoke alarm, which may call the fire department and shut down some electrical power systems. Since control of smoke is difficult in a wind, some can be counted on to enter the intake. Arrangements should be made with the building engineer and the fire department for a temporary by-pass of the alarm mode for the duration of the display.

One additional caution in firing from buildings. You should confirm with the manufacturer of your digital firing system that neither the digital controls of the elevators and other machinery or high voltage wiring that can be found on the roof would not interfere with your firing system.

## BRIDGES AND OTHER STRUCTURES

Because of the difference in these kinds of displays sites each needs to be individually assessed for hazards. These kinds of displays can present unique opportunities and problems as well as personnel hazards. Frequently a high percentage of the set-up can require the use of full body harness and tether. Falls from these structures can result in serious injury or death. Proper safety planning and engineering are essential to the success of the display. All plans for safety, and the development, installation, and firing of the display should be discussed with local Fire Inspectors, structure owners as well as competent safety authorities.

Safety meetings with all workers is a must All workers should receive full briefings on what is to take place and how it is to be accomplished. Full instruction must be given on all safety gear. Continuous management supervision is mandatory on this kind of project.

Bridges and other open high structures often have winds to consider. These winds which can be severe at times and when mixed with rain, snow or ice can provide extreme danger. Complexity of the apparatus and installation should take this into consideration.

If there are persons or vehicles passing below the work in progress all tools and loose gear must have tethers to prevent them from falling. All apparatus must have safety cables securing them to the structure.

Comets should have enough lift and a short enough burn time to insure a complete burning cycle before reaching the ground. Illuminations or strobes should be placed in holders that will prevent dross from falling or dripping. Mines should be specifically constructed for this type of display.

As in all displays consideration should be given to structure electrical systems causing possible problems electrical igniters or firing systems. The safety zone should allow for the location of spectators, height, and direction of firing, winds, and pyrotechnic content.

### **MOUNTAINS, GENERAL**

The term mountains as used here refers to areas around resorts, church camps, Scouting and other youth organization camps, and areas around public access to lakes and scenic areas. Additionally Ski areas and winter carnivals can attract large crowds and frequently, fireworks.

### **MOUNTAINS, SUMMER**

As in most displays the first part of the hazard assessment for a display in the mountains is fire. Close cooperation with the local fire authority is the first step in the display sale and design. Planners should be aware that fire conditions can change rapidly with the weather and seasons and the site may be quite different the day the display arrives then it was several months before when the sale was made.

While displays in metro areas may have reasonable access to first aid, or hospitals, sites such as being discussed here may not have this accessibility. A first aid kit meeting the minimum requirements of the local work rules and at least one person with a current first aid or first responder's card should be present.

In some areas certain life forms such as snakes, insects and plants, can present mild to severe hazards to persons working on a display. Display planners and pyros in charge should ask what might be present and brief all of the work crew before work begins.

Persons having allergies to any plants or insects that may be present should be prepared and equipped to cope with contact, stings, or bites, or, perhaps should not be working in the presence of such hazards.

Some consideration should be given to rockslides, rock outcroppings or other potentially unstable features that endanger spectators, display, buildings or crew. Frank discussions should take place with those persons who are familiar with the local geology. The possibility that vibrations of salutes or lift charges may cause rocks or other materials to loosen and slide or fall should be discussed. This potential should be included in display design considerations.

Winds swirling around the various features of the terrain can be difficult to predict. Pyro materials with parachutes should not be used.

Some firing sites can be close to the edge of a cliff, somewhat above the spectators. A safety rope or railing that meets or exceeds the requirements of the prevailing work rules should be set up at the proper distance from the edge. All persons working closer than that to the edge should be in harness and firmly tethered. The anchor point for the tether must also meet the requirements of prevailing work rules. Care should be taken not to dislodge rocks or other materials that may endanger those below. If this is not possible then there cannot be any persons below the work zone. Firing in steep areas can require the special bracing of mortar racks and other display items.

### **MOUNTAINS, WINTER**

Displays in mountain areas in the winter will have to deal with snow, wet, and cold. While some areas are little different from summer, for purposes of this discussion we will presume cold, wet and snow will be present.

As with summer displays, those in winter in any remote areas should have first aid kits and at least one person with a current first aid card present.

Displays in the mountains in the winter can present several unusual hazards. Driving placarded trucks in winter requires special care and skill. Trucks should leave early enough to allow for winter delays. Tire chains should be carried without fail. Co-drivers are a good idea if the trip is more than 3-4 hours.

All crew should be briefed and prepared for the weather conditions at the display site. At least one person should be familiar with the signs of hypothermia and its treatment. Clothing should be worn in layers so that it can be removed or added as the weather changes.

Winter winds in mountainous terrain can be widely variable and may swirl around the site changing several times a day. Display design must take this into account. The spectator areas may include the entire ski slope, which is usually not shut down during the display. This may force the firing site to a remote area. Even while so near a resort it can be surprisingly easy to become separated from the rest of the crew. In snowing and blowing conditions a lost crew member can happen. All crew should be briefed against wandering off.

Frequently, equipment, pyro materials and crew are transported from the parking lot to the firing site in snow cats. Care should be taken when loading the pyro materials into the cat. They should be separated from heaters and exhaust systems as much as possible. The boxes should be sheltered from sparks or flames from the exhaust. Sharp corners and edges may cut into the boxes and damage contents. Loads should be secured against falling as the slope may be steep.

It should be recognized that skiers, snowboarders, and snowmobile riders may wander from normal trails and into the fallout zone, or approach the actual firing point. Lookouts should be posted to prevent this.

Running the snow cats should pack the snow under where the mortars will be placed down over it several times. This will help prevent the racks being driven into the snow.

Detailed discussion should take place with the ski patrol about the possibility of avalanche. Salutes or other display noise may cause loose or overhanging snow to move. Ski slopes are usually kept clear of this hazard, but the area above the firing site may not be.

After the display the pyro in charge should count heads to be sure all crew are off the mountain. All crew should be checked for possible hypothermia before leaving that night.

## **AIRCRAFT**

The number of aircraft using pyro materials has grown considerably in the last few years. Aircraft types using pyro range from the small experimental, to bi-planes, to helicopters, to many types of turbine power, both military and civilian. Materials are used both day and night, and range from simple smoke to complex custom designed candles, mines and comets, and fountains.

Because of the wide variety of product and aircraft we will deal with the use of pyro materials in general recommendations and the prudent pyro will apply this as he sees that it will fit the situation.

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While aircraft/pyro related incidents have been few in number, some hazards associated with the use of pyro on aircraft may include the following:

- Accidental ignition of pyro on the ground, in hangers, fueling areas, crowded air show displays areas, or among other parked aircraft.
- Dropping burning materials on the ground, buildings, animals, persons, or airport or other facilities causing fires and/or explosions.
- Damage to aircraft flight controls.
- Damage to power plants (engines).
- Damage to aircraft fuel systems or tanks.
- Damage to aircraft electrical systems.
- Damage to avionics.

When viewed from the position of maximum credible, any of the above can cause anything from a scary situation to a full scale disaster. The normal one to two million dollar liability policies carried by most pyrotechnic companies can look very small indeed when faced with any of the above.

Some solutions to help the prudent pyrotechnician avoid hazards such as these are:

- Aircraft owner, pilot, and crew must all have an excellent safety attitude.
- Aircraft owner should be willing to invest what it takes to do it right.
- Specials firing systems, and special holding apparatus for holding the pyro materials should be willingly built and properly installed.
- Aircraft pilot and crew should be totally trained in all facets of transportation, handling, storage, as well as the firing of all items to be used.
- Owner should be willing to obtain a magazine, BATF and any state licenses required.
- Use only items like candles, comets, fountains, and mines. Shells are not recommended.
- Pyro materials should be used only in the manor for which they are designed.
- HOLDERS for pyro materials should be aerodynamic and should completely shield the aircraft in the event of a detonation.
- The point at which the pyro materials are carried should be kept away from areas containing fuel tanks, and aircraft electrical or flight controls.
- Firing systems should be separate, and isolated from all aircraft electrical systems.
- During, and after loading the aircraft with pyro, it should be parked in an area outside the other craft on display, pointed in a safe direction and isolated from close approach by spectators.
- For added protection against unwanted ignition there should be a positive disconnect of the pyro from the firing system. It is suggested that this should be located at the pyro holder mounting point, and should be plugged in by the ground crew only when the aircraft is in takeoff position on the runway.

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A method of positive ignition must be developed for each type of pyro used, so that it will always ignite under the conditions of flight. G forces and wind can make ignition difficult, especially at speeds of 500 or more MPH in a military turbine powered aircraft. Generally, several pieces of black match will suffice, packed in around the ignition fuse and held in place and sealed from the wind by wide clear tape such as that used to seal moving cartons.

All systems should be tested under flight conditions, more than once to insure that all is working as designed.

All of the above may certainly seem like too much to go through. However, the prudent pyro will remember that when that aircraft takes off, you will have no control whatsoever. When that aircraft is across the country from you or possibly in another country, that aircraft, pilot, pyro materials, and crew must safely function every time, all the time. You will have NO control and other than advice on the phone, you will have no effect on the results.

### **FINAL COMMENTS**

The act of being safe in pyrotechnics must come from the attitude of the individual. That attitude should be cultured and developed by both the individual and from the leadership of those in charge of displays, and from the display companies. From training, experience, good leadership, and example, the display pyrotechnician can achieve, keep, and practice good safety habits.

Learning to seek the advice of those experienced in pyrotechnics, and, of professionals educated and skilled in their various disciplines is a lesson that should be earned early. Part of the process of gaining maturity as a pyrotechnician in addition to the learning about pyrotechnic materials, is the recognition of ones own limits and seeking proper help as needed. The assessment and recognition of hazards in unusual shooting sites with the help of the experienced and the professional is certainly a sign of maturity.

J L M 2007