MIFACE INVESTIGATION: #03MI080

SUBJECT: Pyrotechnician Dies When Struck in Head by Firework While Putting on a Display

Summary

On July 3, 2003, a 41-year-old male independent fireworks "shooter" and the "pyrotechnician in charge" of a fireworks display died when he was struck in the back of the head by a firework shell. The display was set up in a gravel pit that had three "levels" with shells placed and lit at each level. The deceased used a propane torch to manually light his zone of shells on the lowest level. He lit the first round of shells to start the show, then climbed up a hill and directed his assistants at the middle level to light their shells. He left them and they lit their zone of shells. One of his assistants working on the middle level had been instructed to light a "cake" on the lowest level. The assistant slid down the hill from the middle level to the lower level and was walking to the "cake" and stumbled upon the deceased. The deceased was lying in the sand with his head partially in the water and his legs pointing in the general direction of two 4-inch empty mortars buried at an angle in the sand. The deceased's flashlight was in his shirt pocket and he was not wearing a hard hat. He did not have a spotter or communication device. His earmuffs were approximately 20 feet away; the right earmuff was not attached to the muff's head strap. The assistant ran up the hill and notified the on-site emergency response unit. The show was stopped and the deceased was declared dead at the scene. Autopsy results showed a blood alcohol level of 0.246% and an antidepressant in his bloodstream.

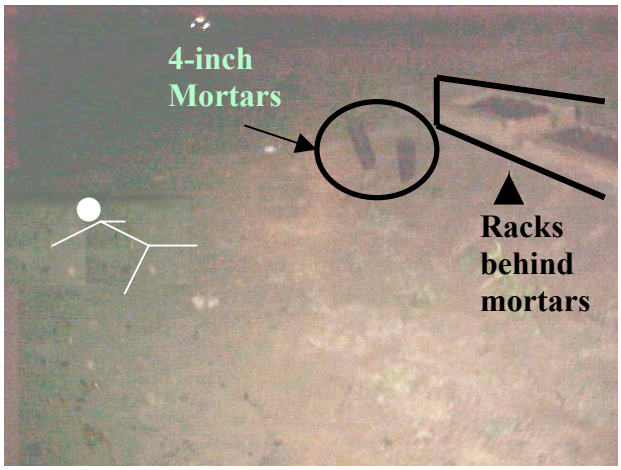

Figure 1. Incident scene with approximate location of deceased

RECOMMENDATIONS

- Do not drink alcoholic beverages while handling or discharging fireworks.
- Bury mortars in the ground to a depth of at least ⅔ to ¾ of their length and ensure they are appropriately angled, prevented from being driven into the ground or re-angled when fired.
- Cover mortars with plastic wrap or with biodegradable material to prevent sparks from other display materials dropping into them and causing pre-ignition and to protect them, if necessary, from adverse weather conditions.

Keywords: Fireworks,
Pyrotechnician, Display Operator

- Light all fireworks at greater than arm's length with an appropriate lighting device, such as a portfire.
- All personnel working in the display area should wear appropriate clothing and personal protective equipment.
- Ensure members of the shoot team can communicate with each other.
- Have an appropriate number of trained "spotters" at a display site.
- Consider using non-incendive lighting devices to illuminate the shell's fuses.
- Ensure that all assistants are fully trained in the proper performance of their assigned tasks.
- Authorities having jurisdiction (AHJs) should be properly trained to identify display-site violations and ensure that appropriate corrections are made before allowing the shoot to proceed.

INTRODUCTION

On July 3, 2003, a 41-year-old male independent fireworks "shooter" and the "pyrotechnician in charge" of a fireworks display died when he was struck in the back of the head by a firework shell. On February 24, 2004, MIFACE researchers interviewed the deceased's father and sister. During the course of writing this report, the medical examiner's report, death certificate, police department report and pictures taken at the scene, and the Michigan Occupational Safety and Health Administration (MIOSHA) citations were obtained.

MIOSHA issued two "Serious" citations to the employer. Serious citation #1: The employer failed to provide a safe workplace and employment free of recognized hazards by allowing employees to manually shoot a fireworks display without taking adequate precautions and exposing employees to severe burns, detonations, deflagration, and death by being struck by the fireworks display. The employer failed to: (a) enforce the use of appropriate personal protective equipment – eye and face protection, foot protection and head protection at the discharge site, (b) require and utilize one or more "spotters" to observe the flight and behavior of shells at the discharge site, (c) provide and use adequate communication means and devices among the employees at the discharge site, (d) provide and use adequate non-incendiary illumination devices at the discharge site, (e) assure all assistant "shooters" were trained in the hazards, procedures, and safeguards while working at the discharge site, and (f) assure that employees under the influence of alcoholic beverages were not allowed at the discharge site. Serious citation #2: The employer did not assess the workplace to determine if hazards that necessitate the use of personal protective equipment are present or are likely to be present, enabling the selection of appropriate equipment. MIOSHA also issued an "Other" citation that stated that the employer failed to report the death of the deceased to the Michigan Department of Consumer and Industry Services within 8 hours.

The deceased had full-time employment unrelated to fireworks. He worked part-time as an independent "shooter". He was the both the "operator" ("pyrotechnician in charge") and lead "shooter" for the evening's fireworks display. The deceased was experienced in the many aspects of planning, installing and lighting off numerous displays and had been involved with fireworks displays for the last seven years. According to his family, he had a "passion" for fireworks, and had been to many Michigan Pyrotechnic Guild meetings and club shoots. He had attended Pyrotechnics Guild International (PGI) "shooter" safety course and had received certification as a lead "shooter". The deceased's family indicated that he had worked for seven years as a "shooter" without injury.

The show's sponsor was the developer of a residential community and was hired to coordinate all aspects of this firework display. Due to revised regulations from the Bureau of Alcohol, Tobacco and Firearms (ATF), the deceased was unable to obtain his ATF permit to purchase the fireworks in time to shoot the show. For the past four years, the deceased was a regular customer of a company that sold pyrotechnic supplies. This company submitted paperwork to the ATF on the deceased's behalf, which allowed him to purchase fireworks as their employee. The company also placed the deceased and three of his assistants working the evening of the incident on their worker's compensation policy. By placing the deceased and his assistants on their worker's compensation policy, MIOSHA considered the company to have "hired" the deceased and his

assistants. MIOSHA deemed that the company was the "employer" for the deceased and his three assistants and thus were issued the citations.

INVESTIGATION

The residential community that was the site of the display was built around a water-filled gravel pit. The gravel pit area had three "levels" with fireworks at each level. The beachfront was sandy. Due to the configuration of the gravel pit, the deceased could not be seen nor could he see individuals working on the other levels.

Several days prior to the shoot, the deceased met with the authorities having jurisdiction (AHJs); township supervisor, police chief and fire chief, to obtain the appropriate permits. On the morning of the show, the deceased and two friends arrived at the discharge site between 9:00 a.m.-10:00 a.m. to set up the display and load the mortars. The display consisted of shooting 2 ½-inch to 10-inch shells. The eight-inch and ten-inch shells were located on the upper level of the gravel pit and would be electronically fired by a licensed "shooter" who worked for the company hiring the deceased and his assistants. The 2 ½-, 3-, 4-, 5-, and 6-inch shells would be manually ignited, and were located on the lowest level (beachfront) and middle level of the gravel pit. The local fire authority inspected and, after the deceased fixed a rack, gave permission for the show to proceed. The fire authority report noted that all racks were secure and the beach display had been reinforced with sand. Emergency medical services were on site. It is unknown if the deceased covered the loaded mortars, or if fuses had safety caps or other equivalent means of protection. According to family members, the deceased would vary the shell's fuse length to time the shooting.

The firing team had four "shooters" and one "spotter" at the discharge site. The "shooters" were the deceased, two of his assistants, and the company representative working the electronic board on the uppermost level of the pit. The deceased and his assistants were responsible for manually lighting the shells on the middle and lower levels of the gravel pit. One of the "shooters" did not have any experience igniting fireworks and had never attended any classes or received any training on the hazards associated with manual ignition of fireworks. This display was his first time at a "shoot". The other "shooter" had approximately eight years experience lighting fireworks and was a PGI-certified "shooter". The company representative was an experienced "shooter" and was PGI-certified as a display operator. The remaining assistant was assigned as the "spotter" for the deceased's two assistants. The "spotter" had spotted for three to five years, and had never acted as a "shooter". The "spotter" stated that she looked for sparks on the "shooters" and that they were not on fire.

The mortars were not illuminated by a fixed illumination source. The two assistants each used a four to five-foot broomstick with a flare duct-taped on the broomstick's end (fusee) as a flashlight to see the mortar fuse. The fusee was also used to ignite the mortars. The "shooters" were assigned to light 3-, 4-, and 5-inch shells and racks on both the ground and the second level. Their spotter was approximately 10-30 feet away from the "shooters" on the middle level. A fire extinguisher was available for use approximately 20 feet away. None of the deceased's assistants were wearing hard hats, headlamps, face shields, or other personal protective/safety equipment.

The two assistants had walkie-talkies and were able to communicate between themselves during the shoot. The deceased gave his walkie-talkie to the "shooter" at the electronic display board so he could be informed when it was time for him to fire his part of the display. The deceased did not have a walkie-talkie or any other type of communication device.

At approximately 9:00 p.m., the deceased test-fired a 2 ½-inch mortar to assess wind speed and direction. The fire department representative reminded the deceased and his assistants to put on protective equipment. Before beginning the shoot, the deceased discussed the sequence of the display with his assistants. Each "shooter" was assigned a zone of shells to light. MIFACE noted a discrepancy about the deceased's location during the display. The fire department report stated that the deceased gathered his assistants on the upper level and stated he was going to be up on a hill observing the actual firing of the display. The coworkers state that the deceased was responsible for manually lighting three salutes, two 3-inch comets, two 4-inch willows and a center 5-inch break salute. During the pre-shoot briefing, it appears that the deceased instructed one of his assistants to go down to the lower level to light shells during the show.

At approximately 10:00 p.m., the deceased climbed down the gravel pit hills and descended to the beachfront. The deceased used a propane torch to manually fire a chain of salutes and two large Lampare shells to start the show. After lighting the shells, he came up the hill and said to the two "shooters" on the middle level "Let's go". The two "shooters" on the middle level lit their fusees. According to their statements, the deceased left the area and walked away towards the top of the gravel pit. They thought he went up to the upper level to speak with the company's "shooter". The "shooters" and spotter did not see him again. The "shooters" manually lit their zones of shells for approximately 20-25 minutes.

At some point during the display, the deceased went down to the lower level beachfront, perhaps to light additional shells. The "shooters" on the middle level slid down the hill on their backs to the lower level to fire some "cakes". While walking to the cakes, one of the "shooters" discovered the deceased. The other "shooter" lit his cake. This "shooter" reported seeing his coworker run up the hill. The coworker discovering the deceased yelled, "man down, cease fire". The emergency personnel on scene were notified and they went down to the beachfront.

Near the deceased, buried and set at an angle in the sand in the direction of the water, were two mortars designed for 4-inch shells. Both mortars were empty indicating that they had been fired. The mortars had each contained a Lampare shell that had a 45-second delay fuse (safety fuse) and a quick match fuse that propagates the flame extremely rapidly lighting the lift charge.

The deceased was found wearing a long sleeve shirt, blue jeans, and leather athletic shoes. He was not wearing a hard hat, safety shoes or safety glasses. A flashlight was in his shirt pocket. His propane torch was near his feet. The deceased was lying face up, his legs were oriented toward the mortars, and the back of his head was partially in the water. The deceased had a 4 ½-inch diameter circular skull fracture. It appears that his head was struck from a firework shell from the right side, moving left. The medical examiner report stated there was "tattooing" on the right side of the head and upper right shoulder. The wound area had a granular substance and the peppering on his shoulder and near the impact site was similar to the substance found in the wound his head. The medical examiner did not identify the granular substance in the report. He

had been wearing earmuffs; they were found approximately 20 feet from his body, with the right earmuff blown off of the muff head strap. No powder burns were found on his head.

All personnel at the discharge site indicated that there were no duds, no shells that exploded at ground level, and no mortar failures. Firefighters stayed at the scene and made arrangements to maintain site security since there were still fireworks that had not been discharged.

This work-related death was unwitnessed, therefore, the exact sequence of events are unknown. Several possible event scenarios have been developed:

- Stray sparks from the lighting of a mortar rack above the mortars submerged in the sand ignited a shell that that struck him. This scenario could have been possible if the deceased had been standing with his back to the mortar(s) slightly to the left of the left-side mortar (See Figure 1). If he had been standing with his back towards the mortars, and arching backwards to look straight up at the breaking shells overhead, the shell could have hit his head.
- The deceased may have lit the 4-inch shells having a 45-second delay fuse on them or one of the 5-inch shells could have been fired first which lit the 45-second fuse unbeknownst to the deceased. After intentionally lighting the 4-inch Lampare shells which were delayed by almost a minute or having been accidentally lit, the deceased waited a short bit and moved in front of the 4-inch angled tubes in order to light one of the nearby cakes. The left-most 4-inch Lampare ignited, striking the deceased's head from the right rear.

In the case of each scenario, the force of the blow from the shell striking his head would throw him forward and cause him to spin counterclockwise coming to rest, face up at the water's edge. During deflagration, shells will spew flame and debris up and out of a mortar with the highest concentration being typically in a 10-foot radius of the mortar. The force of the shell striking the deceased and the debris from the mortar could account for the tattoo effect around the wounds. A 4-inch diameter shell striking an object is likely to expand upon contact, but not slow down or be diverted much. This could account for a 4 ½ -inch diameter wound he sustained. A bigger shell would be more likely to leave a larger wound, making the 4-inch Lampare shell(s) in severely angled mortars as the most likely suspect(s).

The deceased had a blood alcohol level of 0.246% at autopsy. It is unknown if other members of the "shoot team" were also tested for alcohol in their blood.

CAUSE OF DEATH

The cause of death as stated on the death certificate was head trauma. Toxicological results showed that his blood alcohol was 0.246%. An antidepressant was also detected in his blood (no level given). The medical examiner report stated, "what appeared to be "tattooing" was present on the right side of the head and upper right shoulder". Also stated in the medical examiner report, when the body was received, "beneath the head was brown granular material which

averaged approximately ⅛-inch in diameter. The size and shape of these granules was consistent with the tattooing on the right side of the head and upper right shoulder".

RECOMMENDATIONS/DISCUSSION

Since the sequence of events resulting in this work-related death is unknown, the following recommendations based on the above event scenarios have been developed.

- Do not drink alcoholic beverages while handling or discharging fireworks.

NFPA 1123 5.1.8 has a specific prohibition that no person shall be allowed in the discharge area while under the influence of alcohol, narcotics, or medication that could adversely affect judgment, mobility, or stability. The employer was cited under Act 154 PA of 1974, Sec. 11(a) for failure to assure that employees under the influence of alcoholic beverages were not allowed at the discharge site.

The deceased had a blood alcohol in excess of 0.2%. Recognizing that the effects of alcohol intoxication are influenced by individual variations, effects such as feeling dazed/confused or otherwise being disoriented is common. An individual under the influence of alcohol at this level may need help to stand/walk. It is unknown the degree of impairment the deceased may have been experiencing, but it is most likely that his judgment and coordination were impaired.

As an operator, if a member of your crew needs a drink so badly that they can't wait until after teardown, you do not want them on your crew. If they want to drink, tell them to join the crowd (literally). If you are on a crew that has a Lead-Shooter who is drinking or is drunk, you must confront him and ask that he/she step down and allow a qualified person who is not impaired to take over. If he/she refuses, you have the right and even an obligation to quit the show and report him/her. If you have knowledge that someone is impaired by alcohol or drugs and you do not report it, you may become liable both for civil actions and/or criminal penalties.

- Bury mortars in the ground to a depth of at least ⅔ to ¾ of their length and ensure they are appropriately angled, prevented from being driven into the ground or re-angled when fired.

It is unknown at what angle the responding police agency took the incident scene picture for Figure 1. From the picture, it is speculated that the mortars were not buried to the appropriate depth. It appears that at least 12 inches of the mortar is above the ground. A 4-inch mortar must be at least 6-inches in length for each inch of diameter; therefore the minimum length of the mortar should be 24 inches. For the 24-inch mortar to be appropriately buried, at least 16 inches (⅔ of 24 inches) must be below ground.

It is also speculated that the mortars in Figure 1 were buried at an excessive angle. Mortars are typically buried at an angle between 1-5 degrees with 10 degrees being the maximum angle.

- Cover mortars with plastic wrap or with biodegradable material to prevent sparks from other display materials dropping into them and causing pre-ignition and to protect them, if necessary, from adverse weather conditions.

It is highly recommended that you cover all loaded mortars, especially when the following conditions occur: mortars will be left overnight, other display material could drop sparks into the mortars causing pre-ignition or rain or other precipitation is forecast or present. Covering the mortars also permits display operators a method to determine if a shell has fired. Often, plastic wrap is used to cover the mortar because it burns almost 100%, leaves little or no debris, is not conductive, easier to use and generally does not need to be taped to a mortar (as does foil).

Cover all open ends on all quick-match with tape or safety caps. Secure all timed fuses against separation and seal them with tape to protect them from the any weather-related issues and stray sparks.

- Light all fireworks at greater than arm's length with an appropriate lighting device, such as a portfire.

Hand-firing a show has built-in dangers. Fuses burn quickly, leaving the "shooter" little time to get away from the mortar before the explosion that lifts the shell. Never use an "instant-light" propane torch to light a firework shell. Using this type of torch is like using "a bomb to light a bomb". The best tool to hand light a fuse is a "port-fire" (a Fusee- a.k.a. road flare). The fusee should be attached to an extension "wand". There are commercially available wands, however a good homemade alternative is a three-to-four foot length of ¾-inch EMT (thin-wall) electrical conduit with a ¾-inch female-to-female compression coupler on one end. Attach the compression coupler to the "wand" and tighten with a wrench (it will not be coming off again). Next, attach (insert) the fusee into the ¾-inch coupler (they fit tight, but nicely). A gently hand-tightening is all that's needed to insure that the fusee stays in place. This tool allows a "shooter" to remain away from the mortar when lighting and be a few steps further back if something goes wrong. A general safety principle is to never place a part of your body over a shell you have attempted to ignite and never try to relight a fuse if the device does not fire.

- All personnel working in the display area should wear appropriate clothing and personal protective equipment.

NFPA 1123 5.1.3.3 requires that during the firing of the display, all personnel in the discharge site shall wear head protection, eye protection, hearing protection and foot protection and shall wear cotton, wool or similarly flame-resistant, long-sleeved, long-legged clothing. Other natural material may also be worn. Cotton does not generally burst into flame or melt, causing burns. Full-length sleeves and long pants, safety shoes if possible, or at the very least, leather shoes or work boots should also be worn. Tuck the shirtsleeves into your gloves to prevent a point of entry for the sparks and to protect your wrists. A helmet with a face shield is also desirable, as are earmuffs or other approved method of hearing protection, such as earplugs.

The deceased and his assistants were not wearing adequate head and eye protection. It is unknown what type of clothing the deceased's assistants or the "shooter" at the electronics display were wearing. It is unknown whether a hard hat would have prevented his fatal injury,

but by not wearing a hard hat, his head was left unprotected. The deceased did appear to be wearing earmuffs to protect his hearing when the shell struck him.

- Ensure members of the shoot team can communicate with each other.

Each member of the shoot team as well as those responsible for emergency action have a reliable 2-way portable communication device with spare batteries. The 2-way communication allows for communication between team members to communicate about changes/problems encountered during the firing, to alert team members of a change in location of one of the team members, and for any firing team member to quickly summon emergency assistance in case of injury and/or emergency situation. It is unknown if the deceased's lack of a communication device was a factor in this incident.

If a two-way radio is not available, a suitable substitute would be mobile phones, flags, or if lighting permits, hand signals. If non-verbal signaling, such as hand signals or flags are used, the signals must be completely understood by all members of the shoot team. If you are using a FRS radio unit, ensure that you can hear the audio across the display area and over the noise.

Communication would have been especially important at this display, since the "shooters" were required to "crisscross" the site. It is desirable that the lead "shooter" plans the firing sequence so that the "shooters" are not required to continually walk back and forth through the display area.

- Have an appropriate number of trained "spotters" at a display site.

This display site had only one spotter for four "shooters". It appears that the "spotter" perceived that her responsibilities were to insure the personal safety of the "shooters" – i.e., make sure they weren't on fire. Under the NFPA rules, a "spotter" is defined as a member of the fireworks display crew (either the operator or an assistant) who observes the firing and bursting of aerial shells and other display fireworks for the purpose of detecting proper mortar angling, noting the occurrence of duds, and observing for other potentially hazardous situations. The "spotter" should be in direct communication with all of the "shooters" during the conduct of the display.

In this incident, the "shooters" were working on three different levels. The "spotter" was not in direct contact with all of the "shooters". There needs to be enough "spotters" to see the entire shoot and fallout areas. Typically, this means having at least two or more at any show. If the display operator cannot provide all the "spotters" necessary, the sponsor has the responsibility to provide them.

It is important to ensure that the "spotters" are experienced or site-trained to know what to look for. The single "spotter" could not adequately perform all of the job responsibilities inherent for the display site, and does not appear to understand her role at the event Although an increased number of spotters may not have prevented this fatality, for safety purposes, MIFACE recommends that more than one spotter be used when firing team members are not able to be in visual contact with each other and/or working on different levels.

- Consider using non-incendive lighting devices to illuminate the shell's fuses.

In order to illuminate the shells, the assistants had to use the fusee, which put them as risk of inadvertent firing of the shell. Flashlights, battery powered lanterns, head-worn lamps, or other non-incendive illumination, such as chemiluminescent devices provide an alternative to using a fusee as an illumination source. Fusees on "wands" may be used but must be used correctly to illuminate and light fuses. The "shooter" should never look directly at the burning end. If you accidentally look at the burning end you will develop a "bright spot" in your vision. If this happens, you must wait until this "clears".

- The operator should ensure that all assistants are fully trained in the proper performance of their assigned tasks.

The pyrotechnic operator has the primary responsibility for safety during the shoot. Although an operator is permitted to participate actively in the firing of the fireworks display, safety is the primary concern. The operator is responsible to ensure that all assistants are fully trained in the proper performance of their assigned tasks, and that they are knowledgeable of safety hazards. The deceased permitted an individual who did not have any training prior to the shoot to be a "shooter". Although the untrained individual worked with an experienced "shooter" who may have acted as his "buddy", the untrained "shooter" may not have known about the safety hazards associated with firing fireworks. The "spotter", if only watching out for the safety of the "shooters", was also not fulfilling all of the responsibilities of a "spotter".

Any safety issues identified should immediately be reported to the lead "shooter" who then has the responsibility to correct the situation either before firing begins or must halt the show until the situation is corrected.

- Authorities having jurisdiction (AHJs) should be properly trained to identify display-site violations and ensure that appropriate corrections are made before allowing the shoot to proceed.

On any show, there is only one person who may start the show – the lead "shooter" – but there are a large number of persons and who may keep a show from starting and who may halt a show in progress. These include (but are not limited to) the show sponsor, police and fire personnel, and any shoot-team member who sees a violation or inconsistency in the shoot site or setup.

NFPA 1123 defines an "authority having jurisdiction" (AHJ) as the organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure. AHJ's are required to enforce applicable codes and regulations, which at times, can lead to an adversarial relationship with the display operator/team. But to ensure a safe display, the display operator/team and the AHJ must work together, and understand each other's responsibilities and decisionmaking strategies. In this fatality, the fire department representative noted that the firework operators were not wearing safety equipment but apparently did not insist on their use.

MIFACE recommends that AHJ's be knowledgeable regarding the safe practices of both indoor and outdoor fireworks when they approve and are on-site at the time of the display. AHJ training is available through pyrotechnic suppliers as well as non-profit organizations so AHJ's can understand and appreciate the safety aspects of a pyrotechnic display during permit approval and inspection of the display area. In this incident, the local fire department was the AHJ at the

display area. It is unknown if the fire department representative who "approved" the display set-up and allowed it to proceed had received appropriate training to enable him/her to identify other potential problems with the display set-up and the safety precautions not taken by the deceased and his coworkers.

ACKOWLEDGEMENT

MIFACE thanks the PGII certified "shooters" from The Stumptown Shooters Pyrotechnics Club of River Junction, Iowa for their assistance in writing this report.

REFERENCES

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The Royal Society for the Prevention of Accidents (RoSPA), Firework Safety. Reference Internet address: www.saferfireworks.com

Skylighter. Fireworks Safety Information. Reference Internet address: www.skylighter.com

B.R.A.D. Be Responsible About Drinking. Reference Internet Address: www.brad21.org/about_us.html

OSHA Assistance for the Pyrotechnics Industry webpage. Reference Internet Address: http://www.osha.gov/SLTC/pyrotechnic/index.html This page is maintained as a product of the Alliance between OSHA and the American Pyrotechnics Association (APA).

American Pyrotechnics Association. Reference Internet address: http://www.americanpyro.com/

Fireworks Education Safety and Training, Inc. (FEST). Reference Internet address: http://www.fest.bz/

MIFACE

Investigation Report # 03 MI 080

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Please rate the following on a scale of:

Excellent	Good	Fair	Poor
1	2	3	4

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1 2 3 4

Was the report…	**Excellent**	**Good**	**Fair**	**Poor**
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