An earlier version appeared in *Fireworks Business*, No. 225, 2002.

"Impossible" and Horrific Roman Candle Accident

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*[**Authors note:** This article includes a number of notes with ancillary information. This information is not essential to the primary purpose of this article. Accordingly, it is suggested that the reader might wish to initially ignore the notes, and then subsequently, if additional information is desired, read any notes of interest.]*

Introduction

In May of 2000 in Queensland Australia, a most horrific accident[a] occurred involving large bore (2-in., 50-mm) Roman candles, which had generally and widely been thought to have been impossible. Because the set of conditions leading to this accident could occur again, and because requirements in the national fireworks standards (in both the US[2] and Australia[3]) should be modified somewhat to help mitigate the potential for future injuries, a series of articles derived from this accident and its investigation are being written.[b]

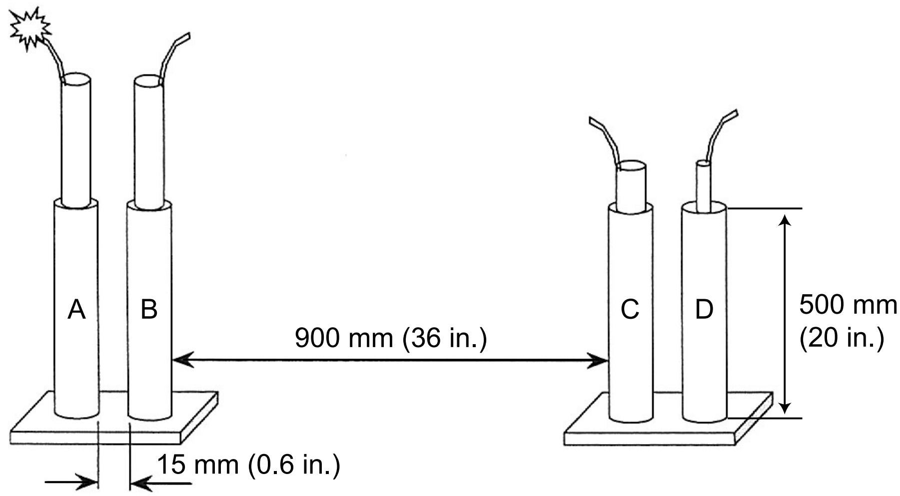
To facilitate their publication, the length of these articles will be limited such that only a portion of the overall subject will be addressed in each. This first article begins with a brief discussion of common Roman candle malfunctions. The bulk of the article presents the basic facts of the accident. Subsequent articles will present: a discussion of the Roman candle characteristics that caused the powerful explosion; partial summaries of the results of the many and in-depth scientific investigations undertaken to elucidate and confirm the cause and course of this accident;[c] recommendations of some changes to the safety procedures for the use of large bore Roman candles; and warnings regarding the manner of manufacture of large Roman candle stars.

Common Roman Candle Malfunctions

It is well known that Roman candle fireworks do malfunction on occasion. The most common malfunctions include: inconsistency in the timing between firing of the individual shots; having more than one star (or comet star) fire at virtually the same time, somewhat like a machine gun; and some shots remaining unfired. However, there are few if any safety ramifications with these types of malfunctions. By far the most common spectator accident with Roman candles is the result of their realignment (tipping over) due to their not being sufficiently secured, after which they proceed to fire projectiles into the crowd.

There are two basic ways in which unintended repositioning of Roman candles occur. Probably most common is when the recoil forces, produced when a star (or other projectile) fires from the Roman candle, exceeds the strength of its support system.[d] For example, this might happen when a Roman candle is secured to a frame above the ground using tape or wire that provides insufficient strength to successfully maintain its position during the course of its firing. Another common way for a Roman candle to become repositioned is when the tube of the Roman candle bursts, thus putting an additional strain on the support system, or otherwise defeating the support system in some way.[e] For example, this might happen when a collection of Roman candles have been bundled together using tape to form a Roman candle battery. In that case, if one Roman candle tube bursts, the resulting forces or fire may sever the tape allow the individual Roman candles to become reoriented.

In reference to other types of Roman candle accidents known to the authors. There was a case



Tube	Firework
A	2-inch 8-shot White Tail Roman Candle
B	2-inch 8-shot White Tail Roman Candle
C	2-inch 5-shot Gold Tail Roman Candle
D	1-inch 8-shot Cracker Tail Roman Candle

Figure 1. Configuration of Roman candle fireworks in twin-tube steel fireworks stands.

where it was alleged that the tube of the Roman candle was propelled into a spectator area (with the stars being propelled in the opposite direction). However, prior to the accident in question, the authors knew of no case where a portion of the support system of a Roman candle was so seriously and violently damaged (even when the tube of the Roman candle bursts) that a portion of the support system of a Roman candle was propelled into a spectator area.

The Bray Park Accident[1]

The accident (explosion) occurred when the fireworks display had been underway for approximately two minutes. Before the explosion occurred, the operator had manually ignited the fuse of one 2-inch, 8-shot white tail Roman candle in tube A (see Figure 1) and then proceeded to ignite a second 2-inch, 8-shot white tail Roman candle approximately 12 feet (3.6 m) away (not shown in Figure 1). The first comet of the 2-inch 8-shot white tail Roman candle in tube A functioned normally. Three seconds later a most powerful explosion occurred. The explosion was described by a witness as 'extremely loud and intense and created a powerful shock wave'.

The twin-tube steel Roman candle fireworks stands involved in the explosion are shown in Figure 1. The three 2-inch, Roman candles in tubes A, B and C each exploded. These Roman candles were the two 2-inch, 8-shot white tail Roman candles in tubes A and B of the first steel fireworks stand and one 2-inch 5-shot gold tail Roman candle in tube C of the second steel fireworks stand 36 inches (900 mm) away. Each of these firework stands consisted of a heavy steel base plate with two steel tubes 20-inches (500-mm) long, 3.00-inches (75-mm) outside diameter with 0.14-inch (3.6-mm) wall thickness welded to the base plate. The Roman candles, with an outside diameter of 2.44 inches (62 mm), were a relatively close fit inside the steel tubes.

The blast pressure (shock) produced by the three exploding Roman candles was sufficient to fragment the three steel tubes in which they were standing. Some of these steel fragments caused a fatality and serious bodily injuries. Fragments of various sizes were found at various distances up to approximately 580 feet (175 m) from the blast center. Fragments were found in the fireworks display area, spectator-viewing locations, and the adjoining neighborhood. A total of 42 steel fragments were recovered.

After extensive research (including thermodynamic and explosion modeling, and numerous and varied field trials) the investigation concluded that:

- The Roman candles contained simple comet stars (i.e., they were solidly compressed pellets of pyrotechnic composition and were not crossettes).[f]
- In the operation of the 2-inch, 8-shot white tail Roman candle in tube A, the first comet had functioned normally.
- After a 3-second delay, when the second comet was expected to be expelled from the Roman candle, the powerful explosion occurred.
- This Roman candle (in tube A) exploded when the second comet in the tube exploded powerfully and very shortly after its ignition (i.e., while still in close proximity to its at-rest position in the Roman candle).
- The powerfully exploding comet caused all of the remaining comets and Black Powder in the Roman candle to explode en masse.
- The cause of the comet exploding was a unique collection of characteristics of the comet, which will be discussed in some detail in the next article in this series.
- The exploding Roman candle (in tube A) caused the metal tube surrounding the candle to expand and fragment, producing high-energy steel fragments.
- The velocity of the steel fragments from tube A are estimated to have been as high as 900 miles per hour (400 m/s).
- Tube A expanded and impinged or struck the adjacent steel tube (tube B) approximately 15 mm (0.6 in.) away, which also contained a Roman candle, and caused the steel tube to be dented inwards.
- The dent compressed the contents of the second 2-inch, 8-shot white tail Roman candle, which caused that Roman candle to also explode en masse and produce steel fragments similar in form and mass to the steel tube fragments from the first tube.
- The velocity of the steel fragments from tube B was estimated to be as high as 1100 miles per hour (500 m/s).
- Both steel tubes in the fireworks stand had totally fragmented leaving only the base plate remaining. This 0.5-inch (12-mm) thick steel base plate had been dished about 0.25-inch (6-mm) deep beneath tube A.
- A fragment or fragments from the first twin-tube steel fireworks stand struck a second twin-tube steel fireworks stand approximately 900 mm (36 in.) away, containing the 2-inch 5-shot gold tail Roman candle in tube C.
- The point of fragment impact was probably 8 inches (200 mm) from the top of tube C.
- The 2-inch 5-shot gold tail Roman candle also exploded en masse.
- The explosion caused the tube to partially rupture producing several small fragments and one large fragment, with a steel collar being a part of this large fragment.
- Tube D was damaged but was not fragmented.
- The fatality and serious injuries were the result of the steel fragments produced during the course of the near simultaneous explosions.

Caution / Warning

To date only one shipment of Roman candles to Australia is known to have had the combination of characteristics (defect) that produced the very powerful explosions described above. The manufacturer's name does not appear on these Roman candles; however, they have the product code KL301B on their label. Figure 2 is a photograph of the product and instruction labels from these Roman candles. Other shipments into Australia of this same type of Roman candle were found to have been manufactured using much the same materials and processes. They were found to have most of the characteristics leading to the production of such powerful explosions as occurred in the Bray Park accident. Also, apparently the same Roman candles have been found in the US. Thus it should be considered that the potential exists for additional catastrophic explosions of these or similar large bore Roman candles. Accordingly, if such items are used, it is appropriate to: 1) use methods and materials to secure these Roman candles that allow the ready escape of any explosive pressures that might be produced such that those materials will not become especially dangerous flying debris, 2) use added separation between any such Roman candles and other Roman candles or any other display item that might become repositioned or damaged as a result of such a powerful explosion, 3) take added precautions for the protection of any display crew working in the immediate area during a display, and 4) use added separation between the Roman candles and spectators.

Conclusion

In this article, only the basic facts of the accident have been presented, generally without explanation or any supporting test results. To the extent practical, that supporting information will be presented in subsequent articles. The next article in this series will present information about the unique combination of characteristics of the Roman candle comet stars that is thought to have allowed them to produce such horrendous explosive forces.

Ancillary Notes

a) The most serious spectator injuries were a fatality (child), severe brain damage with the loss of an eye (adult female), and the partial amputation of a foot (adult male). In addition a male crew member suffered the traumatic amputation of a leg.[1]

b) While the Queensland Department of Natural Resources and Mines did issue warnings and imposed other restrictions, confidentiality agreements associated with the accident investigation and a trial has here-to-fore restricted the authors' ability to freely discuss the details of this accident.

c) The investigation report is roughly 1500 pages in length and contains approximately 20 sub-reports from various private and government research organizations.

d) This type of Roman candle repositioning is often the result of the display operator underestimating the magnitude of the recoil forces produced upon the firing of Roman candle projectiles. For example, even a relatively small diameter display candle (1 in. or 25 mm) can produce peak recoil forces in excess of 100 lbf (450 N).[4] However, these peak forces only persist for a brief moment. On occasion, at least a part of the fault for Roman candles over powering their support lies with the manufacturer, because of things such as the overloading of a Roman

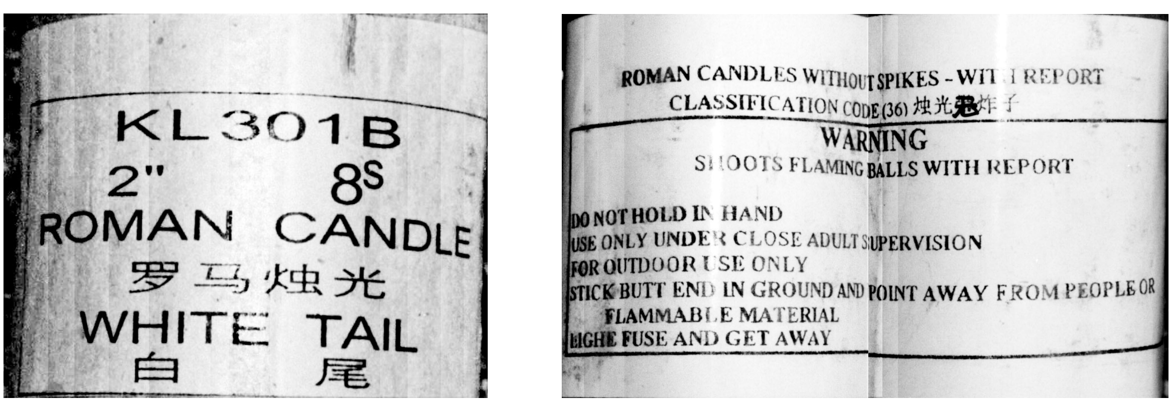


Figure 2. Photographs of Roman candle labels .Note: The left label, with the product number, is hot-pink in color, whereas the instruction label on the right is white.

candle shot, or when an ineffective seal between shots allows two or more projectiles to fire at the same time.

e) Such common Roman candle tube failures are typically the result of the tube being too weak to accommodate the additional pressure caused by things such as: the occasional overloading of one of the shots, the occasional near simultaneous firing of more than one shot, and the occasional jamming of a star in the tube as it attempts to exit the tube. Certainly Roman candle tube failures can be the result of an explosion occurring within them, such as when an explosive projectile (e.g., a salute) functions prior to being expelled.

f) A crossette is a special type of comet star, typically made with a large internal void that is filled with a flash powder. After a period of normal burning, the flash powder is ignited causing the comet star to explode into several smaller burning pieces.

References

1) *Investigation Report - Bray Park Fireworks Tragedy*, Queensland Government, Department of Natural Resources and Mines, 2001.

2) *Code for Fireworks Display*, National Fire Protection Association, NFPA-1123, 2000.

3) *Explosives – Storage Transport, and Use, Part 4: Pyrotechnics – Outdoor Displays*, Australian Standard, AS 2187.4 – 1998.

4) K. L. and B. J. Kosanke, “Recoil Forces Produced by Large-Bore Roman Candles”, unpublished.