An earlier version appeared in: *Fireworks Business*, No. 259, 2005.

# Avoiding Making Comets That Explosively Malfunction

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In recent years, there have been at least three separate instances where white (or silver) comets, which were manufactured in China, have demonstrated a tendency to malfunction by powerfully exploding when they are fired.[1–5] In each instance, the comets were solid masses of composition, as opposed to being crossettes or some other type of intentionally exploding comets. In studying these comets, even though there were three different types of comet devices under three different brand names, it was discovered that they shared some characteristics in common that understandably account for their explosive malfunctions. After providing a limited amount of background information, it is the purpose of this article to identify the problem characteristics and to recommend an easy and cost effective means for manufacturers to avoid similar malfunctions in the future.

The first product[1,2] was a type of 2-inch 8-shot Roman candle that exploded upon firing with such force as to shatter a thick steel mortar used for support, which resulted in one fatality plus traumatic limb amputations for two other people. The second product[3,4] was a type of 5-inch comet shell, improperly described as being a Tiger Tail, that shredded HDPE mortars and fragmented the racks holding them, fortunately without injury. The third product[5] was a 3-inch comet of normal construction that shredded paper mortars and completely disassembled the racks used to hold them, again fortunately without injury. (In each of the three cases, further accidents and injuries were avoided by withdrawing the inventory of these products from use.)

For more detailed information about the specifics of the comet malfunctions as well as information about the analysis of the comets, see the references cited in the previous paragraph.

## The Problem

Each of the comets used potassium perchlorate as their oxidizer, see Table 1. The remainder of the composition was a combination of aluminum and magnalium (a 50:50 alloy of magnesium and aluminum) and a binder. A substantial portion of the metal fuels consisted of very small particles, see Table 2. As a practical matter, for these three formulations, those metal particles smaller than about 100 mesh will be consumed in the flame of the burning comet and are not useful in producing a spark trail. Further, those metal particles smaller than about 200 mesh will potentially participate in explosive burning of the compositions. Accordingly, these compositions could be considered to be little more than a type of flash powder containing larger spark producing metal particles and that had been bound together to form solid masses of composition. The nature of their chemical composition is the first of the two comet characteristics that combined to produce the powerfully explosive malfunctions of these comets.

**Table 1. Approximate Chemical Formulations of the Problematic Comets.**

| Ingredient[a] | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| Potassium perchlorate | 50 | 40 | 40 |
| Aluminum[b] | 20 | 30 | 30 |
| Magnalium (50:50)[b] | 20 | 25 | 20 |
| Binder[c] | 10 | 5 | 10 |

a) Ingredients are reported as percentages and are rounded to the nearest 5%. See the various article references for more information on the methods used to determine the ingredients and their percentages.

b) See Table 2 for metal fuel particle size.

c) In each case the chemical nature of the binder seemed to be different, but its exact nature was not determined.

Microscopic inspections of the various comets revealed that they all had structures that were either poorly consolidated (i.e., they were highly porous in cases 2 and 3) or otherwise provided internal channels that would allow the ready penetration of gases (in case 1). Thus, in each case it

**Table 2. Approximate Mesh Fractions of the Metal Fuels in the Problematic Comets.[a]**

| Mesh Range | Case 1[b] | Case 2 | | Case 3 | |
|---|---|---|---|---|---|
| | Al + Mg/Al | Al | Mg/Al | Al | Mg/Al |
| +60 | 0 | 65 | 10 | 45 | 0 |
| 60 – 100 | 5 | 25 | 10 | 40 | 0 |
| 100 – 200 | 15 | 10 | 35 | 15 | 0 |
| 200 – 400 | 30 | 0 | 25 | 0 | 15 |
| –400 | 50 | 0 | 20 | 0 | 85 |

a) Mesh fractions are reported as percentages, rounded to the nearest 5%.

b) In this study, there had been no attempt to separately determine the mesh fraction of the aluminum and magnalium. The reported values were estimated using information reported in reference 6, which also contains information suggesting that it is magnalium that was the finer of the two metal powders.

seemed apparent that upon burning, there would be the likelihood for substantial penetration of burning gas into the core of the comets. This is significant because it would result in much more rapid burning of the comets, rapid burning that could potentially accelerate to explosion.[7] (This potential was confirmed in Case 1, where the burning of some of the problematic comets, when completely unconfined, produced powerful explosions.) The potential for accelerated burning is the second of the two comet characteristics that combined to produce the powerfully explosive malfunctions of these comets.

Understandably the tendency for these comets to explosively malfunction was the result of the combination of: (1) the flash-powder-like nature of the comet compositions (combining an energetic oxidizer with an excessive amount of very fine metal powder), and (2) the internal structure of the comets (one that potentially allows the ready penetration of burning gas to more-or-less simultaneously ignite the entire mass of composition).

## The Solution

Besides being a safety imperative, a possible solution to the problem is simple. Further, the solution has both has an economic advantage and it likely provides an esthetic improvement as well.

<u>It is simple</u>: Remove the very small particle size magnalium from the composition and replace it with a less reactive fuel like red gum. It seems somewhat likely that the very fine magnalium is present only because it is not being screened from the magnalium being purchased.

<u>It has an economic advantage</u>: It seems to be relatively common for Chinese manufacturers to use magnalium in making flash powder for their salutes. The very small particle-size magnalium is needed for making these salutes, and generally this fine mesh material is the most expensive. If it is screened from the magnalium used in making the comets, an overall cost savings should result. Further, the substituted fuel (e.g., red gum) that replaces the very fine magnalium is also less expensive.

<u>It likely has an esthetic improvement</u>: When the comets function as currently formulated, the heads of those comets will be excessively bright, tending to detract from the main feature of comets, their attractive tails. By replacing a portion of the metal fuel in the comet with something like red gum, the head will be less brilliant and the tail should appear enhanced.

One possible alternative solution would be to use a high percentage of binder and make sure the comets are very solidly compacted with small and relatively few internal voids. However, as a practical matter when manufacturing, there is always the chance that an occasional comet will be minimally compacted for any number of reasons, and one under-compacted comet may mean one dreadful accident. Thus this is not a guaranteed solution, and it does not have the economic and esthetic benefits.

Another possible solution might be to replace the potassium perchlorate with a less powerful oxidizer like potassium nitrate. This would have an economic advantage, but might make it difficult for the burning comet to ignite the primary spark producing fuel, which is the large particle size aluminum.

## The Implementation

Major US importers and the more influential fireworks organizations need to recommend (and if necessary insist) that their Chinese suppliers immediately make this change (or some other effective change).

## Acknowledgment

It must be acknowledged that while the cause of the explosive malfunctions seems to be well established, the effectiveness of the solutions suggested above have not been confirmed by laboratory testing.

It is gratefully acknowledged that L. Weinman commented on an earlier draft of this article.

## References

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