This article originally appeared in *Fireworks Business*, No. 7 2004.

Muzzle Breaks That Appear To Be Flowerpots

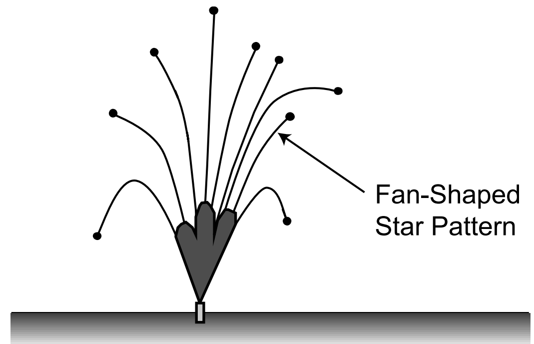
K. L. and B. J. Kosanke

As is sometimes the case when doing research: A) one occasionally discovers something which was not being sought; B) the thing discovered then seems intuitively obvious and one is amazed (and a little embarrassed) not to have figured it out long ago; C) the thing discovered helps to answer some other previously seemingly inexplicable observations; and D) one finds there are some new questions for which no certain answer is immediately available. All four of these happened recently while the authors were investigating the size of hole in the casing of aerial shells (of various sizes) that is needed to produce a fire-leak sufficiently great to cause the shell to explode while it is still inside the mortar.[1,2] During the course of those studies, it was found that a number of events, which visually appeared to definitely be flowerpots, were actually muzzle breaks.

After some introductory information, this article presents a collection of both standard and high frame-rate video images to make the case about muzzle breaks appearing to be flowerpots. An explanation is then offered as to why this should not have been unexpected, and finally the article considers some old and new questions relating to this observation. (While the authors are not aware of these observations having been presented elsewhere in the literature, certainly others may have previously figured this out for themselves.)

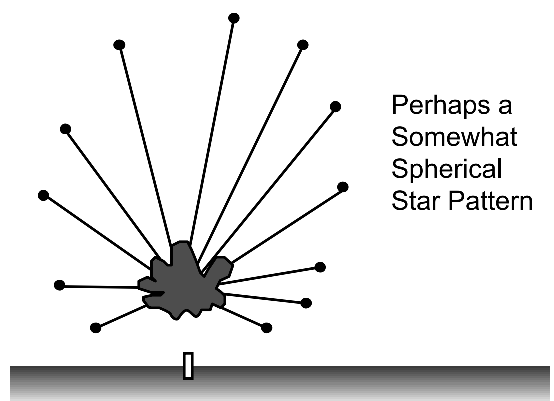
A common definition for a flowerpot is:

A type of aerial display shell malfunction where the shell bursts with relatively low power within a mortar. It produces an upward spray of ignited stars and other effects, as illustrated below[3].



A common definition for a muzzle break is:

A malfunctioning aerial shell which bursts just as it leaves the mortar, scattering high velocity burning stars and other material in all directions near ground level. It appears somewhat like the following illustration.[3]



In the testing being performed, aerial shell malfunctions were caused by piercing the paper shell casing of an aerial shell in the immediate area of their pair of time fuses, to thus allow the entrance of burning lift gases when the aerial shell was fired. The holes were made with mechanically driven awls of various diameters. Figure 1 is a composite image made during one of the test firings. The composite image was made by combining five individual 1/60th second digital video fields, thus spanning a total time interval of 0.083 second. This time interval was chosen because it is only a little less than the time taken for the human brain to process a visual image.[4] That is to say the composite image of Figure 1 is what a human observer would see as this event occurred. (This was confirmed by the authors when they personally witnessed this and several other similar events.)

The shells used in this testing were 3-inch (75-mm) Thunderbird Color Peony - Gold, product number TRA-105, with approximately 1.3 ounces (37 g) of lift powder. In the case of the shell malfunction presented in Figure 1, the awl was 0.090 inch (2.3 mm) in diameter, which when removed left a hole staying open with a diameter of approximately 0.074 inch (1.8 mm).

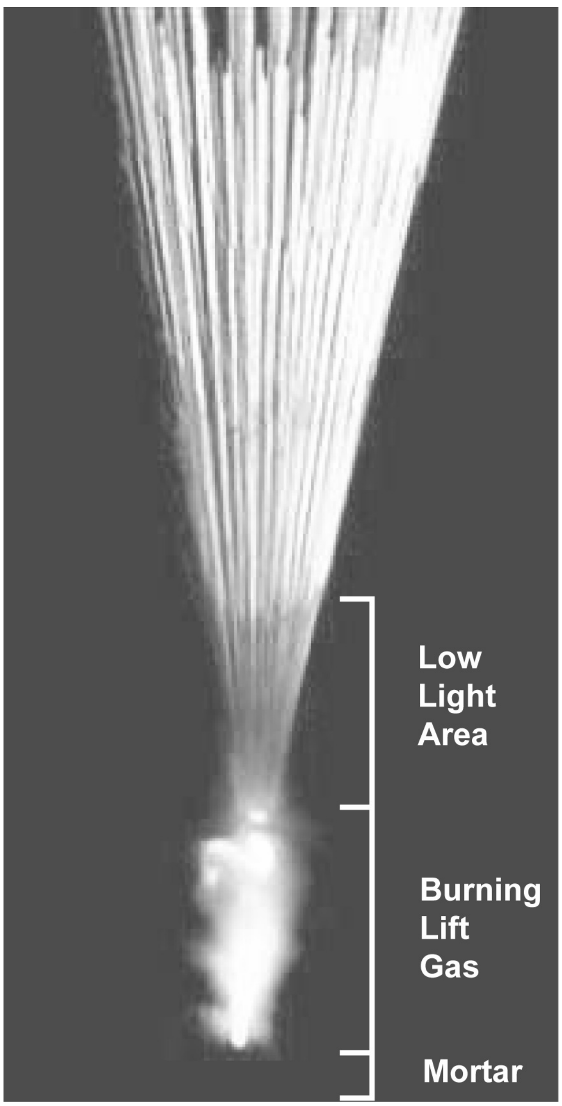


Figure 1. An 83 millisecond composite video image of an intentionally produced aerial shell malfunction.

In Figure 1, the field of view is approximately 30 feet (9 m) vertically and 15 feet (5 m) horizontally. The 24 inch (0.6 m) long HDPE mortar is at the bottom of the image but is not visible in the darkness, and it extended slightly below the bottom of the image. Above the mortar the plume of burning lift gas extends upward approximately 6 feet (2 m). Above this is a low light area extending approximately another 5 feet, where the prime on the stars is burning as the stars proceed upward and outward. Finally the more brightly burning stars are seen to continue approximately another 18 feet (5.5 m) in their upward and outward motion. Upon seeing this image or witnessing the event first hand, few if any practicing pyrotechnists would characterize this malfunction as anything other than what is commonly called a flowerpot.

Recently, to facilitate their fire-leak testing, the authors gained the use of a high frame-rate video system.[5] The early portion of same event presented in Figure 1 is shown in Figure 2 as a collage of six individual images. These video images were acquired at a rate of 2000 frames per second and with a shutter speed of 1/2000 second. The six images shown, selected from a total of nearly 200 video frames spanning the event, were chosen to illustrate some key points during the course of the event. (The identification of what is seen in each image of Figure 1 was made more certain by viewing the entire event several times in slow-motion and by having viewed several other similar appearing events.)

In image 1 of Figure 2, burning lift gas is seen and the aerial shell is approximately 1 foot (0.3 m) above the mortar, as evidenced by the bright and wide plume of lift gas deflecting around the shell. Image 2 was taken 0.0065 second after image 1; the plume of burning lift gas is significantly more pronounced, and the shell has advanced upward another approximately 2 feet (0.6 m). Image 3 was taken 0.0045 second after image 2; the diameter and brightness of the fire above the mortar is seen to increase significantly as a result of the shell breaking approximately 4 feet (1.2 m) above the top of the mortar. Image 4 was taken 0.0155 second after image 3, by which time the star prime has mostly burned away and many of the stars can be seen at the start of forming an almost perfectly symmetric burst pattern. Images 5 and 6 were taken 0.0100 and 0.0200 second after image 4, where the stars are seen to produce an expanding symmetric pattern of a normally symmetric shell burst. (The total span of time for the series of images in Figure 2 is 46 milliseconds.)

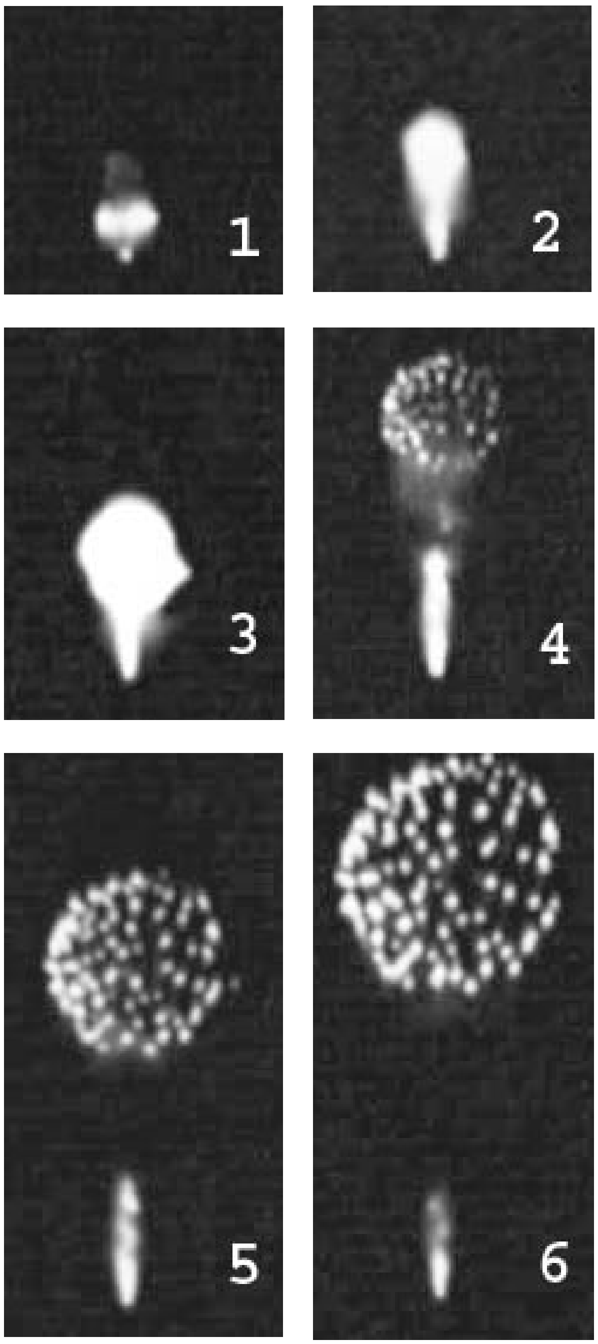


Figure 2. A collection of 6 high speed video images, of the same event presented in Figure 1, spanning an interval of 46 milliseconds.

That the aerial shell exploded after exiting the mortar was confirmed by having monitored the pressure inside the mortar during the shell's firing. When an aerial shell explodes while it is still inside the mortar, the blast wave from the explosion produces a near instantaneous increase in pressure above normal. Figure 3 presents a pair of graphs of mortar pressure as a function of time during the firing of this same type of aerial shell. The upper graph is from the shell firing documented in Figures 1 and 2, wherein the shell exploded after leaving the mortar. In the the lower graph, note the jump in mortar pressure that occurs. In this case, the aerial shell was caused to explode while just barely inside the mortar (by having made a hole in its shell casing using a 0.25-inch awl.)

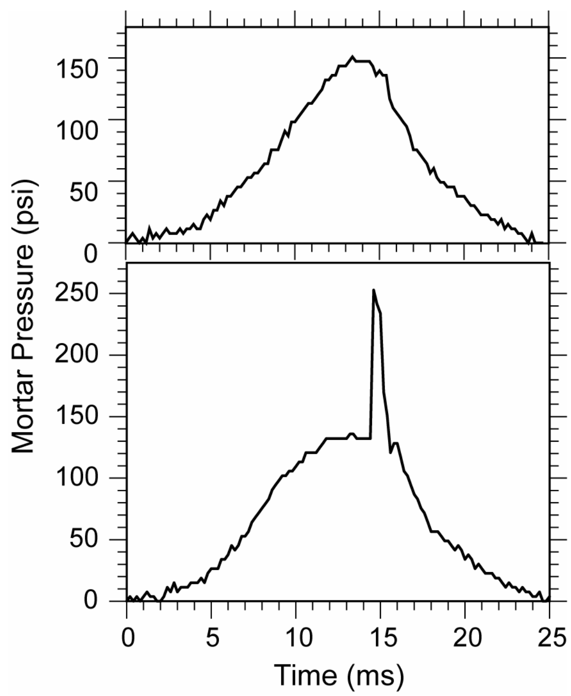


Figure 3. Two graphs of internal mortar pressure during the firing of aerial shells: upper, normal shell firing; lower, shell exploding while just barely within the mortar. Note: 1 psi = 6.9 kPa.

In addition to the strong confirmation offered from the mortar pressure data, the star burst pattern seen in Figure 2 bears added witness to the fact that the shell had exited the mortar before exploding. Consider the three burst patterns presented in Figure 4, which were produced by the

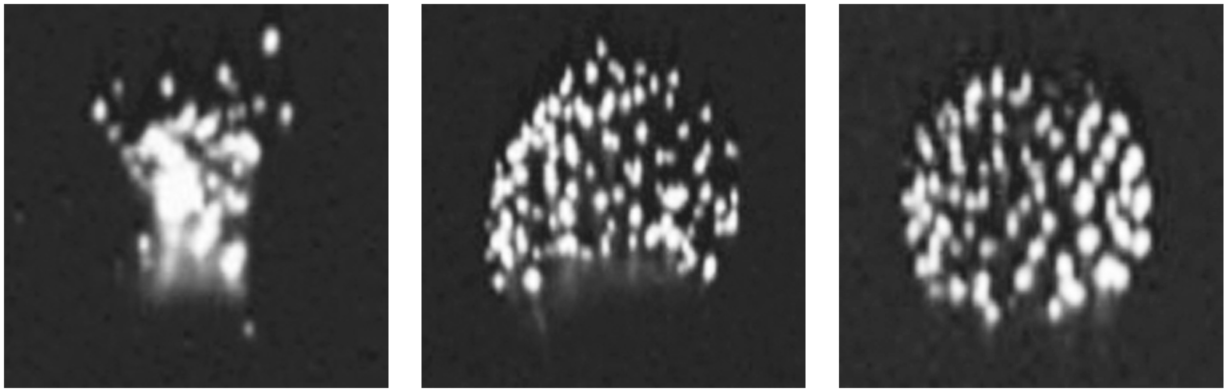


Figure 4. Images of three star burst patterns: (left image) produced by test shells bursting within the mortar, (middle image) just barely above the mortar and (right image) clear of the top of the mortar.

same type of Thunderbird 3-inch (75-mm) aerial shells. The left most image was produced by a test shell that burst a little before exiting the mortar (as was confirmed by monitoring internal mortar pressure). In this case there is a total lack of burst pattern symmetry. The middle image is from a test shell bursting outside, but within a foot or two the top of the mortar. In this case the high pressure lift gas is apparently sufficient to cause the flattening of the bottom of the burst pattern and sometimes a slight bulging out of the top of the pattern. The right most image in Figure 4 was produced by a test shell bursting when several feet above the top of the mortar. Note the near perfect symmetry of this third star pattern, which is essentially identical to that produced by the aerial shell displayed in Figure 2. While these 1/2000 second images are quite distinct from one another, the three events as perceived by a human observer appear essentially identical.

The above paragraphs describe what the authors unintentionally learned regarding the appearance of some muzzle breaking aerial shells during the course of testing for other purposes. This was point A mentioned in the first paragraph of this article. Point B was that this observation probably should not have come as much of a surprise. This is because it is reasonably well known that the human brain takes approximately 0.1 second (100 milliseconds) to process a visual image[4] (which is why motion pictures and television sets produce what appear to be continuous motion, when in actuality they are presenting a series of discrete still images). In effect the brain integrates the flow of visual stimuli to form a composite image and is unable to discern events occurring in times less than approximately 100 milliseconds as being separate or individual events. Accordingly, when the stream of images presented in Figure 2 is processed by one's brain (along with those many other images occurring between those included in Figure 2), the result is a perceived image very much like that presented as Figure 1. Had the authors thought carefully and critically about this, they could have figured out long ago that muzzle breaks of this type would appear to a human observer as being flowerpots.

Point C mentioned in the first paragraph was that such a discovery often provides an explanation to one or more previously seemingly inexplicable observations. One such observation is that many flowerpots produce a sound not noticeably louder than a normally firing aerial shell. For a shell actually exploding while being fired and still inside the mortar, this was hard to explain. Surely the exploding shell would add to the normal mortar firing pressure (as demonstrated in Figure 3), and the sound produced by the release of that greater pressure from the mortar should be louder. If so, then why is the sound of a flowerpot often times not noticeably louder? However, if in fact the aerial shell – thought to have been a flowerpot – actually exploded shortly after it left the mortar, while the combined sound produced (the shell exiting and then the shell exploding) would span a little longer time interval, they would not combine to make a louder sound. Similarly, it was hard to explain why some relatively weak mortars can survive the apparent flowerpotting of powerfully exploding shells without the mortar being damaged or destroyed. Again, if the powerfully exploding aerial shell had actually exited the mortar before exploding, then its not damaging the mortar is certainly understandable.

Point D mentioned in the first paragraph was that a discovery generally leads to one or more not yet definitively answered questions. One such question is, why then do some of those aerial shells that malfunction by exploding just after exiting their mortar present the visual appearance of being a muzzle break and do not appear as flowerpots as in Figure 1? That is to say, what is it about such muzzle breaking shells that causes them to appear as muzzle breaks and not flowerpots? Another question is approximately what percentage of those malfunctions commonly identified as being flowerpots are actually muzzle breaks, and is that percentage a function of shell size? (The authors have some thoughts about these questions but will not speculate until more testing has been conducted.)

Acknowledgment

The authors are grateful to L. Weinman (Schneier / Weinman Consultants) for commenting on an earlier draft of this article, and to SpeedVision Technologies[5] for supplying the high speed video system used in this work.

References

1) K. L. and B. J. Kosanke, "The Effect of Intentionally Caused Fire Leaks into 2-1/4-Inch Consumer Fireworks Shells", *Fireworks Business*, No. 241, 2004; also in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 7 (2003 and 2004)*, Journal of Pyrotechnics, 2006.

2) K. L. & B. J. Kosanke, "The Effect of Intentionally Caused Fire Leaks into 3-Inch Display Fireworks Shells", *Fireworks Business*, No. 249, 2004; also in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 7 (2003 and 2004)*, Journal of Pyrotechnics, 2006.

3) *The Illustrated Dictionary of Pyrotechnics*, Journal of Pyrotechnics, Inc., 1996.

4) *Van Nostrand's Scientific Encyclopedia*, 5th ed., Van Nostrand Reinhold, p 2289, 1976.

5) The high speed video camera system was provided by SpeedVision Technologies, Inc. San Diego, CA, USA (858-450-7107).