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Flowerpots and Muzzle Breaks

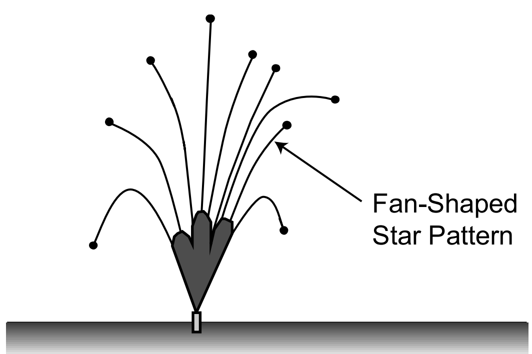
K. L. and B. J. Kosanke

Introduction

Flowerpot and *muzzle break* are descriptive terms for two types of star shell malfunctions. There can be serious safety consequences from these malfunctions, especially for manually fired displays. Some commonly held beliefs as to the cause of these malfunctions are challenged by the available data. This article summarizes some of that data and then draws inferences from that data.

A common definition for a flowerpot is:

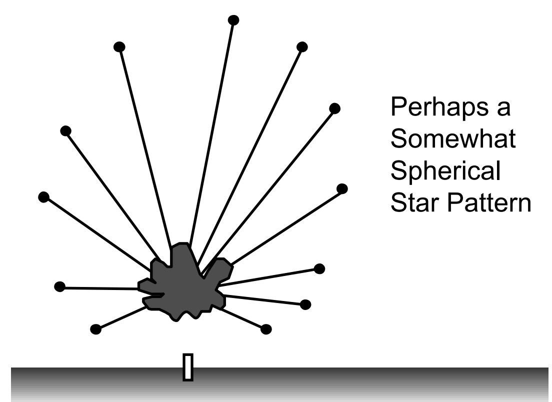
A type of aerial display shell malfunction where the shell bursts with relatively low power within a mortar. It produces an upward spray of ignited stars and other effects, as illustrated below.[1]



The odds of a star shell experiencing a flowerpot depend on many factors, but for typical shells and conditions it is probably in the range of 1 flowerpot in 200 to 500 shell firings.[2] It would seem that the likelihood of a shell experiencing a flowerpot is mostly independent of shell size. For the most part, since the power of the explosion is relatively low and the mortar often remains intact. Flowerpots represent a relatively minor hazard. A hazard that does result is from the potential for burning debris to fall to the ground in the area of the mortars, thus presenting a possibility for the unintentional ignition of other fireworks. This is a minor concern for an electrically fired display with no personnel present and where the fireworks are already loaded into mortars ready for firing. However, when personnel are present, such as for a manually fired display, especially when stores of firework shells are being reloaded, burning debris raining down is a serious safety concern. When a flowerpot occurs for a salute or large caliber star shell, there is the potential for the firing mortar to burst. In that case, the potential hazard from mortar and mortar rack fragments will be much greater.

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.[1]



The odds of a star shell experiencing a muzzle break also depend on many factors, but for typical shells and conditions it is probably in the range of 1 muzzle break per 500 to 2000 shell firings.[2] In addition, it seems that muzzle breaks are significantly more common for large shells as compared with small shells. The hazards posed by muzzle breaks are in two areas. First are hazards arising from the blast force of the exploding aerial shell. For salutes and large shells the blast force can be sufficient to cause injury to persons in the immediate area. The blast force can also be sufficient to reposition nearby mortars, such that shells fired subsequently from those mortars could proceed in dangerous directions. Second are hazards arising from the generally wider spread of burning stars than from a flowerpot. While this poses somewhat similar problems as the burning fallout from flowerpots, the hazard is more extreme with a muzzle break. The burning components from a muzzle break will be traveling much faster in a horizontal direction, thus not allowing sufficient time to react to the threat. Another consequence of the high speed of the burning stars is that their horizontal range will be much greater.

Before a manufacturer can effectively take steps to reduce the occurrence of star shell malfunctions, it would be helpful to accurately understand the nature and cause of those malfunctions. While some may think they know the causes of flowerpots and muzzle breaks, for the most part this seems to be based on conjecture and intuition, rather than solid evidence.

Regarding flowerpots, it is often suggested that the cause is a fire leak into the shell through a small crack or tiny hole in the shell's casing. Another common explanation for flowerpots is that it is a result of *setback*, where a common definition for setback is:

The inertial response to the extreme acceleration of aerial display shells upon firing.[1]

The peak acceleration of a star shell will be approximately 1000 times the acceleration due to gravity.[3] In response to this acceleration, the contents of the shell will forcefully compress into the lower portions of the shell casing. It is possible that this forceful motion of internal pyrotechnic materials may on occasion produce sufficient frictional force to cause the ignition of the shell's contents, leading to the premature explosion of the star shell. Regarding muzzle breaks, it is often suggested that the cause is unusually fast burning (defective) time fuse. However, no published data confirms that these presumed causes for flowerpots and muzzle breaks are correct. In fact, the little published data on the subject seems to contradict these presumed causes. This article will examine the available data and suggest alternate theories more consistent with the data.

Test Data

Several years ago, in an attempt to learn more about the cause of muzzle breaks, a series of tests were conducted.[4] Subsequently, some relevant data was collected during the course of two other brief studies conducted for other purposes.[5,6] Recently some additional data was produced for use in the present study.[7,8] While the overall results of these studies are used in this article, a detailed presentation of those results and the methods used to produce them will not be repeated here.

A total of 35 measurements were made of the time taken for a range of typical spherical star shells to explode after being ignited internally using an electric match. The average values of these *burst delay times* ranged from approximately 30 milliseconds (ms) for 2.25-inch shells to 110 ms for 10-inch shells. (Note that, for all of the testing reported here, the conditions were such that the electric match fired in less than 1 ms.)

A total of 61 measurements were made of the time taken for a range of typical spherical star shells to exit their mortar after firing an electric match to ignite their lift charges. The average *mortar exit time* (the time interval between the electric match firing and the when the shell exited the mortar) was approximately 40 ms. It was observed that there was relatively little if any dependence of mortar exit time on shell size (in the range from 2.25 to 8 inches) fired from mortars of typical construction.

When interpreting the mortar exit time data, it is important to recognize that, for a significant portion of the time while the lift powder is burning and before the shell exits the mortar, there is no detectable increase in pressure inside the mortar, see Figure 1. (This is the time required for fire to spread throughout the mass of lift powder and then to have sufficiently vigorous burning of the lift charge to produce more combustion gas than can easily escape through the gap between the shell casing and mortar wall.)

This is important in the context of this article, where consideration is being given to fire leaks through small cracks or tiny holes into the interior of a star shell as it is being fired. Until there is a significant difference between the pressure in the mortar and that inside the shell, there is no driving force to cause the entrance of the burning lift gas through any small crack or tiny hole. Similarly for setback as a possible cause of flowerpots, until there is a significant rise in the pressure under a star shell, it will not begin to accelerate up the mortar, and there will be no inertial forces to potentially cause the ignition of the shell's internal contents. (For a more complete discussion of the timing of the sequence of events during typical star shell firings, see reference 6.)

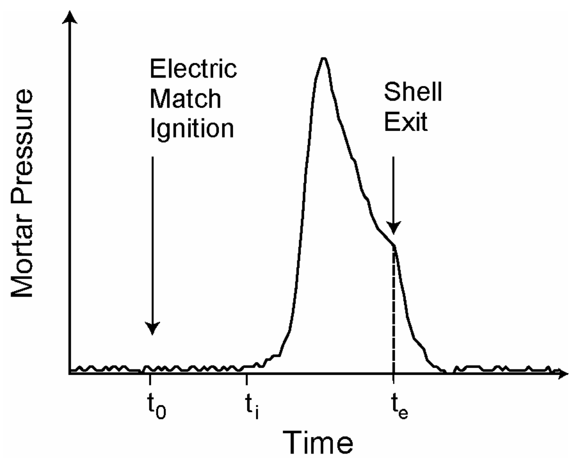


Figure 1. Mortar pressure versus time for the firing of a typical star shell, where the pressure impulse time equals the time difference between t_i *and* t_e*.*

A total of 39 measurements were made of *pressure impulse time* (the time interval between the first detectable rise in mortar pressure, t_i, and when the shell exited the mortar, t_e). In effect, only during the pressure impulse time is there a pressure differential that could force burning lift gas through any small crack or tiny hole in a shell's casing. It was found that the pressure impulse time averaged 20 ms, mostly independent of shell size.

Conclusion

After an amount of fire approximately equal that provided by an electric match has entered a star shell, the average time taken for the shell to explode (approximately 30 to 110 ms, depending on shell size) is always longer than the average time for the shell to exit the mortar once the lift pressure under the shell starts to rise (approximately 20 ms). The inescapable conclusion for such relatively small fire leaks and setback caused ignitions is that on average star shells will have left their mortars well before they have time to explode. However, there are rather large variabilities observed in individual burst delay and pressure impulse times. Thus, if a star shell's pressure impulse time is longer than average, while at the same time its burst delay time is shorter than average, it is possible that some small shells will still be inside the mortar when they explode (as flowerpots). However, larger shells, with their significantly longer burst delay times, will essentially always be well clear of the mortar before they can possibly explode from such small fire leaks or from setback. (This has been confirmed in recent studies, only some of which have been published at this time; see references 7 and 8.)

The overall results of this study are substantially inconsistent with the commonly cited causes of flowerpots. Fire leaks, approximating the fire produced by an electric match, are not expected to produce flowerpots, but rather to cause muzzle breaks. Thus one must conclude that flowerpots are rarely if ever caused by fire leaks through small cracks or tiny holes, or as a result of setback. Although not specifically investigated in the testing reported in this article, it seems certain that the time taken for a star shell to explode depends on the amount of fire leaking into it. To account for the observation that many more star shells flowerpot than muzzle break, most flowerpots must be the result of much more substantial fire leaks, up to and including the more-or-less complete failure of the shell's casing. (Note that the substantial failure of a shell's casing as a cause of many flowerpots is consistent with the empirical observation that the explosive power for many flowerpots is substantially less than would be expected for an intact shell exploding within the added confinement of a mortar. In fact, many flowerpots seem to be not much more violent events than normal shell firings.)

In considering the cause of muzzle breaks, while the data reported here does not disprove the fast burning time fuse hypothesis, it is certain that small fire leaks and setback are also viable (and at least certainly more likely) explanations. Further, the conclusion that it is primarily larger shells that will be well clear of the mortar before they can explode as a result of small fire leaks is consistent with common experience regarding muzzle breaks.[2] This gives one added confidence that the cause of many (most) muzzle breaks is relatively small fire leaks.

Acknowledgment

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