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Factors Affecting the Precision of Choreographed Displays

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For maximum effectiveness of tightly choreographed fireworks displays, it is important that shell bursts occur very near their intended times. For the purpose of this article, it is assumed that electrical firing employing a computer or other means of accurately applying the firing current to electric matches is being used. In addition, it is assumed that the choreographer has accurate information about the firing and burst characteristics of the shells being used, and that no errors are made in the design of the choreography or in the loading of the display. In that case, there are two primary sources of variation that combine to affect the overall precision of the shell burst times. First is the preciseness of the shell firings from their mortars; second is the preciseness of the time fuse burning. (In the context of this article, "preciseness" is intended to indicate consistency or reproducibility of events.)

The display company has some control over the firing precision of shells. The effectiveness of the commonly used methods of electric match installation was briefly studied and reported in a previous article[1] and is summarized again below. The three common points of attachment for electric matches are illustrated in Figure 1 and the degree of firing precision accomplished using each of them is presented in the first three rows of Table 1. (For more information on test conditions and methods, see reference 1.) As expected, the best firing precision (lowest standard deviation) is achieved with an electric match installed directly in the shell's lift charge. However, using an electric match attachment in the shell leader just above the shell, provides a level of firing precision that is equivalent to that achieved with the electric match in the lift charge, within the practical limits of human perception.[2]

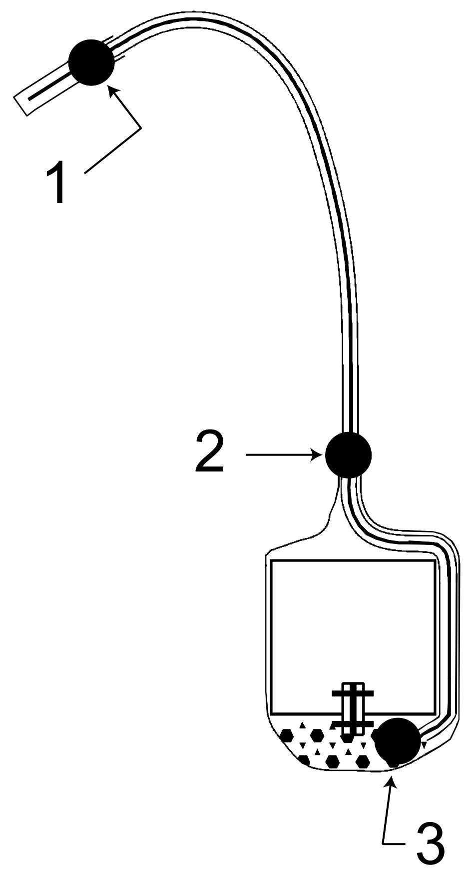

Figure 1. Illustration of the three common points of attachment of electric matches to aerial shells.

Table 1. Firing and Burst Time Results.

Test Conditions	Event Time[a] (s)	Std. Dev.[b] (s)
Attachment Point 1[c]	0.26	0.15
Attachment Point 2[d]	0.11	0.025
Attachment Point 3	0.04	0.005
Time Fuse Burning[e]	3.32	0.31

a) Event time for the various electric match attachment points is the average elapsed time between applying current to the electric matches and the shells exiting from the mortars. Event time for the time fuse burning is the average elapsed time between the shells leaving the mortar and their bursting.

b) The one-sigma standard deviations of the average event times were determined using the $n - 1$ method. This is an indication of the precision (reproducibility) of the timing of the event. Approximately 70% of the events occur within plus or minus one standard deviation of the average.

c) All using 24-inch long shell leaders with high quality quick match from a single manufacturer.

d) All using 6-inch long shell leaders with high quality quick match from a single manufacturer.

e) All shells were 3-inch Thunderbird Color Peony-White taken from the same case of shells.

Other than purchasing high quality shells, a display company generally has little control over the burst precision provided by an aerial shell's time fuse. To gain an estimate of the precision for shells of typical quality, a series of 29 three-inch Thunderbird aerial shells were test fired while being video taped. The shells were Color Peony-White (TBA-106), all taken from the same case of shells. The shells each had a pair of fairly high quality time fuses. Following the test firings, the video tape was studied frame by frame, to determine the time interval between each shell's firing from its mortar and its bursting. The results are presented as the bottom row in Table 1. (Based on a limited number of other testing over the years, it is thought that the burst time uncertainty reported in Table 1 is fairly typical.)

Fairly clearly the greatest source of imprecision in a tightly choreographed display is the uncertainty associated with the burning of the time fuse(s). It is possible that the use of well-made spolettes would reduce the uncertainty somewhat but probably not by very much. Accordingly, when very precise timing of shell bursts is needed, people have turned to the use of tiny electronic timers[3,4] to replace the shells' time fuses. While these electronic units are definitely not inexpensive, when precise timing of bursts is required to accomplish an effect, there would seem to be no alternative at this time.

References

1) K. L. and B. J. Kosanke, "Firing Precision for Choreographed Displays", *Fireworks Business*, No. 194, 2000; also in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 5(1998 through 2000)*, Journal of Pyrotechnics, 2002.

2) L. Weinman and K. L. Kosanke, "Tests of the Perception of Simultaneity of Fireworks Bursts", an unpublished study.

3) T. Craven "Air Launch Fireworks System at the Walt Disney Company", *Proceedings of the 2nd International Symposium on Fireworks*, 1994, p 74.

4) P. McKinley, "An Electronic Pyrotechnic Igniter Offering Precise Timing and Increased Safety", *Proceedings of the 4th International Symposium on Fireworks*, 1998, p 257.