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Aerial Shell Burst Delay Times

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If you have ever wondered how long the shell burst process takes after the time fuse burns through to the interior of the shell, this article may be of interest to you. Although rapid, the process is not instantaneous. A flame front must advance through the burst charge and an amount of combustion gas must be produced that is sufficient to pressurize the shell casing beyond its burst strength. Some time ago, as part of a study of the possible cause of muzzle breaking aerial shells, we needed to determine approximately how long this process takes.[1] That burst delay time data is summarized below.

Burst delay times were measured for spherical aerial shells ranging in size from 3 to 10 inches. The shells were ignited using an electric match inserted into the shell. This was accomplished by making a small hole, only slightly larger than the electric match, by remotely pressing a pointed tool through the shell casing a little above or below the equator of the shell. The tip of the electric match was inserted about 0.6 inch into the shell. (This is approximately the same distance as would be typical of the inside end of the time fuse in a shell without a flash tube to the center of the shell.) The hole was closed using three layers of strapping tape encircling the shell in different directions. As a sensor to indicate the bursting of the shell, two loops of wire encircling the shell were used. The loops crossed the poles of the shell at approximately a 90° angle. These wires were held in position on the shell using small dabs of hot-melt glue along its length. To make the measurement, the test shell was suspended above the ground, and then electrically attached to the timing and firing apparatus. The electric match was energized with sufficient current to cause its ignition in less than one millisecond. The contents of the shell were thus ignited, causing the shell to burst (explode). As the casing expands and fragments, the loops of wire break. Burst delay times were determined using an electronic timer to measure the time between application of current to the electric match and when the wire loops break.

For the burst delay times to be representative of typical shells, the shells used in these measurements came from seven different manufacturers. These manufacturers were: Yung Feng (Y), Horse (H), Temple of Heaven (T), Onda (O), Red Lantern (R), Sunny International (S), and Flying Dragon (F). In the data presented in Table 1, the manufacturer is identified using the code letter listed for each manufacturer. Burst delay times are also presented in Table 1. It would have been preferred to have tested a larger number of shells and to have used a wide and consistent set of manufacturers for each shell size. However, this was not possible because of economic constraints.

While most of the burst delay times for each shell size are fairly well grouped, there are occasional values that are significantly longer than the rest of the group. The most extreme example is the delay time for the Horse brand 8-inch shell, which was 329 ms as compared with 52 and 96 ms for the other two shells tested. Similarly, the 122 ms for the 3-inch Temple of Heaven shell and the 104 ms for the 4-inch Red Lantern shell, are significantly longer than the burst delay times for the other shells in those size groups. It is felt that these longer delay times were real. This is because, in each of these three cases, the time interval, between pressing the button to energize the electric match and when the shell explosion occurred, was noticeably longer than for the other shells. The cases of longer than normal burst delay times may represent some type of anomalous ignition of the shells' contents, in which the fire transfer from the match was substantially less effective than in the other cases. This notion is supported by the fact that in two other cases, although the electric match fired normally inside the shell, the contents were not ignited and the shells failed to explode. In both cases, a second attempt (after another electric match was installed) produced a

Table 1. Aerial Shell Burst Delay Times.

Shell Size (mm)	Shell Size (in.)	Burst Delay Time (ms) / Manufacturer	Average Time (ms)	Fitted Time (ms)
75	3	30/S, 32/S, 36/Y, 41/S, 48/T, 76/H, 122/T	43[a]	41
100	4	21/S, 44/Y, 50/R, 51/H, 53/R, 78/T, 81/S, 104/R	54[b]	51
125	5	26/S, 40/S, 59/O, 62/R, 73/T	52	60
150	6	54/H, 55/S, 77/T, 82/F, 89/T	71	70
200	8	52/Y, 96/Y, 329/H	74[c]	89
250	10	134/O	134	108

(a) The burst delay time of 122 ms was not included in the average.

(b) The burst delay time of 104 ms was not included in the average.

(c) The burst delay time of 329 ms was not included in the average.

shell explosion with the delay time typical for shells of that size. In order to not bias the data by including the abnormally long burst delay times, they were excluded when calculating the average delay times reported for each size shell.

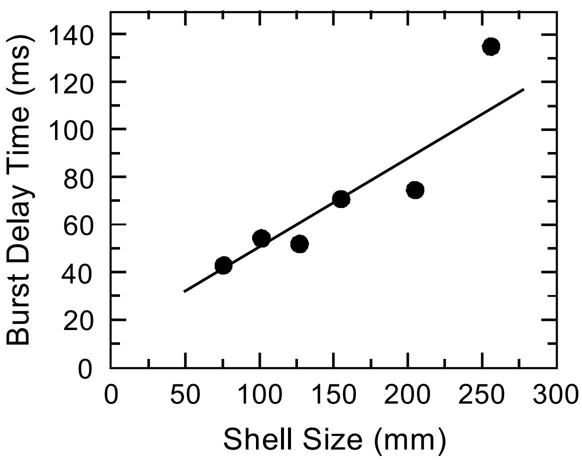

Figure 1. Average shell burst delay times as a function of shell size.

Average shell burst delay times, as a function of shell size, are presented as a graph in Figure 1. In calculating the linear least squares fit to the data, the average delay times were weighted according to the number of shells of each size that were included in the average. It is apparent that there is a significant increase in burst delay times for larger shells, with the least squares fitted burst delay times ranging from approximately 40 ms for 3-inch shells, to approximately 110 ms for 10-inch shells. That larger shells take longer to burst (explode) is reasonable, as a result of the need to produce more combustion gases to pressurize their larger volumes.

Reference

1) K. L. and B. J. Kosanke, "Hypothesis Explaining Muzzle Breaks", *Proceedings of the Second International Symposium on Fireworks* (1994). Also in *Selected Publications of K. L. and B. J. Kosanke, Part 3 (1993and 1994)*, Journal of Pyrotechnics (1996).