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Typical Aerial Shell Firing Time Sequence

K. L. and B. J. Kosanke

As part of a continuing study of the nature and causes of aerial shell malfunctions, it was useful to produce a detailed time sequence for the events occurring during the firing of typical (properly functioning) aerial shells. In particular, this information was needed to facilitate the investigation and analysis of those types of malfunctioning aerial shells that explode within or just above their firing mortar. The in-mortar malfunctions are so-called "flowerpots" and "aerial shell detonations" (which are sometimes more accurately referred to as "violent in mortar explosions" or VIMEs). The just-above-the-mortar malfunctions are so-called "muzzle bursts". While it is recognized that few if any non-researchers will find much practical information in this article, it was written in the thought that such information might be of general interest to those wishing to better understand the shell firing process.

The information used in preparing this time sequence of shell firing events comes from several sources, some of which has been published previously. The sources of information include normal and high frame rate video recording of aerial shell firings, mortar pressure profiles (internal mortar pressure as a function of time) during actual shell firings, and simple calculations based Newton's second law of motion (Force = Mass × Acceleration).

The basic configuration of the aerial shell and mortar before firing is shown in Figure 1. In this study it is assumed that the shell is fired using a quick match shell leader with black match as the delay element. When ignited on its very tip, the black match takes an average of 2.6 seconds to burn and reach the quickmatch portion of the shell leader.[1] After reaching the quick match portion of the shell leader, on average another 0.3 second is required for the fire to reach the lift charge.[2]

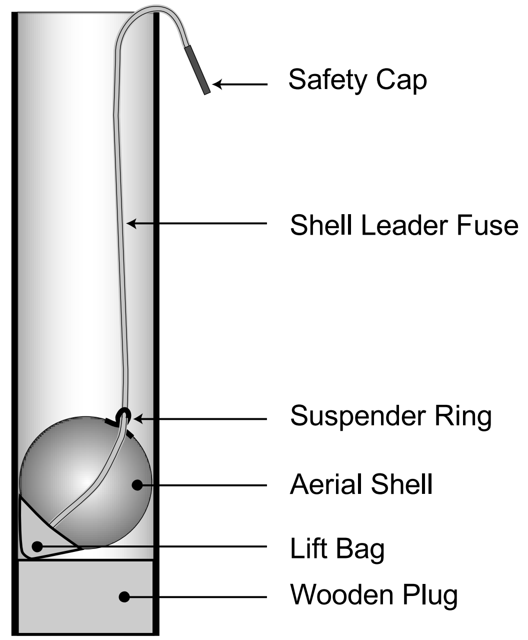

Figure 1. A sketch of an aerial shell in its mortar before firing.

Once the lift charge ignites, the fire propagates through it as substantial amounts of flame begin to be produced. The first (left-most) image of Figure 2 depicts the mortar when the flame has filled the area below the aerial shell and it has advanced around the sides of the shell to just past its top. Based on high frame rate video recordings, this occurs in approximately 7 milliseconds (0.007 second) after the fire from the shell leader first reached the lift charge. (For an electrically fired aerial shell, this would also be the time after the firing of an electric match inserted into the lift charge.) Next in the process, the second image in Figure 2, the flame has advanced up the length of the mortar and just begins to emerge from its top. This requires approximately another 10 milliseconds. However, at this time the pressure under the shell is still insufficient to overcome the force of gravity and cause the shell to begin to move. In the third image, the flame has reached well above the top of the mortar, the mortar pressure below the shell is starting to rise significantly and the

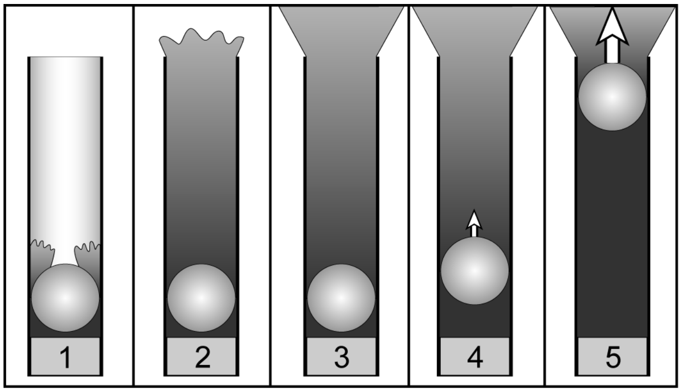

Figure 2. A series of drawings illustrating the sequence of events during a normal aerial shell firing.

upward force on the aerial shell has just reached the point of equaling the downward force of gravity. Time has now advanced approximately another 2 milliseconds. In the fourth image the shell has risen approximately 12 percent of the length of the mortar, and the pressure under the shell has just reached its maximum. This has required approximately another 5 milliseconds. In the fifth image of Figure 2, after another approximately 7 milliseconds, the aerial shell is about to exit the mortar and the pressure under the shell has already decreased substantially. At this point the total time elapsed since the ignition of the lift charge is approximately 31 milliseconds. The now quite rapidly moving aerial shell (traveling at a rate of approximately 500 feet per second) exits the mortar approximately 2 milliseconds later. The total time elapsing since the lift charge was ignited is approximately 33 milliseconds (i.e., 0.033 second). This compares well with previously published results of a series of measurements of aerial shell exit times. In that study, it was found the average exit time for an 8-inch spherical aerial shell was 35 milliseconds.[3]

Details of the mortar pressures developed and the upward progress of the aerial shell is presented in Figure 3, where time zero corresponds to the start of ignition of the lift charge. The solid line in the graph is the mortar pressure developed during the firing of a typical 8-inch spherical aerial shell. The dashed line is the displacement of the aerial shell as it travels up the mortar. This was calculated from the measured mortar pressure as a function of time, and the actual diameter and the mass of the shell. (That the calculation of displacement was correct is confirmed by the fact that the calculated exit time exactly matches the time of shell exit documented by a slight discontinuity in the derivative of the mortar pressure curve.) The numbered pairs of points in Figure 3 correspond to the series of images in Figure 2.

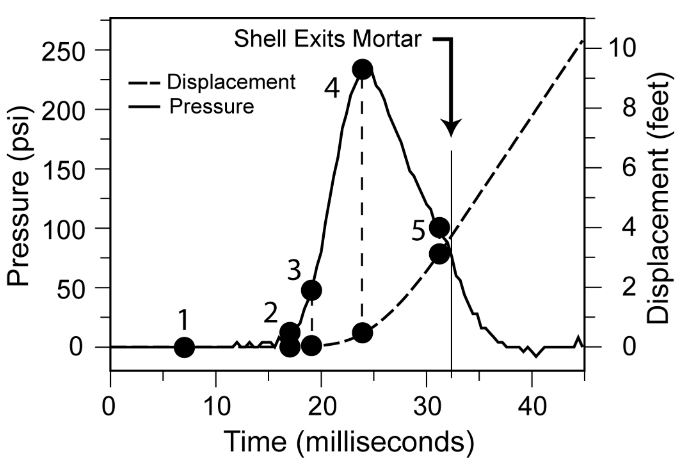

Figure 3. Graphs of mortar pressure and aerial shell displacement as functions of time.

Note that the sequence of events after igniting the lift charge spans a time interval short enough to be perceived by a human observer as occurring instantaneously. While the detailed information about the timing of a normal shell firing presented in this article might be of general interest, its principal usefulness lies in support of studies attempting to discover more about the cause and course of various within-mortar and near-above-mortar aerial shell malfunctions.

References

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