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Aerial Shell Burst Height as a Function of Mortar Length

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[This article is augmented with a number of text notes, indicated using superscript letters. While it is hoped these provide useful information, they are not essential, and the reader may wish to ignore them unless further information is desired.]

From time to time over the years there has been discussion of the effect of mortar length on the burst height achieved by fireworks aerial shells. However, rarely has burst height versus mortar length data been presented,[1,2] even then the data has been of limited value. In one case, the results were predictions using a ballistics model where only the maximum possible height reached by aerial shells was presented, not the measured height at the time of their actual burst.[a] In the other case, only a one shell was fired for each mortar length, and the method of determining the height of the shell burst was rather imprecise. The study being reported in this article is more useful in that actual burst heights were reasonably accurately measured and there were several firings from each mortar length. Unfortunately, this study only examined the effect of mortar length on 3-inch (75-mm) spherical aerial shells. While it is expected that similar results would be found for other shell types and sizes, that cannot be assured.

The test shells used in this study were Thunderbird brand, Color Peony-White (TBA-106). For consistency, all the test shells were taken from the same case of shells. The shells had an average mass of 136 g, with an average diameter of 2.72 inches (69 mm), and an average of 37 g of lift charge (apparently 4FA granulation). The mortars used in this study were high density polyethylene (HDPE) with an inside diameter of 2.93 inches (74.4 mm)[b]. Ten different mortar lengths were used, ranging from a maximum of 60 inches (1.5 m) down to just 6 inches (150 mm) (in each case, the length was measured from above the mortar plug). There were three to five test firings for each mortar length examined, for a total of 42 test firings. Approximately 10 minutes were allowed to elapse between each use of a mortar to allow time for the mortar to cool before its next firing.

The burst height of these shells was determined by measuring the amount of time elapsing between the burst of the shell (as determined optically) and the arrival of the sound of the burst.[c,d] The individual burst heights and a trend line visually fit to those data points are shown in Figure 1.[e] Further, the average burst height for each mortar length is presented in Table 1. While the measured burst heights are probably greater than many might have expected, for a number of reasons it is believed they are correct for the conditions existing for these tests.[g] However, it is the trend in burst height that is of most general interest. Accordingly, presented in the last column of Table 1 are burst heights normalized to that achieved using a 20-inch (510-mm) mortar.[h]

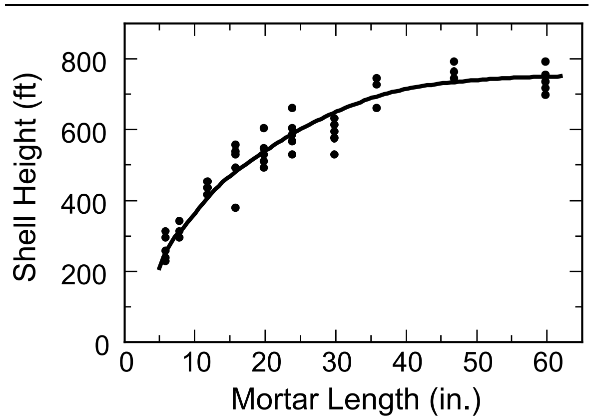

Figure 1. A graph of the burst height results as a function of mortar length for 3-inch spherical aerial shells.

Table 1. Average and Normalized 3-inch Shell Burst Height for Various Mortar Lengths.

Mortar Length (in.)	Number of Tests	Average Height (ft)[f]	Normalized Burst Height
60	5	740	1.39
47	3	760	1.36
36	3	710	1.29
30	5	590	1.20
24	5	590	1.09
20	5	530	≡1.00
16	5	495	0.90
12	3	430	0.76
8	3	310	0.58
6	5	260	0.48

To convert from inches to millimeters, multiply by 25.4.

To convert from feet to meters, multiply by 0.305.

It may be of interest to note that reducing the mortar length from 20 to 6 inches (510 to 150 mm) produced a reduction in the average aerial shell burst height by about 50 percent. This result was somewhat of a surprise, even though earlier calculations using the Shimizu's[1] ballistic model had suggested that the reduction would not be overwhelming. It was surprising because the top of the mortar was only about 2 inches (50 mm) above the top of the aerial shell. Even though model calculations had suggested that the aerial shell would still be propelled to a significant height, it was hard to believe, because it seemed to contradict "common sense".

Increasing the mortar length from 20 to 60 inches (0.51 to 1.5 m) was found to produce an increase in burst height by about 40 percent, with the strong suggestion that further increases in mortar length cannot be expected to produce much more of an increase in burst height. That the effectiveness of ever longer mortars decreased, essentially to the point of no longer producing greater burst height, was not a surprise. This is because ballistic modeling had predicted this and it seemed quite logical.

It is hoped that this brief article provided some interesting and useful information about the effect of mortar length on aerial shell burst height.

Notes

a) For common mortar lengths, aerial shells typically burst prior to reaching what would be their maximum height. There will be a somewhat greater difference between burst height and maximum possible height for longer than normal mortars. Also, for especially short mortars the opposite will be true, where the shells may burst on their way back down, after having reached their maximum height.

b) While the mortar diameter was smaller than desired, it was typical of many HDPE mortars made from commercially produced pipe. This pipe was SDR 17 (standard dimensional ratio), which is specified as having an internal diameter (ID) of 2.97 inches (74.5 mm).[3] However, manufacturers consistently produce pipe with a wall thickness greater than the minimum specification. Because the outside diameter of the pipe is tightly controlled, the thicker walls cause the ID to be less than specified. In this case, the pipe was supplied with an ID of only 2.93 inches (74.4 mm).

c) The air temperature was approximately 68 °F (17 °C) at the time of the measurements. This corresponds to a speed of sound of approximately 1126 feet (343 m) per second, which was the value used in calculating the burst height of the test aerial shells.

d) If desired, see references 4 and 5 for discussions of two slightly different methods using the delay in arrival of the sound of the explosion to determine the distance to the explosion.

e) The average deviation of the individual data points from the trend line is 37 feet (11 m).

f) As an expression of the statistical uncertainty in the measurements, average burst heights are only reported to the nearest 10 feet (3 m).

g) There are a number of reasons for believing the burst height results are correct: 1) the method for determining burst height is simple; 2) the data produced was internally consistent; 3) the testing was conducted in western Colorado at an altitude of 4600 feet (1400 m) above sea level, where the reduced air density results in lower drag forces, allowing aerial shells to reach greater heights than when fired at elevations nearer to sea level; 4) the relatively small internal mortar diameter causes the shells to exit the mortar at greater velocities and thus be propelled to greater heights; and 5) these results are reasonably consistent with previous measurements[6,7] performed at lower elevations and with nominal diameter mortars.

h) A 20-inch (510-mm) mortar length was chosen because it is thought that is the approximate length of the most commonly used mortars for 3-inch (75-mm) single break aerial shells.

References

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