Communications

Brief technical articles, comments on prior articles and book reviews

Shell Altitude vs. Mortar Length

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Introduction

During the mid 1980's, I was the President and General Manager of San Diego Fireworks, Inc. At many of our Pyrotechnic Safety and Training Seminars, I was asked about the correlation between mortar length and altitude attained by aerial shells. Further, I have overheard many theories relating to a "vacuum" created within a mortar, if that mortar is longer than some optimum length. Others have made statements indicating that exceptionally long mortars would project shells well beyond "normal" altitudes for given sizes of shells.

Upon reaching saturation of these various theories, our staff decided to perform some basic tests to see if any of these theories had merit.

Prior to making the determination to conduct this field test, we had the opportunity to view videotape produced by a Japanese firm. This videotape showed shells being fired from a thick-walled glass mortar. Our observations indicated that there was a considerable amount of gas generated by the lift charge and that the vast majority of this gas was produced well after the shell had left the open end of the mortar during launch.

Although our methods were not purely scientific, in that we did not use precise measurement instruments, we did use devices that were recognized in the industry as acceptable and would be able to determine if the theories were in fact accurate or erroneous. We were not looking for precise data, but data sufficient to determine if these theories warranted further investigation.

Approach

The decision was made to purchase a ten-foot length of mortar tube material. The material selected was three-inch i.d. HDPE, a currently approved mortar material by the California State Fire Marshal (CSFM) for use in the public display fireworks industry. This section of tube was fitted with a three-inch o.d. wooden plug that also met the CSFM regulations.

This mortar was used to launch three-inch aerial shells supplied by a manufacturer that we had determined, from past experience, provided consistent quality shells and that demonstrated the most repeatable lift times, when tested for choreography purposes annually. Further, we wanted to be sure to use shells from the exact same production lot, in order to minimize any variations in the product used. We selected a full case of three-inch shells manufactured by Yung-Feng Fireworks. The variety was a Green Chrysanthemum.

The shells were fired using a Daveyfire SA2000 B Electric match that had the head inserted into the lifting charge of each shell. The wire leads from the match were routed through a 1/8-inch hole placed in the base of the mortar, just above the wooden plug. This routing was done to eliminate any potential interference with the launching of the aerial shell. We determined that the gas loss from the 1/8-inch hole was insignificant.

Following each firing, the mortar was cleaned to remove any remaining shell lift bag debris. It was then shortened by six inches. The mortar was again loaded, placed upon a firm plate of steel to minimize recoil, and attached securely to a steel post set vertically in the earth. This was done to assure vertical stability during repetitive firings. This process was repeated until the mortar length reached 12 inches (one foot).

Altitude Measurement

In order to measure—simply, but reasonably accurately—the altitude attained by the shells, we used a commercially available protractor manufactured by Estes Rocket Company, for determining the altitudes of model rockets. The Estes product name was the "Altitrak Altitude Finder" part number 2232.

This device can be calibrated for use at one of three different distances from the launch site to the measurement site. The device is calibrated for use at 75, 150 or 300 meters from the launch site to the measurement site. The three different distances are for three different ranges of altitudes produced by their products. It is recommended that the user select the distance from the launch point to the measurement point that most closely equates to the expected altitude of the device being measured.

The device is aimed at the product being launched and a trigger is pulled back, which releases the measurement pendulum. The product is tracked to the point at which it reaches its apex and the trigger is then released, which captures the position of the pendulum. The altitude is determined by reading the appropriate scale on the pre-calibrated quarter rings on the device. We selected the range of 150 meters from point of launch to point of measurement.

Data Measured

The Table 1 presents the mortar length versus the altitude measured. Figure 1 is a graph of the same data.

Conclusion

Looking at the data and excluding the last data point at the 12-inch mortar length, we find the average altitude was 163.2 meters. The lowest point recorded was 141 meters and the highest point was 186 meters.

We expected some deviation due to other minor characteristics such as shell spin, slight wind drift, and variations inherent in the less than precision method of measurement.

Table 1. Mortar Length vs. Altitude.

Mortar Length (feet)	Altitude (meters)
10.0	141
9.5	157
9.0	186
8.5	142
8.0	169
7.5	147
7.0	167
6.5	171
6.0	178
5.5	159
5.0	175
4.5	166
4.0	156
3.5	164
3.0	170
2.5	172
2.0	155
1.5	163
1.0	74

However, we found that there was no direct correlation between mortar length and attained shell altitude until the mortar was cut to less than 1.5 feet (18 inches) in length. Further, we also found that there is no apparent vacuum created when mortars are excessively long.

Subsequent to our rather crude tests, a formal test was published.[1] This article presents data that is consistent with the data we recorded. The Kosanke and Schwertly data was gathered using a device called the "Pyro-Meter II".

The Pyro-Meter uses electronic counters, latching mechanisms, and optical eyes to precisely measure such altitudes. Their data indicated that the average burst height for a 3-inch shell was 124 meters with a maximum altitude of 140 meters and a minimum of 110 meters. We believe variations between the Kosanke and Schwertly data and our data are attributable to the type of shells used (ball versus cylindrical, which affects wind drag) altitude of the test site, humidity (which affects air density), etc. This also assumes the mortar used in their test was at least 1.5 feet in length.

References

1) K. L. Kosanke, L. A. Schwertly and B. J. Kosanke, "Report of Aerial Shell Burst Height Measurements" *Pyrotechnics Guild International Bulletin*, No. 68, 1990.

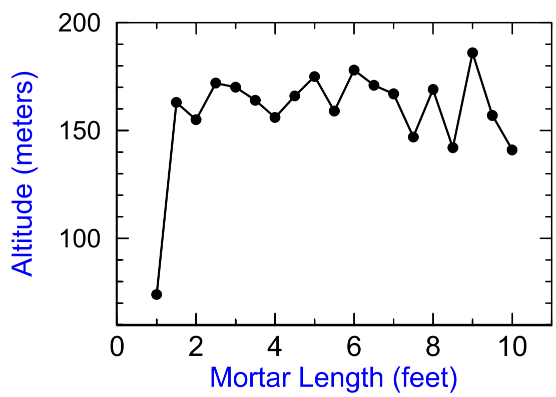

Figure 1. Graph of mortar length versus altitude attained for three-inch shells.