# Measurements of Sound Pressure Levels for Aerial Shell Mortar Firings and Star Shell Bursts

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***Abstract**: A large number of sound pressure level (SPL) measurements were recorded for the firing and bursting of firework star shells ranging in size from 3 to 6 inch (75 to 150 mm). The results of a series of 400 measurements of SPLs of firework aerial shell mortar firings as a function of distance from the mortars are reported. Also, the results of a series of 200 measurements of SPLs of firework star shell explosions occurring at their normal burst heights are reported.*

***Keywords**: Sound pressure levels, shells,*

## Introduction

It is a requirement in many countries that workers must be protected from hearing loss resulting from exposure to loud sounds in their work environment. However, while some data have been published on the sound pressure levels (SPLs) produced by fireworks, those data are far less than exhaustive. This is especially the case for SPL exposures experienced by workers during the course of performing firework displays. To augment the existing data, a large number of measurements of SPLs have been recorded for the impulse sounds produced by firing and functioning of small to medium-size firework star shells.

## Fireworks

Only hard-breaking, well-constructed, Chinese-manufactured, spherical, single-break, chrysanthemum and peony star shells were used for these measurements. Principally, those aerial shells were manufactured by Sunny, Lidu and An Ping. Only small to medium-size star shells, 3 to 6 inch (75 to 150 mm), were used. Salute shells and multi-break shells were not used.

## Instrumentation

The instrument used to record sound pressure levels was a Quest Technologies 1800 (a type 1 instrument), operated in the 'peak' mode and using 'linear' weighting, with a QE-4110 microphone, and calibrated using a Quest Technologies QC-10 calibrator. When calibrated as normal, the maximum SPL capable of being recorded in this configuration is 170 dB. However, under conditions when a few sound levels slightly exceeded this limit, measurements were made with the instrument gain recalibrated to allow measurements to approximately 174 dB. In all cases, the SPL instrument was positioned 5 ft (1.5 m) above the ground, at the approximate level of the ear of a typical person.

In some cases, when recording SPLs not exceeding 140 dB peak-linear, a calibrated Quest Technologies 2700 (a type 2 instrument) using its standard microphone was also used.

## Mortar firing sounds

Sound pressure levels of star shells were recorded at various distances from the firing mortar. Over the range of distances investigated, 12 to 300 ft (3.6 to 90 m), any difference in SPLs for buried mortars versus mortars in above ground racks was insignificant compared with the normal variations in SPL from firing to firing for the same size star shell. Accordingly, to improve the reliability of the data, both data sets (for buried mortars and mortars in racks) were merged.

The data were recorded over an interval of several

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**Table 1.** *Mortar firing SPL data (peak-linear) for 3 inch (75 mm) star shells.*

| Distance[a] (ft) | No. of measurements | Sound pressure level (dB) [b] | | | |
|---|---|---|---|---|---|
| | | Min. | Max. | Average | Fitted |
| 12 | 14 | 152 | 166 | 160 | 156 |
| 25 | 7 | 141 | 153 | 145 | 148 |
| 50 | 21 | 131 | 148 | 141 | 141 |
| 75 | 11 | 128 | 140 | 136 | 139 |
| 100 | 15 | 134 | 142 | 137 | 137 |
| 150 | 17 | 129 | 137 | 134 | 135 |
| 200 | 17 | 123 | 138 | 133 | 132 |
| 300 | 18 | 122 | 139 | 131 | 129 |

[a] To convert feet into SI units (m), divide by 3.28. [b] SPL values are reported to the nearest 1 dB.

years, always in Spring in eastern Tennessee (USA), at an elevation of approximately 1200 feet (470 m) above sea level. On various days, the temperature ranged from approximately 65 to 75 °F (18 to 24 °C). The atmospheric pressure was not recorded, but given the weather conditions was in the normal range.

The mortar firing SPL curves for the different size shells each had the same general shape as a function of distance. This was expected because the physics of sound propagation in this environment changed very little for the different size shells. To improve the statistical reliability of the data, given the wide range in individual test results, the same curve shape was used for all shell sizes. The exception was to adjust the curve slightly up or down for the best fit of the data for each size shell.

Included in the data tables (Tables 1 through 4) that follow are the averaged SPL results along with the minimum and maximum values recorded at each distance. The graphs (Figures 1 through 4) present the averaged SPL results along with the minimum and maximum values recorded at each distance. Also included in the data tables are the curve-fitted SPL results, as a function of distance, taken from the graphs.

## Shell bursts at altitude

Sound pressure levels of spherical, single-break star shell explosions occurring at their typical burst altitudes were recorded. The data were taken under the same physical conditions stated above, and within approximately 100 feet (30 m) of the firing mortars. Based on prior measurements and the atmospheric conditions, the average burst heights would have ranged from approximately 400 feet (120 m) for the 3 inch (75 mm) star shells to 780 feet (240 m) for the 6 inch (150 mm) star shells. These data are presented in Figure 5 and Table 5.

**Table 2.** *Mortar firing SPL data (peak-linear) for 4 inch (100 mm) star shells.*

| Distance [a] (ft) | No. of measurements | Sound pressure level (dB) [b] | | | |
|---|---|---|---|---|---|
| | | Min. | Max. | Average | Fitted |
| 12 | 20 | 155 | 173 | 164 | 160 |
| 25 | 14 | 143 | 158 | 151 | 152 |
| 50 | 11 | 137 | 153 | 146 | 145 |
| 75 | 14 | 137 | 146 | 142 | 143 |
| 100 | 10 | 137 | 143 | 139 | 140 |
| 150 | 8 | 130 | 142 | 138 | 138 |
| 200 | 8 | 133 | 137 | 136 | 136 |
| 300 | 8 | 130 | 134 | 132 | 132 |

[a] To convert feet into SI units (m), divide by 3.28. [b] SPL values are reported to the nearest 1 dB.

**Table 3.** *Mortar firing SPL data (peak-linear) for 5 inch (125 mm) star shells.*

| Distance [a] (ft) | No. of measurements | Sound pressure level (dB) [b] | | | |
|---|---|---|---|---|---|
| | | Min. | Max. | Average | Fitted |
| 12 | 15 | 150 | 169 | 163 | 163 |
| 25 | 12 | 147 | 160 | 154 | 154 |
| 50 | 12 | 138 | 155 | 148 | 148 |
| 75 | 13 | 140 | 151 | 146 | 146 |
| 100 | 11 | 140 | 145 | 143 | 143 |
| 150 | 9 | 137 | 148 | 141 | 141 |
| 200 | 12 | 135 | 145 | 140 | 138 |
| 300 | 8 | 133 | 140 | 135 | 135 |

[a] To convert feet into SI units (m), divide by 3.28. [b] SPL values are reported to the nearest 1 dB.

***Table 4.*** *Mortar firing SPL data (peak-linear) for 6 inch (150 mm) star shells.*

| Distance [a] (ft) | No. of measurements | Sound pressure level (dB) [b] | | | |
|---|---|---|---|---|---|
| | | Min. | Max. | Average | Fitted |
| 12 | 8 | 153 | 174 | 165 | 163 |
| 25 | 25 | 142 | 160 | 154 | 154 |
| 50 | 21 | 141 | 155 | 149 | 148 |
| 75 | 17 | 142 | 151 | 146 | 146 |
| 100 | 8 | 136 | 147 | 144 | 144 |
| 150 | 8 | 138 | 145 | 141 | 141 |
| 200 | 14 | 124 | 146 | 137 | 139 |
| 300 | 6 | 126 | 137 | 132 | 136 |

[a] To convert feet into SI units (m), divide by 3.28. [b] SPL values are reported to the nearest 1 dB.

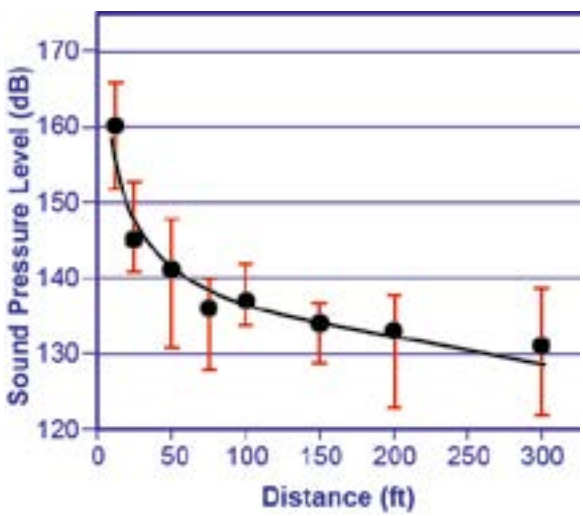


**Figure 1.** *Mortar firing SPL data (peak-linear) for 3 inch (75 mm) star shells.*

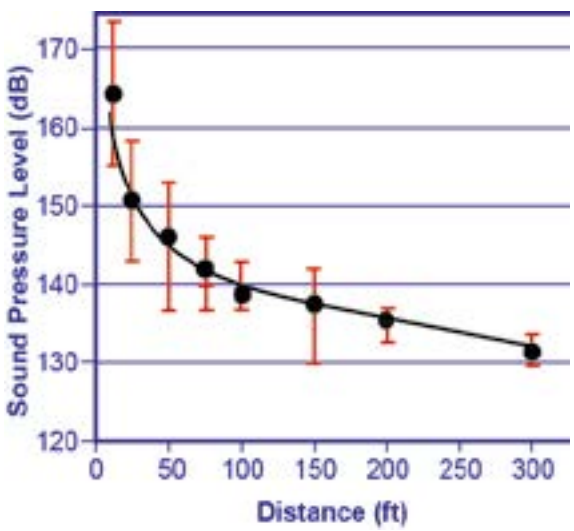


**Figure 2.** *Mortar firing SPL data (peak-linear) for 4 inch (100 mm) star shells.*

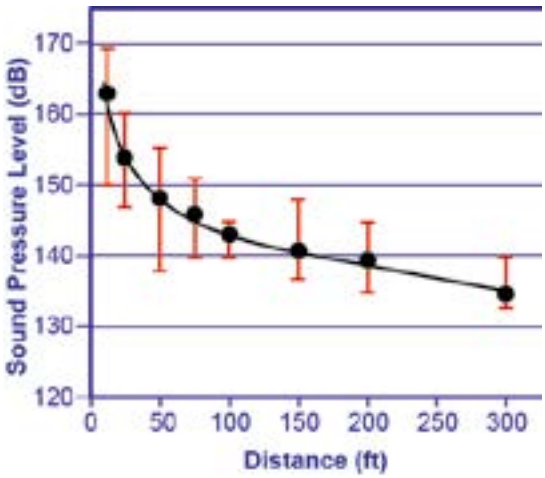


**Figure 3.** *Mortar firing SPL data (peak-linear) for 5 inch (125 mm) star shells.*

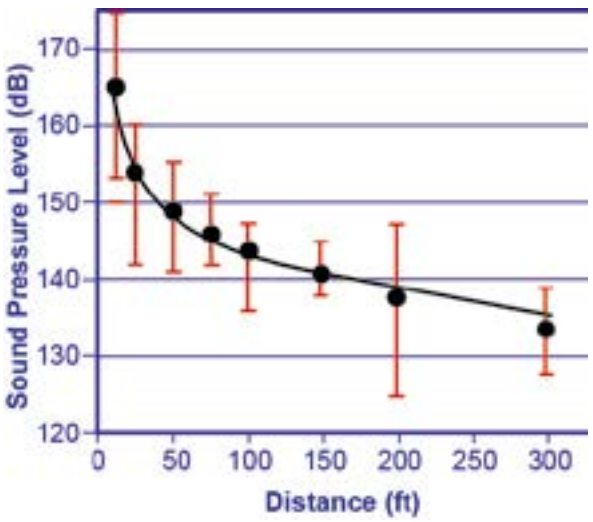


**Figure 4.** *Mortar firing SPL data (peak-linear) for 6 inch (150 mm) star shells.*

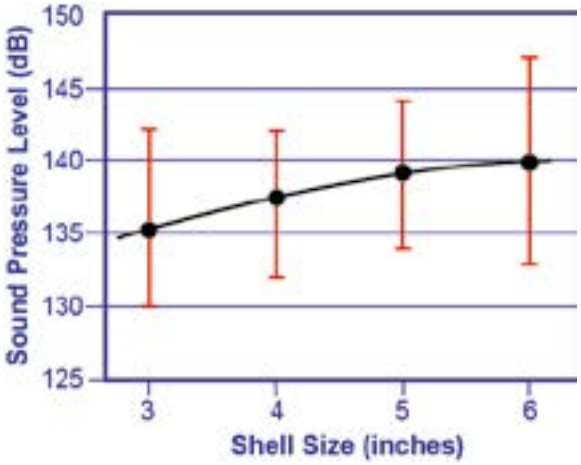


**Figure 5.** *Shell burst SPL data (peak-linear) for 3 to 6 inch (75 to 150 mm) star shells.*

**Table 5.** *Shell burst SPL data (peak-linear) for 3 to 6 inch (75 to 150 mm) star shells.*

| Size [a] (in.) | No. of meas. | Sound pressure level (dB) [b] | | |
|---|---|---|---|---|
| | | Min. | Max. | Ave. |
| 3 | 56 | 130 | 142 | 135.2 |
| 4 | 32 | 132 | 142 | 137.8 |
| 5 | 49 | 134 | 144 | 138.8 |
| 6 | 58 | 133 | 147 | 139.5 |

[a] To approximately convert inches into SI units (mm), multiply by 25. [b] Minimum and maximum levels are reported to the nearest 1 dB and average levels are reported to the nearest 0.1 dB.

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