NBS TECHNICAL NOTE 793

Development of a Procedure for Measuring the Noise of Paper Caps

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Development of a Procedure for Measuring the Noise of Paper Caps

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DEVELOPMENT OF A PROCEDURE FOR MEASURING THE NOISE OF PAPER CAPS

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1. INTRODUCTION

In December 1970, the Bureau of Product Safety of the Food and Drug Administration[1/] requested the National Bureau of Standards to measure the peak sound pressure levels and durations of paper caps fired in toy cap pistols. A series of tests on six cap pistols was subsequently carried out in the anechoic chamber of NBS by members of the Sound Section. A written test method entitled "Method for Determining the Sound Pressure Level Produced by Toy Caps"[1][2/] was issued as a result of these tests. In conjunction with this test method, a set of regulations [2] concerning caps was issued by the Bureau of Product Safety.[1/] These regulations required the following:

1. Caps which exceed peak sound pressure levels of 158 decibels (dB) re: 20μPa[3/] are banned from the market.

2. Caps which produce peak sound pressure levels in the range 138-158 dB must bear a warning label on the carton, and the manufacturer must conduct or participate in a program to develop caps that produce a peak sound pressure level of 138 dB or less. Manufacturers with products in this category must also submit reports to the Consumer Product Safety Commission[1/] on the status of this program.

3. Caps which produce peak sound pressure levels less than 138 dB are allowable on the market with no restrictions.

In 1971 and 1972, a series of additional tests was run by the NBS Applied Acoustics Section for the Bureau of Product Safety to determine into which category of the regulation several different types of caps fell. As these tests proceeded, it was noted that there was a great deal of variation in the measurements. This variation seemed to be attributable to the type of cap pistol used to fire the caps. Proceeding under the assumption that the different peak sound pressure levels produced by the different guns were due to the different firing mechanisms or different spring tensions employed on the various models, it was decided to choose one pistol model at random and use it as a standard firing apparatus. This proved to be unsuccessful since guns of the same type and model did not provide consistent results. Aside from these inconsistencies, it was deemed impractical to designate a particular model and type of cap gun as a standard, since toys are constantly being modified or discontinued, and the standard gun could well become obsolete in a short period of time. With these considerations in mind, the decision was made to design a standard firing apparatus for measuring the noise of paper caps. The results of the measurements referred to above, and a summary of the procedure subsequently developed, are presented in this report.

2. TESTING OF COMMERCIAL CAP GUNS

2.1 Equipment and Set-Up

In order to minimize effects due to acoustic reflections and to maximize consistency in positioning of microphones (with respect to the cap guns), an electro-mechanical apparatus was constructed to hold and trigger the commercial cap guns. This apparatus consisted of a horizontal pipe 0.9 m long which was coated with sound absorptive material and attached to 1.3 m high vertical stand. A sketch of this apparatus can be seen in Figure 1. The gun under test was cemented to a pipe coupling which was screwed to the horizontal arm. A solenoid was connected to a steel rod which in turn pulled the pistol trigger. The solenoid was activated by a relay which was driven by a 25 millisecond voltage pulse. The duration of the pulse was chosen to prevent full excursion of the solenoid, thus avoiding noise from the solenoid striking its frame.

An 1/8-inch condenser microphone with a protective grid was used for sound pressure level measurements. It was located 25 cm from the point of explosion, in accordance with test method 191.17 [1], and positioned so that the microphone diaphragm was always at grazing incidence relative to the outgoing pressure wave from the cap explosion. The microphone was placed so that it was not closer than 1 meter from the floor, ceiling, or any wall of the test room. The apparatus on which the gun was mounted was placed near the center of the room, and tests were run to ascertain that signals reflected by the room boundaries arrived at the microphone well after the end of the primary sound pulse. The microphone was connected to a preamplifier for impedance matching and then to an amplifier which in turn was connected to the vertical amplifier of a storage oscilloscope. Peak amplitudes and durations were obtained directly from the stored trace on the oscilloscope. A second microphone, located approximately 11 cm on

1/ The Consumer Product Safety Act of October 12, 1972, transferred responsibility for these activities from the Bureau of Product Safety, Food and Drug Administration, to the Consumer Product Safety Comm.

2/ The figures in brackets refer to the literature references at the end of this report.

3/ 1 pascal (Pa) = 1 newton per square meter (Nm^{-2}).

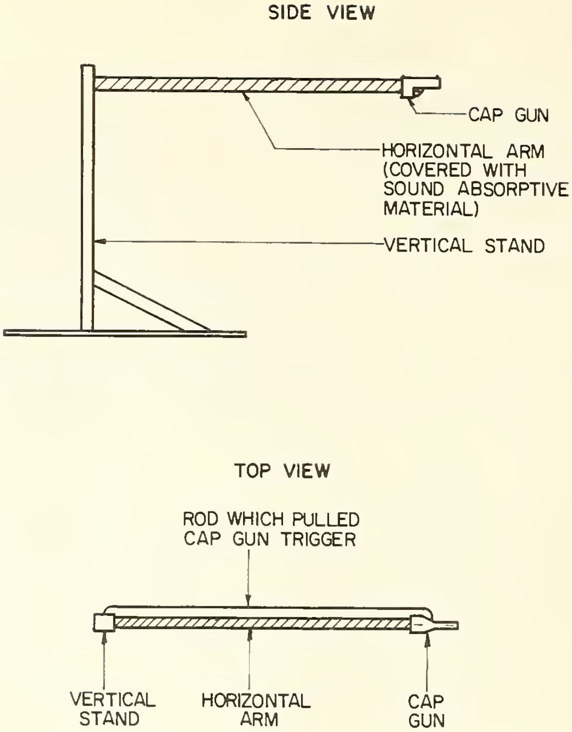

Figure 1. Sketch of apparatus used to hold and fire commercial cap guns.

the opposite side of the cap gun, was used to trigger the sweep of the oscilloscope before the sound wave was transduced by the measuring microphone, thus assuring that the total signal resulting from the explosion of the cap was stored. A pistonphone was used for calibration of the measuring system (microphone, preamplifier, measuring amplifier, and oscilloscope) at one frequency (250 Hz). The calibration was extended over a frequency range of 20 Hz to 70 kHz using an electrostatic actuator. A complete list of the equipment used is given in Appendix B.

Test method 191.17 recommends that the tests be conducted in six test positions (see Figure 2). In early tests, several additional test positions were employed, since it was not certain at that time what positions would be recommended in test method 191.17. However, after the test method was issued, the test configuration used was modified to comply with the published method.

The A- and B-peak voltages and durations for each shot were read from the screen of the storage oscilloscope. For each test condition, averages of the following were obtained: the A-peak voltage, the A-duration, the B-peak voltage, and the B-duration. The peak voltages and durations are as defined in the report issued by the NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) entitled "Proposed Damage-Risk Criterion for Impulse Noise (Gunfire)". [3] Figure 3 illustrates the CHABA definitions of these quantities. In the figure, the positive peak voltage (A-peak) is represented by P_1 and is the highest instantaneous voltage level reached at any time by the impulse. The pressure-wave duration (A-duration) is from point V to point W and is the time required for the initial wave to reach the peak voltage level and return momentarily to the baseline. The B-peak voltage is depicted by P_2 and is the second highest instantaneous voltage level reached at any time during the impulse. The pressure-envelope duration (B-duration) is the total time that the envelope of the pressure fluctuations (positive and negative) is at least 10% of the recorded postive peak pressure level. In Figure 3, the B-duration would be from V to X, plus Y to Z. In the tests of the toy caps, the peak voltages were converted to peak sound pressure levels (in decibels relative to 20 μPa) using the response of the calibrated measuring system.

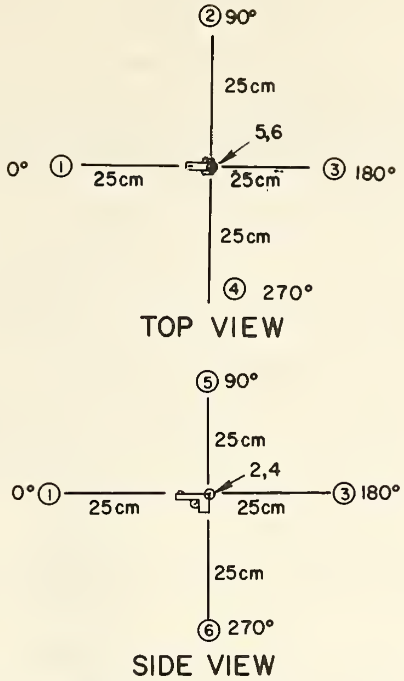

Figure 2. Test configuration for determining the maximum sound pressure level of toy cap guns. All positions were 25 cm from the point of explosion. Positions 1-4 were on a horizontal plane through the cap gun barrel. Position 5 was directly above the point of explosion and position 6 was directly below it.

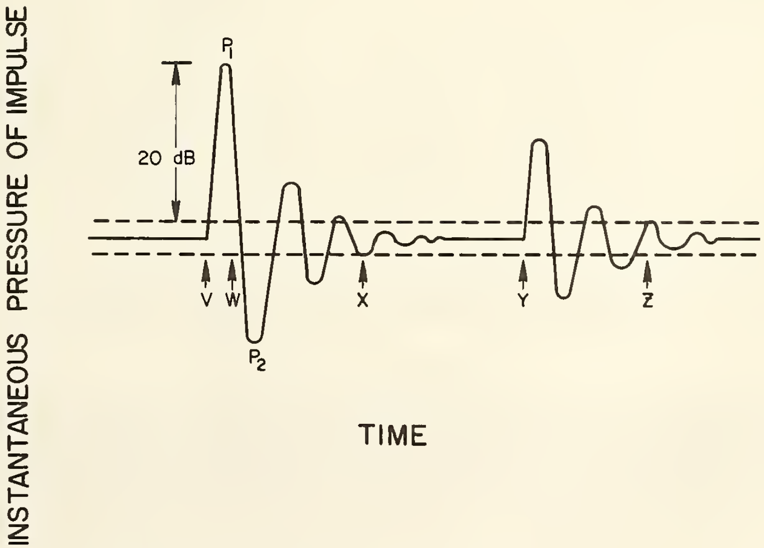

Figure 3. Waveform of impulse noise (gunfire), from Ward, et al. [3]

2.2 Variables Investigated

a. Determination of Position at Which the Maximum Sound Pressure Level Occurred

The first factor investigated was determination of the position at which the maximum peak sound pressure level occurred. Measurements were made, using the equipment described in Section 2.1, at the positions shown in Figure 2. The tests showed that the maximum sound pressure level occurred when the microphone was placed at position 5. Although the difference between the results at position 5 and those at the other positions were judged to be insignificant, the maximum average readings consistently occurred at position 5.

b. Effect of Type of Cap Pistol

In order to determine the variability introduced by different models of cap guns, it was decided to test four commercial toy cap guns, using a single brand of caps. The four cap guns were made by the same manufacturer and were designated as Nos. 1, 2, 3, and 4. Cap guns 1 and 2 were the same model. The caps used in these tests were designated as Type A.

The procedures for taking data and for calibration were identical to those described in Section 2.1. The tests were conducted at positions 1-6, as shown in Figure 2, and a total of ten shots was fired at each position. The data taken verify that position 5 was the position of maximum sound pressure level for all four guns (see Table 1). As can be observed from the data, the difference between the highest and lowest average values (guns 1 and 4) amounted to 9 dB. Even the difference between the same model cap pistols (guns 1 and 2) was 5 dB. This variation was considered to be significant, and with this and the other considerations mentioned in Section 1 in mind, a decision was made to develop a standard firing apparatus for paper caps.

Table 1. Average positive peak sound pressure levels (based on ten shots) and range of values for four cap pistols using Type A caps*. Position refers to those shown in Figure 1.

Cap Pistol Type	Average A-peak, in dB re: 20 μPa					
	Position					
	1	2	3	4	5	6
#1	149^{+2}_{-1}	160^{+2}_{-2}	158^{+2}_{-2}	152^{+4}_{-6}	160^{+1}_{-3}	149^{+2}_{-2}
#2	146^{+3}_{-5}	151^{+3}_{-3}	153^{+2}_{-3}	152^{+3}_{-4}	155^{+2}_{-2}	149^{+4}_{-3}
#3	154^{+4}_{-4}	150^{+3}_{-3}	147^{+2}_{-4}	151^{+3}_{-3}	158^{+3}_{-3}	143^{+1}_{-3}
#4	145^{+3}_{-7}	143^{+8}_{-4}	150^{+2}_{-5}	149^{+2}_{-4}	151^{+4}_{-6}	145^{+4}_{-5}

*Detailed data on the average A-peak, A-duration, B-peak, and B-duration can be found in Tables C-1 through C-4 of Appendix C.

3. DEVELOPMENT OF STANDARD CAP GUN

The standard cap gun which was developed is shown in Figure 4. It consists of a chamber (partially filled with lead shot) which slides up and down on a rod supported from above, in this case, by a drill press. (The drill press is not a necessary part of the standard cap gun apparatus. For these tests, it was merely a convenient means of holding the cap gun in position.) The outer tube is held suspended by a solenoid attached to the upper section of the rod. A hammer, .95 cm square, is mounted on the bottom of the chamber. Underneath the chamber and hammer is an anvil supported by a base. The caps to be tested are placed, one at a time, in this anvil prior to being fired.

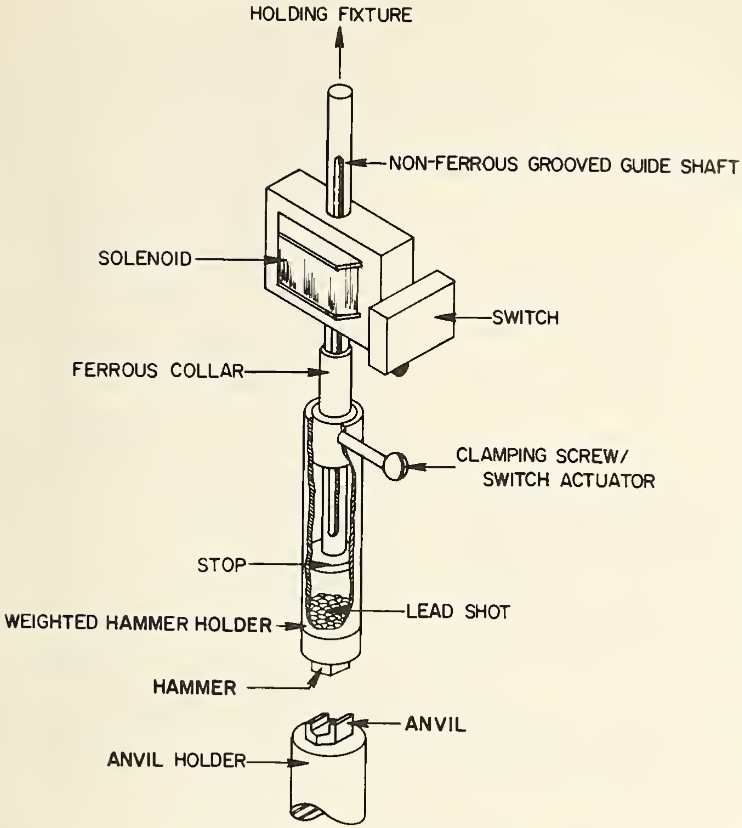

Figure 4. Simplified drawing of the standard cap gun.

In order to operate the cap gun, the chamber which carries the hammer is raised manually until the magnet latches it. A single cap is placed in the center of the anvil. When the power to the electro-magnet is turned off, the chamber bearing the hammer is released, thus dropping the hammer and firing the cap resting in the anvil. Detailed engineering drawings of the standard cap gun apparatus can be found in Appendix D.

3.1 Description of Test Set-Up

The tests of the standard cap gun were conducted using the general procedures for taking data and for calibration described in Section 2.1. Data were taken at six microphone positions, each being 25 cm from the point of explosion (see Figure 5) and a total of ten shots was fired at each position. Type B roll caps4/ were used for all tests conducted on the standard cap gun.

3.2 Variables Investigated

a. Type of Hammer

It was important to know whether imprecise machining of the hammer used on the standard cap gun would cause any variation in the results. Therefore, several different hammers (see Figure 6) were used, and sound pressure level measurements were made at the six microphone positions shown in Figure 5. For these tests, the total mass of the hammer plus chamber was 1.25 kg. In all cases, the hammers were dropped 3.5 cm. corresponding to a momentum at impact of 1.0 kg m s^{-1}. The average peak sound pressure levels (A-peak) and range of values recorded in these tests are given in Table 2. As can be seen from

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4/ Although Type A roll caps were used in the previous tests on commercial cap guns, it was found, both from the data taken and through visual inspection, that there was a great deal of variability among rolls of the Type A cap and among caps on the same roll. For example, on a roll of Type A caps chosen at random, the diameter of the powder spots varied from 2.5 mm to 3.5 mm. On this same roll several powder spots were surrounded by stray nodules of gun powder. Both these factors can affect the sound level output of the caps. Since the purpose of the tests on the standard cap gun was to ascertain its variability, it was important to keep the variability of the caps to a minimum, and Type B caps met this requirement better than Type A. A second consideration of less importance is that the Type B caps misfired less often than the Type A, thus resulting in a considerable saving of time over the course of the tests. It should also be noted that Type B caps were tested in commercial cap pistols, and the A-peak levels recorded were similar to Type A caps.

the data, the difference between the highest and lowest average peak levels was only 3 dB, and in most cases, the average data values were in the 156-157 dB range. These data indicate that it did not matter which hammer was used when conducting tests with the standard cap gun, and thus, that precise machining of the hammer is not a critical factor.

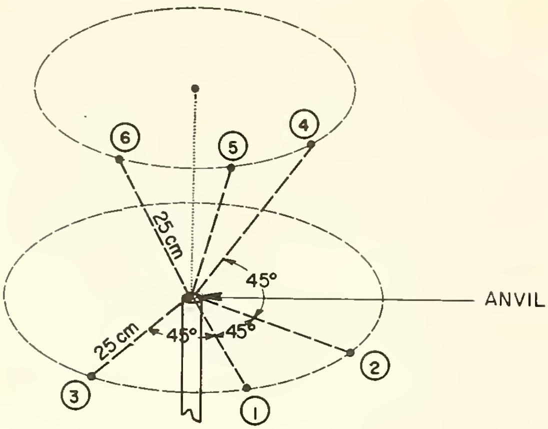


Figure 5. Positions used to determine the sound pressure levels of caps fired in the standard cap gun. All positions were 25 cm from the point of explosion. Positions 1-3 were on a horizontal plane through the cap gun anvil, with position 1 being in front of the slot in the anvil and positions 2 and 3 being 45° to either side. Positions 4-6 were 45° above the point of explosion, with position 5 in front of the anvil, and positions 4 and 6, 45° to either side.

Since all the tests that had been carried out on commercial caps and cap guns had been done with Type A roll caps, it was decided to test a commercial gun using Type B caps. From this information, it could then be determined if the data from the standard cap gun were representative of commercial products. The firing apparatus for commercial cap guns was set up and cap gun No. 1 loaded with Type B caps was attached to it. Measurements were taken only at the maximum position (position 5) of the test configuration shown in Figure 2. It should be noted that position 5 of Figure 2 is not necessarily equivalent to any of the positions used for testing the standard cap gun, although, superficially, it would be expected to correspond most closely to position 1 of Figure 5. The average A-peak sound pressure level found for cap gun 1 (position 5) was: 155^{+4}_{-7} dB*. Comparing this to the results given in Table 2, it can be seen that this average value is within +3, -4 dB of the average values obtained for the various hammers. Thus, it can be concluded that (1) within the range examined, the hammer configuration does not affect the measurement results, and (2) the results produced are representative of commercial cap guns.

Although it has been stated that the choice of hammer and its machining makes little difference in the results, it is recommended that the type (e) hammer (dome-shaped with 2.54 cm (1 in.) radius) be used because it is easy to make, and causes fewer misfires. In addition, the grooved hammers would not be recommended at all. The grooves tend to become clogged with cap debris and have to be cleaned after every fifth shot. This cleaning process is more time-consuming than actually running the tests.

b. Impact of Striking Device

It was found that if the 1.25 kg hammer and chamber were dropped a distance less than 3.5 cm, the caps would not consistently explode. To determine if increasing the drop height affected the experimental results, hammer type (e) (dome-shaped with 2.54 cm radius) was placed on the standard cap gun, and the drop height was increased to 9.5 cm, corresponding to a momentum at impact of 1.7 kg m s^{-1}. The mass of the hammer plus chamber was not changed. The averages and ranges of A-peak sound pressure levels for this test5/ are compared in Table 3 with the corresponding data (i.e., those for hammer e) from Table 2.

*Detailed data on the average A-peak, A-duration, B-peak, and B-duration are given in Table C-11 of Appendix C.

5/ Detailed data on the average A-peak, A-duration, B-peak, and B-duration are given in Table C-12 of Appendix C.

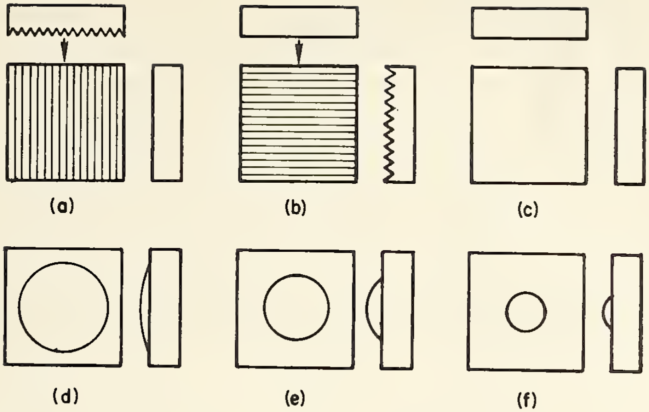


Figure 6. Types of hammer used in testing the standard cap gun. The main drawing of each hammer shows the hammer as it would appear when held suspended and viewed from underneath. Front and side views (the arrow indicates the direction of alignment with the open end of the anvil) are given to provide a better perspective of each hammer. Type (a) had grooves cut into it in order to resemble the firing hammer of a commercial cap gun. Type (b) is type (a) hammer turned 90°. Type (c) is flat. Types (d), (e), and (f) are dome-shaped with surface radii of 7.62 cm, 2.54 cm, and 1.27 cm, respectively.

Table 2. Average and range of A-peak sound pressure levels (based on ten shots) for the six hammers tested with the standard cap gun using Type B caps*. In all cases, the hammer and chamber weighed a total 1.25 kg and were dropped 3.5 cm. Positions refer to those shown in Figure 5.

Hammer Type	Average A-Peak, in dB re: 20 µPa					
	Position					
	1	2	3	4	5	6
a	158^{+3}_{-5}	156^{+4}_{-6}	154^{+1}_{-3}	154^{+4}_{-4}	157^{+2}_{-2}	153^{+3}_{-3}
b	156^{+3}_{-5}	157^{+4}_{-4}	154^{+5}_{-5}	152^{+3}_{-7}	151^{+4}_{-6}	151^{+4}_{-5}
c	155^{+4}_{-8}	151^{+3}_{-5}	154^{+3}_{-3}	155^{+4}_{-3}	153^{+3}_{-3}	155^{+3}_{-5}
d	153^{+4}_{-4}	153^{+3}_{-6}	155^{+3}_{-9}	153^{+5}_{-4}	156^{+3}_{-9}	155^{+3}_{-4}
e	156^{+2}_{-7}	155^{+4}_{-6}	153^{+3}_{-6}	153^{+4}_{-2}	153^{+4}_{-3}	153^{+3}_{-5}
f	157^{+2}_{-3}	156^{+2}_{-3}	153^{+4}_{-5}	155^{+3}_{-5}	156^{+1}_{-3}	155^{+3}_{-3}

*Detailed data on the average A-peak, A-duration, B-peak, and B-duration are given in Tables C-5 through C-10 of Appendix C.

Table 3. Comparison of A-peak sound pressure levels (based on ten shots) corresponding to hammer drop heights of 3.5 and 9.5 cm. (The hammer was type e. Positions refer to those shown in Figure 5.)

Hammer Drop Height, cm	Average A-peak, in dB re: 20 μPa					
	Position					
	1	2	3	4	5	6
3.5	156^{+2}_{-7}	155^{+4}_{-6}	153^{+3}_{-6}	153^{+4}_{-2}	153^{+4}_{-3}	153^{+3}_{-5}
9.5	155^{+6}_{-3}	156^{+2}_{-7}	156^{+4}_{-7}	155^{+3}_{-4}	155^{+4}_{-4}	155^{+3}_{-4}
Difference	-1	+1	+3	+2	+2	+2

The differences are seen to be small, and probably not statistically significant, in comparison with the spread in individual readings due mostly to the variation among individual caps. Thus, for the A-peak sound pressure level readings taken at hammer drop heights of 3.5 and 9.5 cm, it appears that the height from which the hammer is dropped does not significantly affect the data.6/

3.3 Findings

In summary, the use of different hammers or adjustment of the height from which the hammer dropped had no significant effect on the results of measurements made with the standard cap gun. Also, the standard cap gun produces results similar to those of a commercial cap gun. This should allay any concerns as to whether the standard apparatus is representative of the real-world situation. Therefore, on the basis of this information, the standard cap gun is recommended as a reliable means for detonating paper caps in a reproducible manner. The procedure for use of the standard cap gun is presented in the following section of this report.

4. RECOMMENDED PROCEDURE FOR MEASURING THE NOISE OF PAPER CAPS7/

4.1 Standard Cap Gun

The standard cap gun shall consist of a hammer which strikes the cap, an anvil in which the cap is placed, and a mechanism by which the hammer may be dropped from a fixed height so as to accurately strike the cap in the anvil. Specifically, the cap gun shall meet the following specifications:

1. The steel hammer (see Figures 7 and D-2) shall be 0.95±.05 cm square and at least 0.6 cm thick. The bottom of the hammer (i.e., the face which strikes the cap) shall be convex, with a 2.5±0.5 cm radius of curvature. The hammer shall be rigidly attached to the center of the bottom of a metal weight such that the combined mass of the hammer and weight is 1.25±.10 kg. No lateral dimension of the weight shall exceed 2.6 cm.

2. The steel anvil shall be of the general configuration shown in Figures 7 and D-2. The recessed portion in which the cap is placed shall be 1.1 cm wide so that the hammer, when dropped, will consistently strike the bottom of the receptacle squarely without touching the sides. The anvil shall be rigidly attached to a rigid pedestal which is at least 20 cm high with no lateral dimension exceeding 2.6 cm. The pedestal in turn shall be rigidly affixed to a massive, rigid base.

3. The mechanism which is used to drop the hammer shall be such as to ensure that the hammer drops squarely, without rotating, into the receptacle in the anvil. The mechanism shall be such as to ensure that the hammer drops 3.5±0.5 cm before striking the anvil.

6/ It may seem that there is a contradiction between these findings and the much larger variations in peak sound pressure level which resulted from the use of different commercial cap guns. It is postulated that the variations observed for different commercial guns were due to one or more of a number of factors which affected acoustic radiation from the point of the explosion. These include: the design of the anvil in which the cap rests, the angle at which the hammer strikes relative to the anvil, and the extent to which the small mass of the hammer and the varying spring tension permit hammer recoil after the explosion. In the standard cap gun described here, anvil design is held constant, the hammer always hits squarely, and the hammer is too massive to recoil significantly under the force of the explosion.

7/ The standard cap gun is not, at this time, part of any Federal regulation.

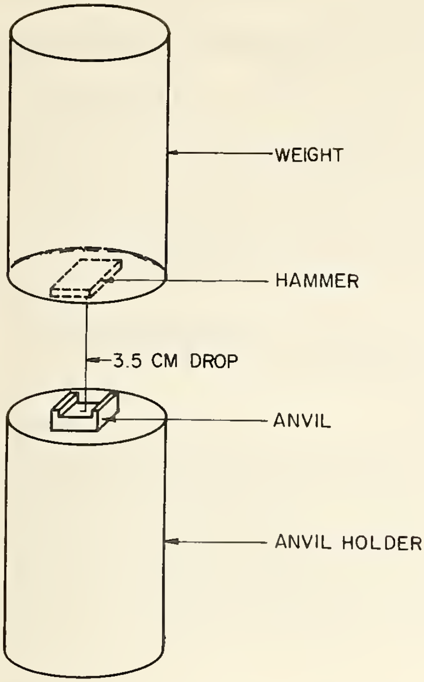


Figure 7. Orientation of hammer and anvil on standard cap gun.

4.2 Measurement Instrumentation

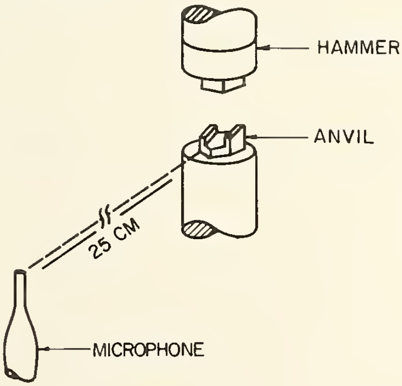
The measurement system for the test shall include a microphone, a preamplifier, and an oscilloscope.

(1) The measurement system shall have a free-field response uniform to within ±2 decibels from 50 hertz to 70 kilohertz or beyond and a dynamic range covering the interval 70 to 160 decibels relative to 20 micropascals. Depending on the model, the microphone shall be used at normal or at grazing incidence, whichever gives the most uniform free-field response. The microphone-preamplifier system shall be calibrated both before and after the test of the standard cap gun. The calibration shall be accurate to within ±1 decibel. If the calibration is of the pressure type or of the pistonphone plus electrostatic actuator type, it shall be corrected to free-field conditions in accordance with the manufacturer's instructions.

(2) The oscilloscope shall be the storage type or one equipped with a camera. It shall have a response uniform to within ±1 decibel from 50 hertz to 250 kilohertz or higher. It shall be calibrated to within ±1 decibel against an external voltage source periodically during the tests.

4.3 Measurement Procedure

(1) Place the cap gun and testing equipment so that neither the cap gun or microphone is closer than 1 meter from any wall, floor, or other large obstruction. Locate the cap gun and the microphone in the same horizontal plane, in line with the opening of the anvil, with a distance of 25 cm between the diaphragm of the microphone and the point of explosion (see the figure below). Let the hammer drop a height of 3.5 cm. Measure the resultant peak sound pressure levels and durations in accordance with the CHABA impulse-noise damage-risk criteria [3].



(2) Fire 25 shots, obtaining readings on the oscilloscope of the maximum peak voltages and durations for each shot. Average the results of the 25 firings.

(3) Convert the average voltage value to sound pressure level in decibels relative to 20 micropascals using the response to the calibrated measuring system.

4.4 Reporting of Results

The following information shall be recorded for each type of cap tested:

(1) Complete identification and description of the test equipment.

(2) Complete identification of materials tested.

(3) Complete description of deviations, if any, from the prescribed test procedure.

(4) Number of shots fired during test.

(5) Average A- and B-peak sound pressure levels and durations recorded during tests.

(6) Range of recorded sound pressure levels and durations.

5. REFERENCES

[1] U. S. Federal Register, Method for Determining the Sound Pressure Level Produced by Toy Caps, 36, No. 134, Section 191.17, p. 13030 (July 13, 1971). This standard is reproduced in Appendix A.

[2] U. S. Federal Register, Exemptions from Classification as a Banned Toy, 36, No. 134, Section 191.65a, p. 13030 (July 13, 1971).

[3] Ward, W. D., et al, Proposed Damage Risk Criterion for Impulse Noise (Gunfire), Report of Working Group 57, NAS-NRC Committee on Hearing, Bioacoustics and Biomechanics (CHABA) (July 1968).

191.17. Method for Determining the Sound Pressure Level Produced by Toy Caps. (From: Federal Register 36, No. 134, p. 13030, July 13, 1971)

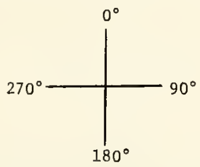
(a) Equipment Required. The equipment for the test includes a microphone, a preamplifier (if required), and an oscilloscope.

(1) The microphone-preamplifier system shall have a free-field response uniform to within ± 2 decibels from 50 hertz to 70 kilohertz or beyond and a dynamic range covering the interval 70 to 160 decibels relative to 20 micronewtons per square meter. Depending on the model, the microphone shall be used at normal or at grazing incidence, whichever gives the most uniform free-field response. The microphone shall be calibrated both before and after the test of a model of cap. The calibration shall be accurate to within ± 1 decibel. If the calibration is of the pressure type or of the pistonphone plus electrostatic actuator type, it shall be corrected to free-field conditions in accordance with the manufacturer's instruction.

(2) The oscilloscope shall be the storage type or one equipped with a camera. It shall have a response uniform to within ± 1 decibel from 50 hertz to 250 kilohertz or higher. It shall be calibrated to within ± 1 decibel against an external voltage source periodically during the tests.

(b) Procedure.

(1) Use the type pistol that would ordinarily be used with the caps being tested. Place the pistol and testing equipment so that neither the pistol nor the microphone is closer than 1 meter from any wall, floor, ceiling, or other large obstruction. Locate the pistol and the microphone in the same horizontal plane with a distance of 25 centimeters between the diaphragm of the microphone and the position of the explosive. Measure the peak sound pressure level at each of the six designated orientations of the pistol with respect to the measuring microphone. The 0° orientation corresponds to the muzzle of the pistol pointing at the microphone. The 90°, 180°, and 270° orientations are measured in a clockwise direction when looking down on the pistol with its barrel horizontal, as illustrated by the following figure.



(2) The hammer and trigger orientations are obtained by rotating the pistol about the axis of the barrel, when the pistol is in the 90° or 270° orientation, so that the hammer and the trigger are each respectively closest to and in the same horizontal plane with the microphone.

(3) Fire 10 shots at each of the six orientations, obtaining readings on the oscilloscope of the maximum peak voltage for each shot. Average the results of the 10 firings for each of the six orientations.

(4) Using the orientation that yields the highest average value, convert the value to sound pressure levels in decibels relative to 20 micronewtons per square meter using the response to the calibrated measuring microphone.

APPENDIX B

List of Equipment

Manufacturer[a/]	Instrument	Model No.
	Measuring Equipment	
Brüel & Kjaer	1/8-inch Microphone	4138
Brüel & Kjaer	Adapter	UA 0036
Brüel & Kjaer	Preamplifier	2619
Brüel & Kjaer	Measuring Amplifier	2606
Brüel & Kjaer	1/4-inch Microphone	4136
Brüel & Kjaer	Adapter	UA 0035
Brüel & Kjaer	Preamplifier	2619
Brüel & Kjaer	Sound Level Meter	2204
Tektronix	Oscilloscope	[b/]
	Calibration Equipment	
Brüel & Kjaer	Pistonphone	4220
Brüel & Kjaer	Beat Frequency Oscillator	1022
Brüel & Kjaer	Graphic Level Recorder	2305
Brüel & Kjaer	Microphone Calibration Apparatus	4142
Brüel & Kjaer	Measuring Amplifier	2606
Brüel & Kjaer	Electrostatic Acutator	UA 0033

[a/] Certain commercial equipment, instruments, and materials are identified in this report in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

[b/] In the tests made on commercial cap guns and caps to determine the position at which the maximum peak sound pressure level occurred, a Tektronix 549 oscilloscope was used. In all other tests, a Tektronix 564 storage oscilloscope, 3A6 vertical amplifier, and a 2B67 time base were used.

APPENDIX C

Complete Results of Measurements Made Using Four Cap Guns and the Standard Cap Gun

The following tables contain the complete results of measurements made using cap pistol Nos. 1-4 (employing Type A roll caps) and the standard cap gun (employing Type B roll caps). The average A-peak sound pressure levels were previously summarized in Tables 1 and 2 of this report.

Table C-1. Average peak sound pressure levels and durations (based on ten shots) for cap gun No. 1 using Type A roll caps. Position refers to those shown in Figure 1.

Position	1	2	3	4	5	6
A-peak, dB	149	160	158	152	160	149
A-duration, ms	.07	.05	.06	.05	.04	.08
B-peak, dB	142	150	154	143	150	144
B-duration, ms	.30	.28	.29	.31	.32	.36

Table C-2. Average peak sound pressure levels and durations (based on ten shots) for cap gun No. 2 using Type A roll caps. Position refers to those shown in Figure 1.

Position	1	2	3	4	5	6
A-peak, dB	146	151	152	152	155	149
A-duration, ms	.06	.05	.06	.05	.05	.06
B-peak, dB	140	144	149	146	150	145
B-duration, ms	.33	.35	.32	.39	.38	.36

Table C-3. Average peak sound pressure levels and durations (based on ten shots) for cap gun No. 3 using Type A roll caps. Position refers to those shown in Figure 1.

Position	1	2	3	4	5	6
A-peak, dB	154	150	147	151	158	143
A-duration, ms	.05	.05	.07	.06	.05	.07
B-peak, dB	148	144	143	146	152	137
B-duration, ms	.31	.26	.28	.28	.32	.41

Table C-4. Average peak sound pressure levels and durations (based on ten shots) for cap gun No. 4 using Type A roll caps. Position refers to those shown in Figure 1.

Position	1	2	3	4	5	6
A-peak, dB	145	143	150	149	151	145
A-duration, ms	.08	.04	.05	.04	.05	.08
B-peak, dB	140	142	147	146	146	144
B-duration, ms	.34	.32	.32	.34	.32	.34

Table C-5. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (a) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Position refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	158	156	154	154	157	153
A-duration, ms	.06	.05	.05	.06	.06	.06
B-peak, dB	150	147	146	148	149	146
B-duration, ms	.40	.34	.31	.31	.35	.35

Table C-6. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (b) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Positon refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	156	157	154	152	151	151
A-duration, ms	.05	.05	.05	.06	.06	.05
B-peak, dB	147	151	147	146	145	146
B-duration,ms	.25	.28	.26	.32	.29	.32

Table C-7. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (c) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Position refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	155	151	154	155	153	155
A-duration, ms	.04	.05	.04	.05	.05	.06
B-peak, dB	148	144	148	148	146	148
B-duration, ms	.27	.28	.26	.33	.29	.32

Table C-8. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (d) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Positon refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	153	153	155	153	156	155
A-duration, ms	.05	.05	.04	.06	.06	.06
B-peak, dB	146	147	148	146	149	148
B-duration, ms	.30	.29	.32	.26	.25	.26

Table C-9. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (e) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Position refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	156	155	153	153	153	153
A-duration, ms	.04	.04	.05	.05	.05	.06
B-peak, dB	148	148	146	148	147	147
B-duration, ms	.28	.26	.29	.32	.31	.32

Table C-10. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (f) (see Figure 6) using Type B roll caps and dropped from a height of 3.5 cm. Position refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	157	156	153	155	156	155
A-duration, ms	.04	.04	.04	.05	.04	.05
B-peak, dB	149	149	146	148	149	147
B-duration, ms	.24	.26	.26	.28	.29	.29

Table C-11. Average peak sound pressure levels and durations (based on ten shots) at the maximum position for cap gun No. 1 using Type B roll caps. Position refers to that shown in Figure 1.

	Position 5
A-peak, dB	155
A-duration, ms	.05
B-peak, dB	148
B-duration, ms	.39

Table C-12. Average peak sound pressure levels and durations (based on ten shots) for hammer Type (e) (see Figure 6) using Type B roll caps and dropped from a height of 9.5 cm. Position refers to those shown in Figure 5.

Position	1	2	3	4	5	6
A-peak, dB	155	156	156	155	155	155
A-duration, ms	.05	.05	.05	.05	.04	.05
B-peak, dB	148	150	148	149	147	148
B-duration, ms	.27	.30	.27	.31	.32	.30

APPENDIX D

Engineering Drawings of the Standard Cap Gun

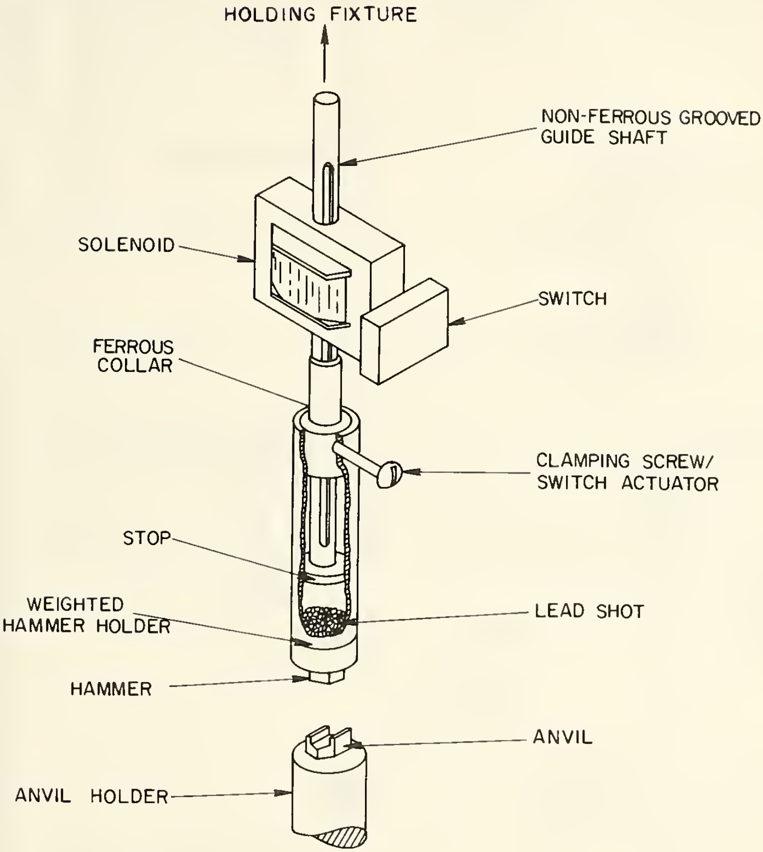


Figure D-1. Assembly drawing of the standard cap gun.

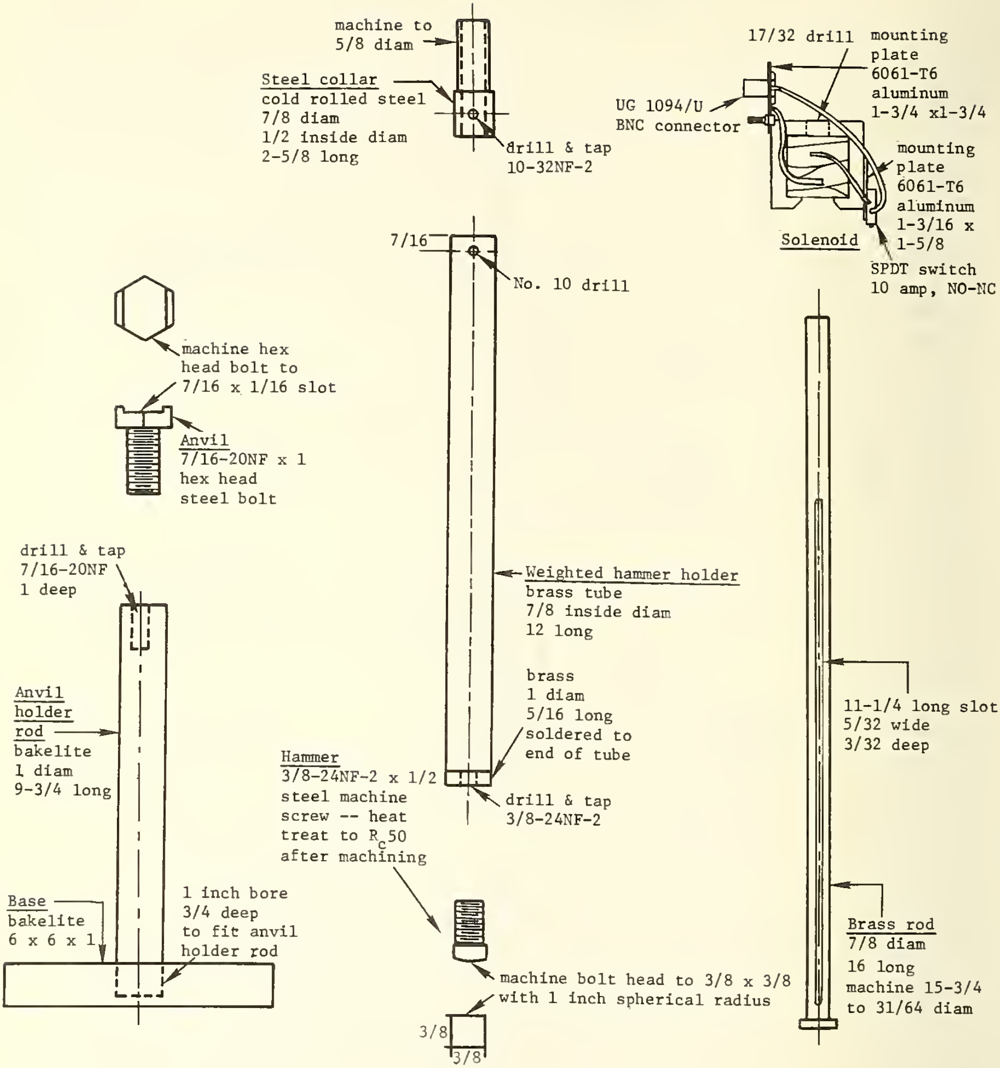


Figure D-2. Machine drawing of the standard cap gun (all dimensions are in inches, 1 inch = 2.54 cm).

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

In recent years, a great concern has been expressed for consumer protection and safety, especially for children. As an outgrowth of this concern, acoustical testing of potentially hazardous noise-producing toys has been carried out at the National Bureau of Standards for the Bureau of Product Safety (FDA) under the authority of the Toy Safety Act of 1969. This paper discusses in detail the testing work carried out on commercial cap guns and caps, which culminated in the development of a standard firing apparatus for testing paper caps. Engineering drawings of the standard apparatus are given as well as a recommended procedure for using this apparatus to test paper caps.

17. KEY WORDS (Alphabetical order, separated by semicolons)

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