NBSIR 75-693

Measurement Methodology for Determining the Sound Output of Model Airplanes and Noise Producing Bicycle Attachments

Marilyn A. Cadoff and William A. Leasure, Jr.

Applied Acoustics Section
Mechanics Division
Institute for Basic Standards
National Bureau of Standards
Washington, D. C. 20234

April 1975

Final Report for Period 7/73—6/74

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, Maryland 20014

NBSIR 75-693

MEASUREMENT METHODOLOGY FOR DETERMINING THE SOUND OUTPUT OF MODEL AIRPLANES AND NOISE PRODUCING BICYCLE ATTACHMENTS

Marilyn A. Cadoff and William A. Leasure, Jr.

Applied Acoustics Section
Mechanics Division
Institute for Basic Standards
National Bureau of Standards
Washington, D. C. 20234

April 1975

Final Report for Period 7/73 – 6/74

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Bethesda, Maryland 20014

U. S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

MEASUREMENT METHODOLOGY FOR DETERMINING THE SOUND OUTPUT OF MODEL AIRPLANES AND NOISE PRODUCING BICYCLE ATTACHMENTS

1. Introduction

The Applied Acoustics Section of the National Bureau of Standards is conducting an ongoing program for the Consumer Product Safety Commission which was intended to: (1) identify noise producing toys which are potentially hazardous to children's hearing and/or safety, (2) develop generic test methods by which the noise exposure due to such toys can be determined, and (3) acquire data on selected toys as requested by the Consumer Product Safety Commission.

At present, there is no measurement methodology for determining the noise levels associated with model airplanes or noise producing bicycle attachments (e.g., horns and devices which imitate motor sounds), and there is no known existing data base. This report presents a proposed measurement methodology for this group of toys, and data obtained on several of these toys utilizing the proposed methodology.

2. Definitions

Intermittent noise: A noise whose sound pressure level [is less than or] equals the ambient environmental level two or more times during the period of observation. The period of time during which the level of the noise remains at an essentially constant value different from that of the ambient is on the order of one second or more[1].[1/]

Steady-state noise: Ongoing (continuous) noise whose sound pressure level remains essentially constant (that is, fluctuations are negligibly small) during the period of observation[1].

3. Technical Back-Up

3.1. Product Classification

3.1.1. Model Airplanes: Model airplanes are normally categorized according to their engine displacement. The engine size ranges from about 0.010 cu. in. to 0.800 cu. in. The engines typically associated with children's model airplanes are usually no larger than 0.049 cu. in. displacement; however, the free-flight and radio-controlled airplanes used by model airplane enthusiasts (typically teenagers and adults) can range as high as 0.800 cu. in. The engines are 2-cycle and turn at very high rotational rates -- 12,000 to 23,000 rpm, resulting in a firing frequency of about 200-383 Hz. The noise produced by these engines can be characterized as steady-state.

3.1.2. Bicycle Horns: The horns used on bicycles generally can be separated into two groups. One group is comprised of the type of horn where the noise generating mechanism is a squeezable rubber bulb on the end of the horn. The noise produced by this type of horn can be characterized as intermittent noise. The other type of horn is comprised of a cylinder of compressed gas on which a plastic horn-shaped actuator is mounted. When the actuator is depressed, the compressed gas is released through a pinhole in a metal diaphragm in the actuator. Initially -- for approximately 5-10 seconds -- the noise emitted is essentially steady-state; however, the compressed gas in the canister tends to freeze unless a conscious effort is made to keep the canister warm (e.g., holding it tightly with gloved hands). If the canister is not kept warm, the noise emitted by the device fades very rapidly, and about 5 minutes is required before the device can be reused.

3.1.3. Bicycle Attachments Which Imitate Motor Sounds: The bicycle attachments which imitate motor sounds are characterized as steady-state noise producers. They are battery operated and emit a continuous noise, the level of which is controlled by the operator.

The parties affected by the aforementioned noise producing toys and the effects of the noise must be identified. The operator(s) of the toy is affected and the nature of the effect can include communication interference as well as possible hearing damage. Although hearing loss is not a potential problem for neighbors and bystanders, they certainly can have their tasks interfered with or be annoyed. The measurement methodology presented in this report primarily considers the operator(s) of the toy.

[1/] Figures in brackets refer to the literature references at the end of this report.

3.3. Methodology Development

There are no current measurement methodologies for determining the noise levels associated with this class of toys, and there is no known existing data base.

It is proposed for practical reasons to utilize the A-weighted sound level as the basic measure for model airplane and bicycle attachment noise. The A-weighted sound level was selected because it correlates reasonably well with the known effects of noise on the individual[2] and it can be read directly on commercially available instrumentation which meets accepted performance standards.

The ideal test environment for the conduct of tests on toys in this class would be a free-field environment. An acoustically free field is an environment without any sound reflecting obstacles. When operated in such an environment, a device will radiate free progressive sound waves. Perfect free-field conditions are difficult to obtain in practice; however, nearly ideal free-field conditions can be obtained in an anechoic chamber. It would be possible to test noise producing bicycle attachments in such a chamber; however, it would not be a suitable test environment for model airplane engines due to the dangers associated with the build-up of exhaust fumes and the potential damage to the absorbent wedges as a result of oil dripping from the engine or spilled fuel. This, coupled with the fact that few, if any, toy manufacturers would have easy access to an anechoic chamber, led to the investigation of an outdoor test site as a suitable alternative. It was felt that if the toy to be tested was mounted high (3 metres) above a grass-covered surface with no obstacles other than the ground surface within 5-metres of the toy under test or the microphone[2/], and measurements were made close to the toy (1 metre), then essentially free field conditions would exist. For these distances the shortest path for any reflected signal -- source to ground and back to the lowest microphone position -- would be 5-metres, and the level of the reflected signal would be well below the source level. The data resulting from this study confirmed this hypothesis.

In order to select appropriate measurement positions -- both number and location -- measurements were made at numerous positions surrounding the various noise sources. Although primary emphasis was on the selection of measurement locations corresponding to operator ear locations -- to allow for assessment of the hazard presented to the operator of the toy -- other measurement locations utilized during this study also provided an indication of the noise levels impacting bystanders.

For those toys for which there is a fairly well-defined operator location (bicycle attachments as compared to model airplanes) measurements were made at the approximate location of the operator's ear. For this study the operator location is defined as 51 cm behind the device and 40.5 cm above it. This position was determined by measuring the arm-to-trunk and trunk-to-ear distances of several children between the ages of 5 and 8 and choosing approximately the median value. It was felt that this would represent worst case conditions for the device under test. Since bicycle attachments are normally positioned below the operator's ear, additional measurement locations were selected to sample the semicircular arc of 1 metre radius above the device. In the case of model airplanes, the operator position cannot be accurately ascertained. With the exception of the short time which the operator spends very close to the airplane during engine startup, the operator is at a position below and at an indeterminate distance from the airplane. This position is basically determined by the length of the control line, which is a matter of personal preference with regard to ease of operation. Therefore, in order to provide the best indication of the hazard presented to the operator by the model airplane, the measurement locations for testing the airplanes were chosen to sample the two semicircular arcs (located 90° apart, see Figure 1) of 1 metre radius below the device.

With the exception of bicycle horns, the maximum A-weighted fast response sound level should be utilized as the criteria for judging compliance with the regulation and for assessing the hazard, if any, presented to the toy's operator or bystanders. In the case of the horns, a hold feature -- which stores the maximum rms value of the applied signal -- must be utilized to ensure that the maximum A-weighted sound level is measured. Appendices A and B contain data on toys tested according to the above procedures.

A few special notes are necessary to aid in the conduct of the tests:

Model airplane engines should be removed from the plastic fuselages for testing. It was found that the engine/propeller vibrations generated during operation with the entire model airplane mounted rigidly on the pole resulted in the engine breaking through the plastic and destruction of the fuselage.

[2/] It should be noted that the 5-metre restriction cannot be met when testing bicycle horns due to the fact that a person must be present to actuate the devices -- unless a mechanical actuator system were designed.

The bicycle horn which utilizes compressed gas in a canister tends to freeze up, with a corresponding drop in the sound output. Unless a conscious effort is made to keep the canister warm (e.g., holding it tightly in gloved hands, wrapping it in cloth), the noise emitted by the device fades rapidly, and about a 5-minute wait is required before the device can be retested.

4. Regulation

4.1. Measurements Made at Operator Location

Utilizing the measurement methodology outlined in Section 6:

4.1.1. Toys which exceed an A-weighted sound level of Y decibels re 20 micropascals are banned from the market.

4.1.2. Toys which produce A-weighted sound levels in the range X-Y decibels must bear a visible warning label, and the manufacturer must conduct or participate in a program to develop toys that produce an A-weighted sound level of X decibels or less. Also, manufacturers with products in this category must submit regular reports to the Consumer Product Safety Commission on the status of this program.

4.1.3. Toys which produce A-weighted sound levels less than X decibels are allowable on the market with no restrictions.

4.2. Measurements Made at Positions Other Than Those at the Operator Location

Utilizing the measurement methodology outlined in Section 6:

4.2.1. Toys which exceed an A-weighted sound level of S decibels re 20 micropascals are banned from the market.

4.2.2. Toys which produce A-weighted sound levels in the range R-S decibels must bear a visible warning label, and the manufacturer must conduct or participate in a program to develop toys that produce an A-weighted sound level of R decibels or less. Also, manufacturers with products in this category must submit regular reports to the Consumer Product Safety Commission on the status of this program.

4.2.3. Toys which produce A-weighted sound levels less than R decibels are allowable on the market with no restrictions.

5. Acoustic Environment

5.1. Measurement Location

5.1.1. The sound source shall be mounted on a pole no greater than 2.54 cm ± 0.2 cm in diameter and 3 metres ±0.1 metre above a grassy surface in an environment where no other sound reflecting obstacles, with the exception of the ground plane, are present within 5 metres of either the location of the toy or the microphone. Note that the microphone must be separated from the sound level meter by an extension cable sufficiently long that the person reading the sound level meter does not violate the 5-metre requirement. An exception to the 5-metre restriction is allowed in the case of the bicycle horns where an operator may be present within the 5-metre zone to actuate the device. However, at no time shall the operator of the device position himself directly between the device under test and the microphone.

5.1.2. During tests conducted on model airplanes, the microphone shall be located at ten different positions (see Figure 1 for a sketch of the test configuration) -- five measurement positions are located in the same vertical plane as the model airplane's propeller (position 3 is located directly under the propeller) while the remaining five measurement positions are located in the same vertical plane as the model airplane's longitudinal centerline (position 8 is located directly under the propeller). The microphone shall be located 1.0 ±0.04 metre from the model airplane engine at all measurement locations.

5.1.3. During tests conducted on noise producing bicycle attachments, the microphone shall be loca-at five different positions (see Figure 2 for a sketch of the test configuration) in the same vertical plane as the centerline of the device under test and 1.0 ±0.04 metre from the attachments. At the sixth measurement location, corresponding to the operator's ear, the microphone shall be located 51.0 ±1.5 cm behind and 40.5 ±1.5 cm above the device under test (see Figure 2).

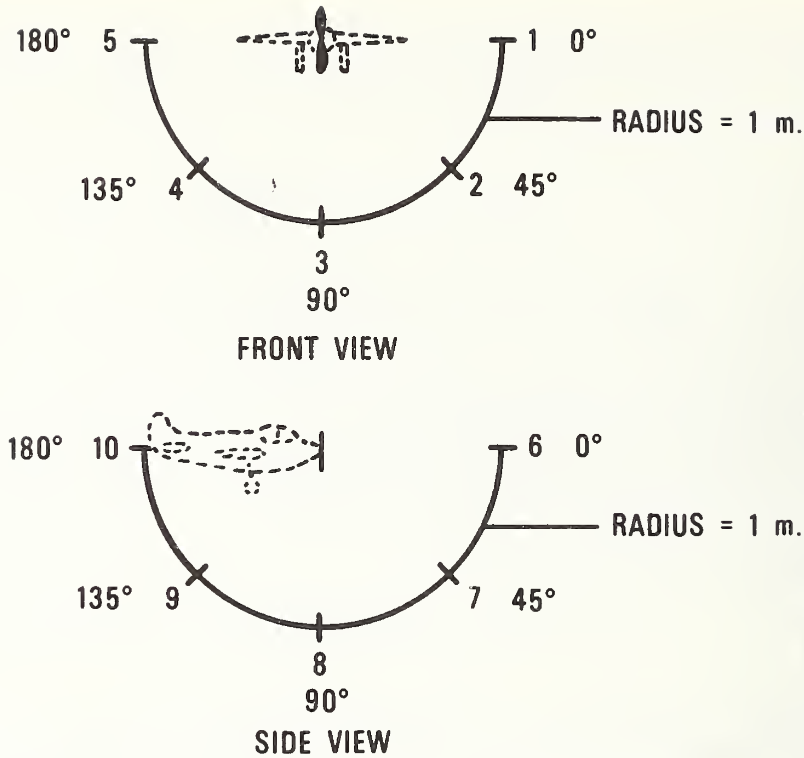

Figure 1. Test configuration for determining the maximum sound level of model airplanes (engine only). All measurement positions are 1.0 ± 0.04 metre from the sound source. Positions 1-5 are in the same vertical plane as the model airplane's propeller and measurement positions 6-10 are in the same vertical plane as the model airplane's longitudinal center line.

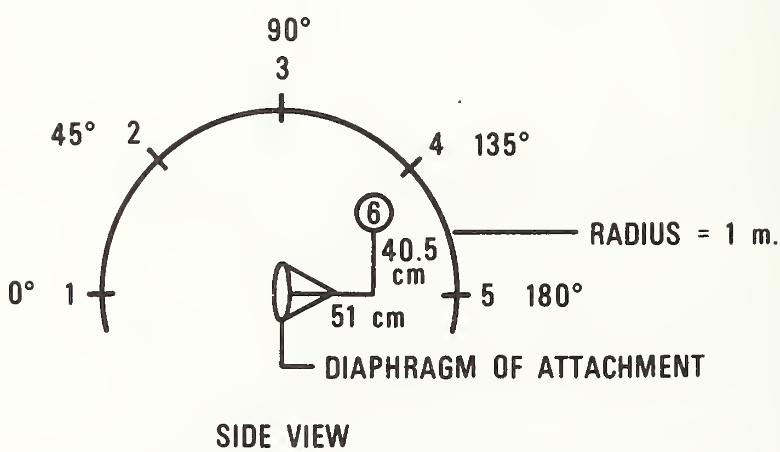

Figure 2. Test configuration for determining the maximum sound level of noise-making bicycle attachments. All positions are oriented in relation to the center of the diaphragm of the attachment. Positions 1-5 are 1.0 ± 0.04 metre from the sound source. Position 6, corresponding to the operator's ear, is 51.0 cm ± 1.5 cm behind the attachment and 40.5 cm ± 1.5 cm above it.

5.2. Environmental Conditions

5.2.1. If calibration devices are used which are not independent of ambient pressure (e.g., a pistonphone), corrections must be made for barometric or altimetric changes according to the recommendation of the instrument manufacturer.

5.2.2. When measurements are made out-of-doors, the following conditions must be met.

a. Measurements shall not be made when the wind speed exceeds 5 metres/second.

b. Measurements shall not be made during precipitation.

5.3. Background Noise

The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB below the regulated level.

6. Measurement Methodology

6.1. Instrumentation

6.1.1. Microphone: The microphone shall have the following characteristics. It shall be a one-half inch microphone or smaller, and shall have a dynamic range covering the interval 50 to n decibels relative to 20 micropascals, where n decibels is 10 dB greater than $\underline{S}$ or $\underline{Y}$ decibels.

6.1.2. Windscreen: The windscreen shall not affect the measured A-weighted sound levels from the noise source in excess of ±0.5 dB. This may be experimentally evaluated by comparing the measured A-weighted sound level with and without the windscreen, at a position close enough to the source that wind noise is not a factor.

6.1.3. Sound Level Meter: The sound level meter, including the microphone, shall meet the specifications of a Type 1 meter as given in American National Standard Specification for Sound Level Meters, S1.4-1971[3]. The sound level meter shall be equipped with a hold feature which indicates the maximum RMS level of the input signal. The integrating time constant for the hold circuitry shall be 35 msec. The microphone on the sound level meter shall be oriented with respect to the source so that the sound strikes the diaphragm at the angle for which the microphone was calibrated to have the flattest frequency response characteristic over the frequency range 100 Hz to 20 kHz.

6.1.4. Additional Instrumentation Requirements:

a. An anemometer or other device for measurement of ambient wind speed accurate within ± 10% at 5 m/sec.

b. A barometer for measurement of ambient pressure accurate within ±1%.

6.2. Calibration

The measurement system shall be calibrated both before and after the tests at each microphone position. The calibration shall be accurate to within ±0.5 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. The calibrator shall be checked annually against a laboratory standard microphone whose calibration is directly traceable to the National Bureau of Standards to verify that its output has not changed.

A complete calibration of the instrumentation over the frequency range of interest shall be performed at least annually using methodology of sufficient precision and accuracy to determine that the instrumentation is in compliance with the requirements of Section 6.1.

6.3. Measurements

6.3.1. The following procedure will be used to determine the sound level produced by model airplanes and bicycle attachments which imitate motor sounds.

a. The quantity to be measured is the A-weighted sound level for fast meter response as defined in American National Standard S1.4-1971[3]. The model airplane engine under test shall be operated in accordance with the manufacturer's instructions. The bicycle attachments which imitate motor sounds shall be operated at the setting which produces the maximum sound output.

b. One reading shall be obtained at each measurement location. Run the toy for a period of ten seconds, and record the highest reading observed on the sound level meter.

c. The highest sound level recorded during these tests shall be utilized to determine compliance with the regulation.

d. The wind velocity and barometric pressure shall be measured at the toy height and within one metre of the location of the toy when the toy is not being operated.

6.3.2. The following procedure shall be used to determine the sound level produced by bicycle horns.

a. The quantity to be measured is the A-weighted sound level with the sound level meter in the hold (rms level of the signal) mode. The horns shall be operated in such a way as to produce the maximum sound output.

b. A minimum of five readings shall be obtained and recorded for each measurement location. The average of the five readings for each measurement location shall also be recorded for that measurement location.

c. The highest average sound level recorded during these tests shall be utilized to determine compliance with the regulation.

d. The wind velocity and barometric pressure shall be measured at the toy height and within one metre of the location of the toy when the toy is not being operated.

6.4. Data to be Contained in Test Report

1. Complete identification and description of the test equipment.
2. Complete identification of the sound source under test.
3. Mounting and operating conditions of the sound source.
4. Location of sound source in the test area.
5. Description of the test area.
6. Description of test conditions, including ambient wind speed during measurements (m/sec) and atmospheric pressure (mm Hg).
7. Complete description of deviations, if any, from the prescribed test procedure.
8. Number of measurements made during tests.
9. Positions at which the measurements were made.
10. Date and time when the measurements were performed.
11. The maximum A-weighted sound level, using the fast response characteristic (for model airplanes and bicycle attachments which imitate motor sounds) or the maximum average A-weighted sound level using the rms hold mode (for bicycle horns), for each measurement location during the tests.
12. For bicycle horns, the range of the recorded A-weighted sound levels.

7. References

[1] American National Standard Methods for the Measurement of Sound Pressure Levels, S1.13-1971 (American National Standards Institute, New York, New York, July 14, 1971).

[2] Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Report No. EPA 550/9-74-004 (U. S. Environmental Protection Agency, Washington, D. C., March 1974).

[3] American National Standard Specification for Sound Level Meters, S1.4-1971 (American National Standards Institute, New York, New York, April 27, 1971).

8. APPENDIX A

Sound Level Produced by Noise Producing Bicycle Attachments

The A-weighted sound levels emitted by three noise producing bicycle attachments were measured at a nominal distance of one metre from the device. In addition, measurements were also made at a position approximating the operator's ear -- 51 cm behind the device and 40.5 cm above (see Figure A-1). The toys tested were as follows:

1. Toy A - bicycle horn: The noise producing mechanism was a squeezable rubber bulb.

2. Toy B - bicycle horn: The noise was generated by depressing a plastic, horn-shaped actuator, thereby releasing bursts of compressed gas from a metal canister through a pin hole in a thin metal diaphragm in the actuator.

3. Toy C - bicycle attachment to imitate motor sounds: This device is battery-operated with a manual setting which controls the level of noise produced. All tests on this device were conducted with the setting at "FULL". (It was determined that the maximum sound level occurred at this setting.)

The tests were conducted in the NBS anechoic chamber with the toys rigidly mounted on the top of a three-metre pole. A one-half-inch free-field condenser microphone positioned at normal incidence was used for the measurements. The microphone was connected (via a 3-metre cable) to a sound level meter set at the hold (indicating the maximum rms value of the signal) mode for Toys A and B, and at "FAST" response for Toy C. A pistonphone was used for calibration of the measuring system (microphone and sound level meter) at one frequency (250 Hz) before and after each test. In addition to direct sound level meter readings, a limited amount of data were recorded for later analysis -- (1) 15 seconds of data for Toy B at measurement positions 1 and 6 and (2) 30 seconds of data for Toy C at measurement position 3. The tape recorded sound output was then processed utilizing a real-time analyzer which was linked to a mini-computer-based data analysis system. The data analysis system sampled the recorded sound levels at 0.1 second intervals and printed out the A-weighted sound level for each 0.1 second sample and the one-third octave band spectrum for the sample where the maximum A-weighted sound level occurred. A complete list of the equipment used is given in Table A-1.

One averaging technique which is receiving acceptance in the standards community states that the number of measurements to be made at each position shall equal or exceed the range in decibels between the lowest and highest of the readings. For example, in Table A-2, position 4, the highest reading was 95.0 dB and the lowest 92.0 dB, and the range was 3 dB. Thus, a minimum of three readings is required. For this reason only four and three readings for Toys A and B, respectively, were made, instead of the five required by the methodology. After examining the data, it was decided to keep the methodology as simple as possible; therefore, five readings at each position were recommended as it was felt that this would more than adequately account for the range in readings that might be encountered for these toys.

The results of the measurements are given in Tables A-2 through A-4 and Figures A-2 through A-7. The data in Figure A-2 illustrates the effect that the freezing of the compressed gas in the canister has on the sound level of Toy B. In a period of 15 seconds, the sound level has dropped 22 dB. This recording was taken when a conscious effort was being made to keep the device warm. When an effort is not made to keep the canister warm, the sound output will only continue for about 5 seconds (see Figure A-3 for an example). Figures A-4 and A-5 are examples of representative spectra for Toy B. As can be seen, the sound output of this toy is mainly composed of high frequency components.

Figure A-6 is a plot of A-weighted sound level versus time for Toy C. This toy starts up in a rather jerky fashion, reaches a peak sound output (at approximately 5-6 seconds), and then settles into an oscillating pattern in which the sound level varies about 2 dB every 2-4 seconds. Thus, the sound output of this toy can be described as only nominally steady state. Figure A-7 is an example of a representative spectrum for Toy C.

A short series of tests were run outdoors over a grass-covered ground surface for Toy B. In comparing the results of these measurements with those taken indoors, they were found to be in close agreement with each other. For example, the average A-weighted sound level for position 1 in the anechoic chamber was 103.5 dB, while the average sound level at position 1 outdoors was 102.8 dB.

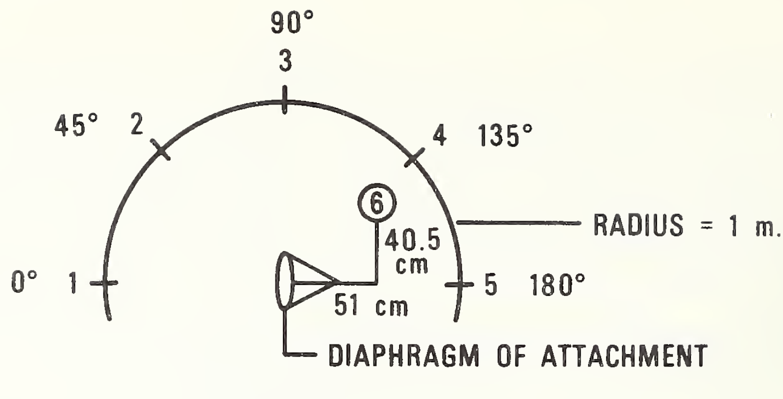

Figure A-1. Test configuration for determining the maximum sound level of noise-making bicycle attachments. All positions are oriented in relation to the center of the diaphragm of the attachment. Positions 1-5 are 1.0 ± 0.04 metre from the sound source. Position 6, corresponding to the operator's ear, is 51.0 cm ± 1.5 cm behind the device and 40.5 cm ± 1.5 cm above it.

Table A-1. Equipment used for Tests of Toys A, B, and C.[3/]

Manufacturer	Instrument	Model No.	Serial No.
Brüel & Kjaer	1/2-inch microphone	4133	310856
Brüel & Kjaer	Sound level meter	2204	252772
Nagra	Tape recorder	IV-S	1081
Brüel & Kjaer	Pistonphone	4220	284737
Brüel & Kjaer	Real-time analyzer	3347	--
Raytheon	Mini-computer	704	--

[3/] Certain commercial equipment and instruments 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 equipment identified is the best available for the purpose.

Table A-2. A-weighted sound level (in dB re 20 μPa) produced by Toy A. Position refers to those shown in Figure A-1. The average value for each position is based on four readings.

	Position					
	1	2	3	4	5	6
	100.0	96.0	94.0	92.0	93.0	101.5
	100.0	96.0	94.0	95.0	94.0	100.0
	99.0	98.0	95.5	95.0	94.0	100.0
	100.0	98.0	95.0	94.5	94.0	100.0
Average	99.8	97.0	94.6	94.1	93.8	100.4

Table A-3. A-weighted sound level (in dB re 20 μPa) produced by Toy B. Position refers to those shown in Figure A-1. The average value for each position is based on three readings.

	Position					
	1	2	3	4	5	6
	103.0	100.0	98.0	96.5	91.5	110.0
	105.0	100.0	97.0	95.5	94.0	109.0
	102.5	99.0	96.5	94.5	91.0	109.5
Average	103.5	99.7	97.2	95.5	92.2	109.5

Table A-4. A-weighted sound level (in dB re 20 μPa) produced by Toy C. Position refers to those shown in Figure A-1. The value for each position represents a single reading.

Position	
1	60.0
2	64.5
3	67.0
4	64.0
5	61.0
6	66.5

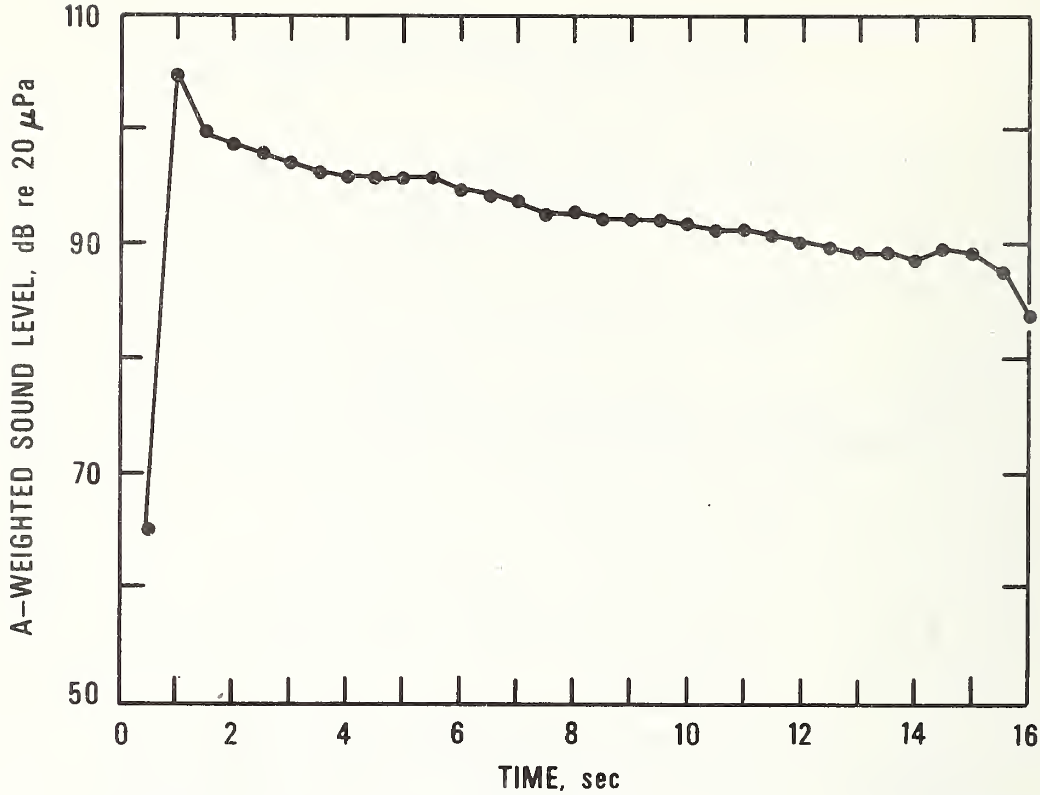

Figure A-2. A-weighted sound level (in dB re 20 μPa) versus time for Toy B. The reading was taken at position 1 as shown in Figure A-1.

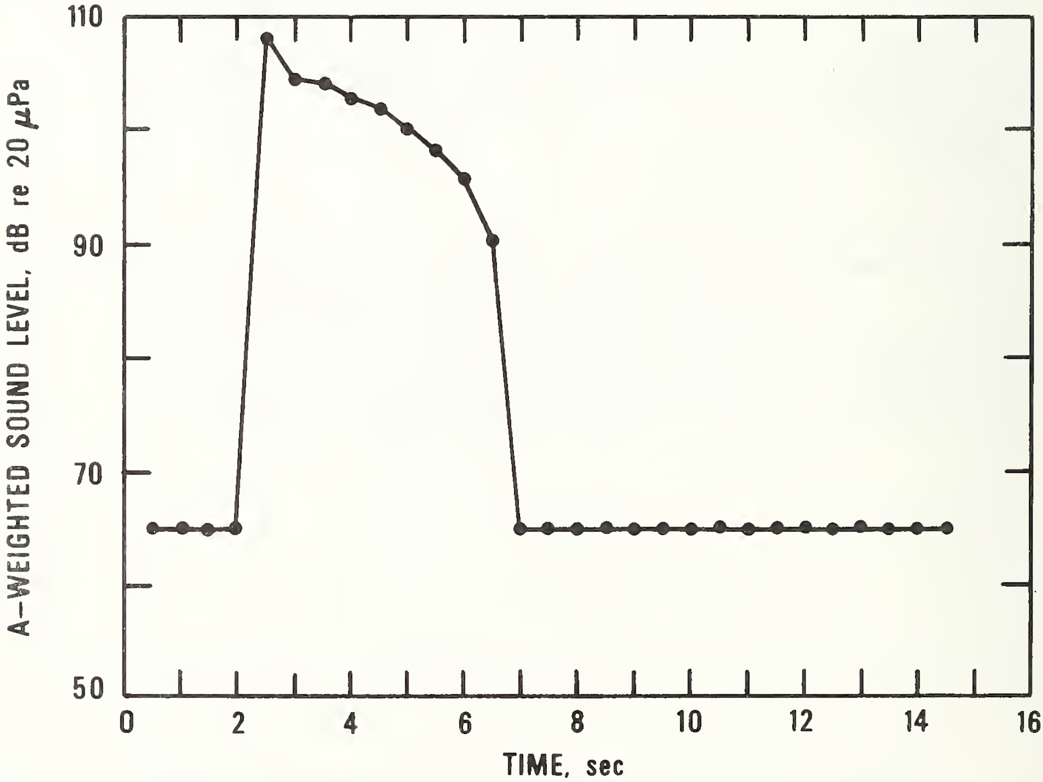

Figure A-3. A-weighted sound level (in dB re 20 μPa) versus time for Toy B. The reading was taken at position 6 (operator location) as shown in Figure A-1.

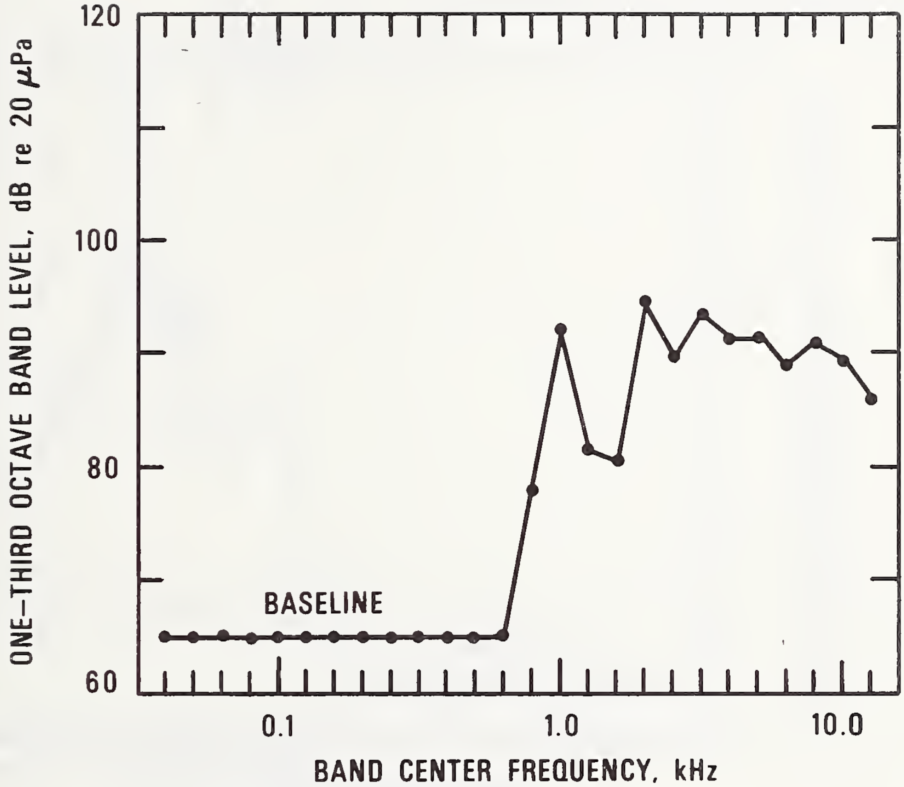

Figure A-4. One-third octave band levels for Toy B. The reading was taken at position 1 as shown in Figure A-1. [The computed A-weighted sound level (in dB re 20μPa) was 104.8]. Note that the one-third octave band where the peak sound level occurs is 2000 Hz, which is in the frequency range of maximum sensitivity of the ear (1000-4000 Hz).

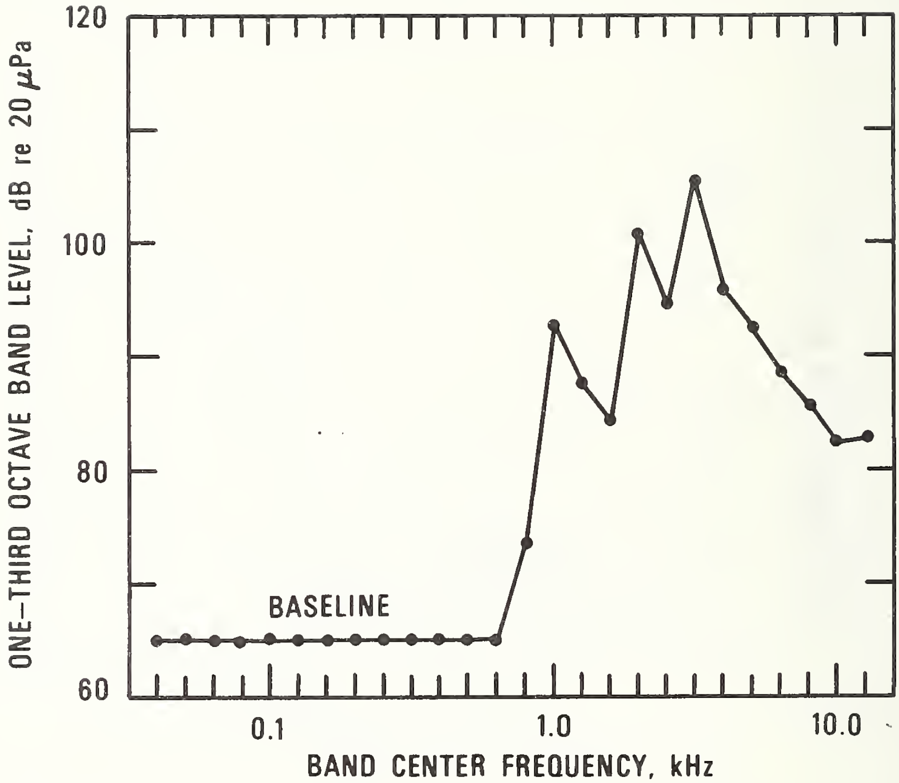

Figure A-5. One-third octave band levels for Toy B. The reading was taken at position 6 as (operator location) shown in Figure A-1. [The computed A-weighted sound level (in dB re 20 μPa) was 109.0]. Note that the one-third octave band where the peak sound level occurs is 3150 Hz, which is in the frequency range of maximum sensitivity of the ear (1000-4000 Hz).

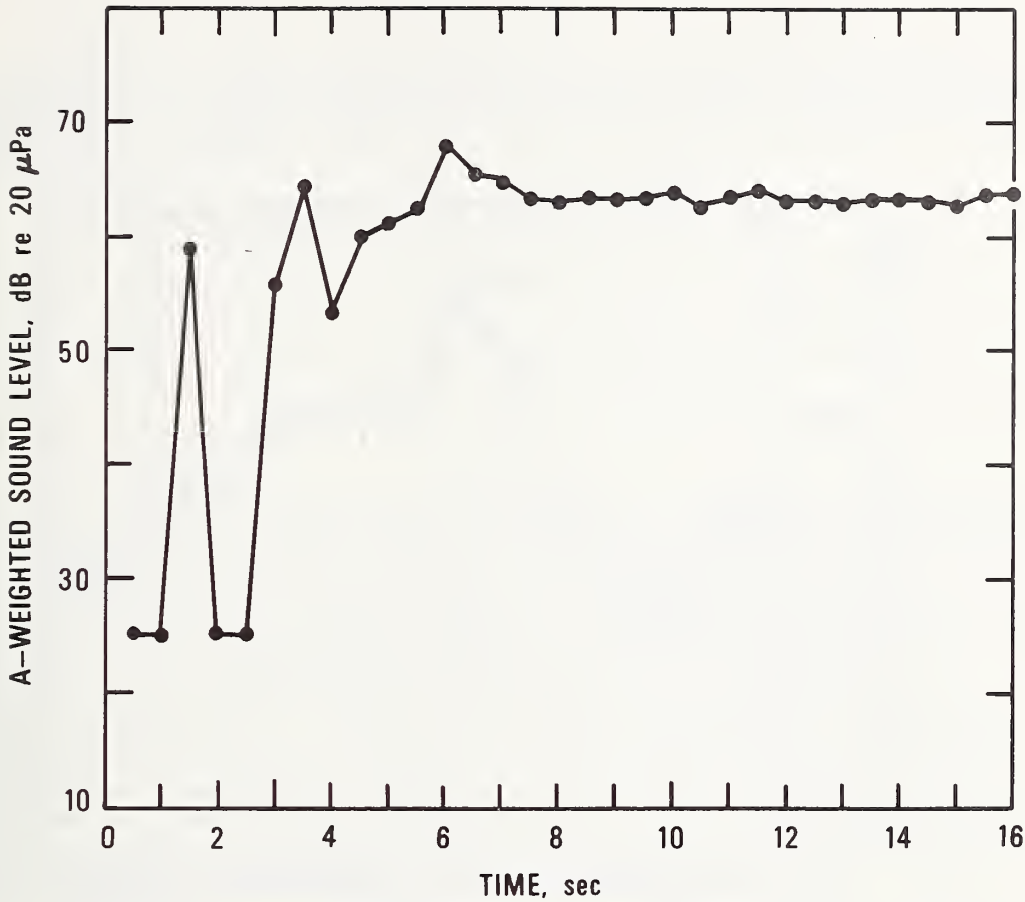

Figure A-6. A-weighted sound level (in dB re 20 μPa) versus time for Toy C. The reading was taken at position 3 as shown in Figure A-1.

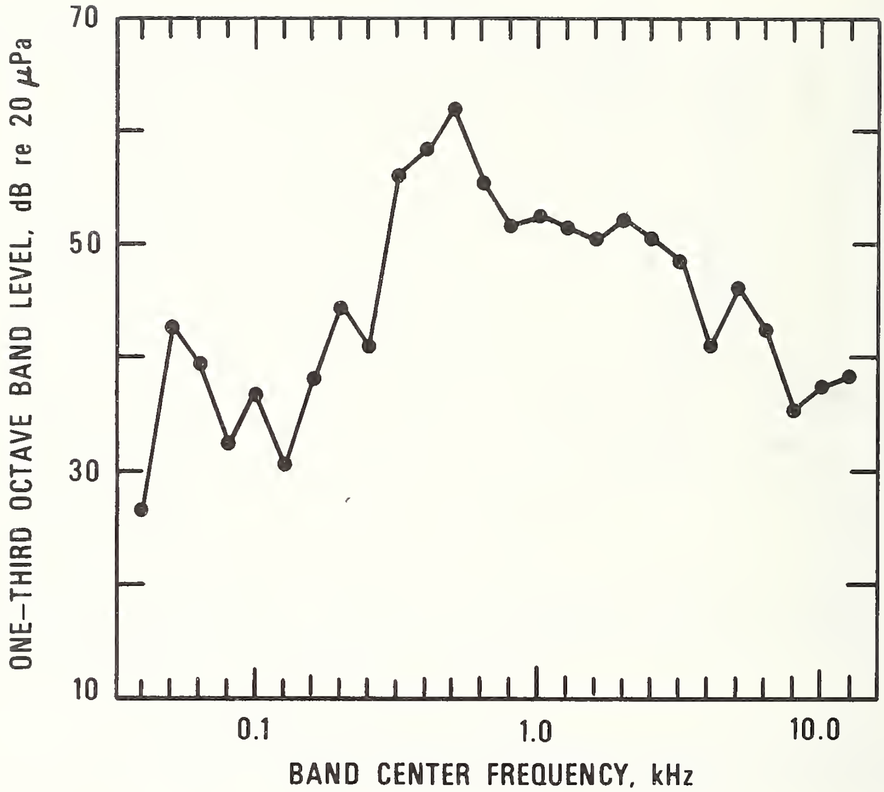

Figure A-7. One-third octave band levels for Toy C. The reading was taken at position 3 as shown in Figure A-1. [The computed A-weighted sound level (in dB re 20 μPa) was 64.6.]

9. APPENDIX B

Results of Tests on Model Airplane Engines

The maximum A-weighted sound levels produced by four different model airplane engines were measured at sixteen positions, each of which was nominally one metre from the device under test (see Figure B-1). Positions 1-8 were in the same vertical plane as the model airplane's propeller and positions 9-16 were in the same vertical plane as the model airplane's longitudinal centerline. The test sample included:

1. Brand D: 0.020 cu. in. engine displacement, 3-blade propeller (engine not equipped with a muffler).

2. Brand D: 0.049 cu. in. engine displacement, 3-blade propeller (engine equipped with a muffler).

3. Brand D: 0.049 cu. in. engine displacement, 3-blade propeller (engine not equipped with a muffler).

4. Brand E: 0.049 cu. in. engine displacement, 2-blade propeller (engine not equipped with a muffler).

At the onset of testing, the entire model airplane -- engine/propeller plus plastic fuselage -- was mounted on the top of a 3-metre pole. However, the engine/propeller vibrations generated during operation with the entire model airplane rigidly mounted on the pole resulted in the destruction of the plastic fuselage. For this reason, the engine/propeller only were tested in this study. The tests were conducted out-of-doors over grass with no sound reflecting obstacles, other than the grass covered ground plane, within 5 metres of the toy under test or the measuring microphone. A one-half inch free-field condenser microphone positioned at normal incidence was utilized for these measurements. The microphone was connected, via a 10-metre extension cable, to a sound level meter set for fast response and the A-weighting network. A pistonphone was used for single point (250 Hz) calibration in the field of the measurement system (microphone and sound level meter) before and after each test. In addition, at a single microphone position for each engine -- position number 5, 1 metre below the propeller -- the sound output was recorded on tape for further analysis. The analog tape was processed utilizing a one-third octave band real-time analyzer which was interfaced to a mini-computer-based data analysis system. The data analysis system then printed out the noise spectrum for each particular engine at the time corresponding to the occurrence of the maximum A-weighted sound level at measurement position number 5. A complete list of equipment utilized for data acquisition, reduction and analysis is given in Table B-1.

The data are given in Figures B-2 through B-5 and Tables B-2 through B-5. Since the noise emitted by model airplane engines is essentially steady-state, the measurement results are based on a single reading at each microphone location.

In addition, in order to assess the adequacy of the outdoor test site -- source mounted on top of a 3-metre pole over a grass covered ground plane -- as a "free-field" environment, supplementary measurements were made on three of the four model airplane engines at locations 2-, 4-, 8-, and 16-metres from the side of the engine (see Figure B-1) along a line which was chosen as an estimate of the orientation of the model airplane's control line in actual practice. On the basis of these data, it was observed that the noise radiated from the model airplane engines tested under these conditions closely conformed to spherical spreading, i.e., there was approximately a 6 dB attenuation per doubling of distance in the direction tested.

In general, the spectra for engines without mufflers are dominated by mid to high frequency (1-8 kHz) exhaust and/or engine radiated noise, which is also the frequency range of maximum sensitivity of the ear. The noise associated with the firing frequency of the engine (200-315 Hz) is present in all cases. It is interesting to look at the effectiveness of the muffler on engine number 2. A significant reduction in the sound pressure levels in the 1-8 kHz range resulted in an overall reduction of 15 dB in the maximum A-weighted sound level at all microphone locations, even though the noise level corresponding to the firing frequency of the engine was somewhat higher for the muffled engine than for the unmuffled engine. The effect of the muffler on the performance and fuel consumption of the engine was not determined.

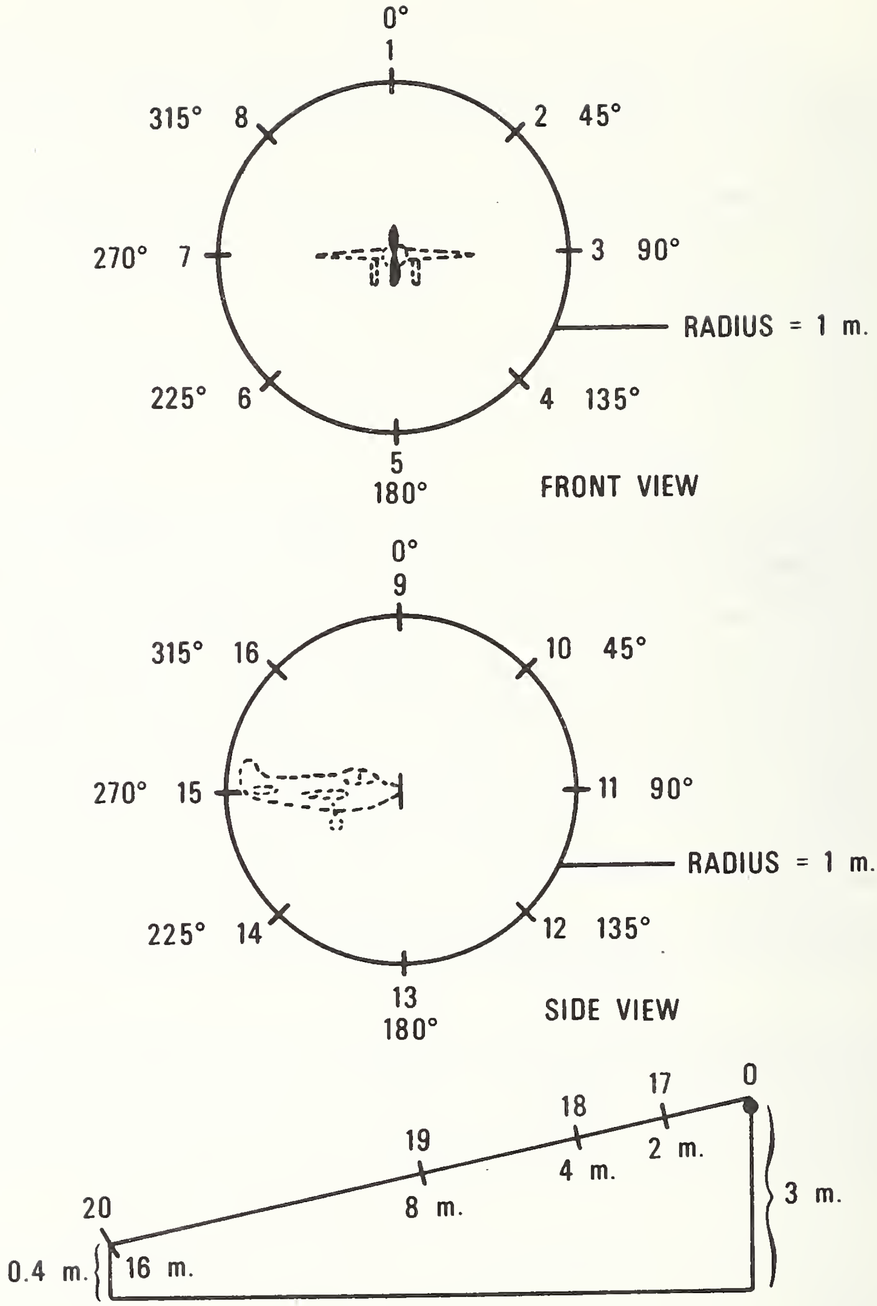

Figure B-1. Test configuration for determining the maximum sound level of model airplanes. Positions 1-16 are 1.0 ± 0.04 metre from the sound source. Positions 1-8 are in the same vertical plane as the model airplane's propeller and positions 9-16 are in the same vertical plane as the model airplane's longitudinal centerline. Positions 17-20 are 2, 4, 8, and 16 metres, respectively, from the side of the sound source along a line which is an estimate of the orientation of the model airplane control line in actual practice.

Table B-1. Equipment Used for Tests of Model Airplanes.[4/]

Manufacturer	Instrument	Model No.
Brüel & Kjaer	1/2-inch microphone	4133
Brüel & Kjaer	Sound level meter	2204
Brüel & Kjaer	Pistonphone	4220
Nagra	2-channel tape recorder	IV-S
Brüel & Kjaer	Real-time analyzer	3347
Raytheon	Mini-computer	704

[4/] Certain commercial equipment and instruments 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 equipment identified is the best available for the purpose.

Table B-2. The A-weighted sound levels (in dB re 20 μPa) produced by airplane engine number 1. Measurements were made at the positions shown in Figure B-1.

Position	A-weighted Sound Level dB	Position	A-weighted Sound Level dB
1	98	11	98
2	98	12	99
3	96	13	101
4	96	14	99
5	100	15	96
6	95	16	98
7	96	17	---
8	97	18	---
9	98	19	---
10	98	20	---

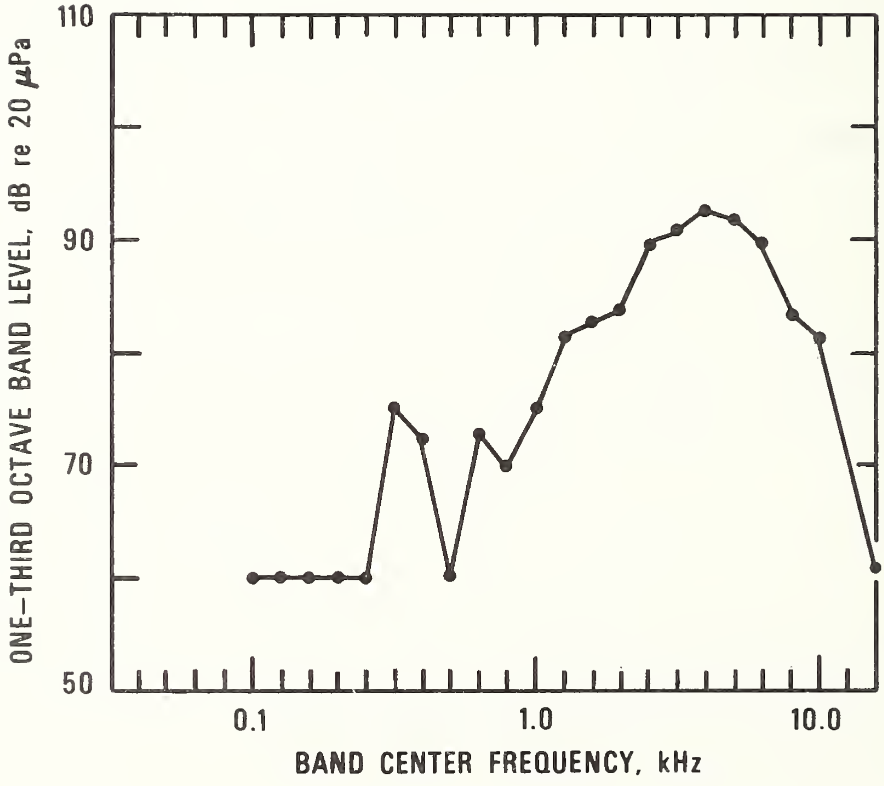

Figure B-2. Noise spectrum produced by airplane engine number 1. The location where the measurement was made is position 5 as shown in Figure B-1.

Table B-3. The A-weighted sound levels (in dB re 20 μPa) produced by airplane engine number 2. Measurements were made at the positions shown in Figure B-1.

Position	A-weighted Sound Level dB	Position	A-weighted Sound Level dB
1	85	11	87
2	83	12	86
3	81	13	84
4	82	14	83
5	84	15	81
6	84	16	83
7	84	17	74
8	85	18	70
9	85	19	63
10	86	20	58

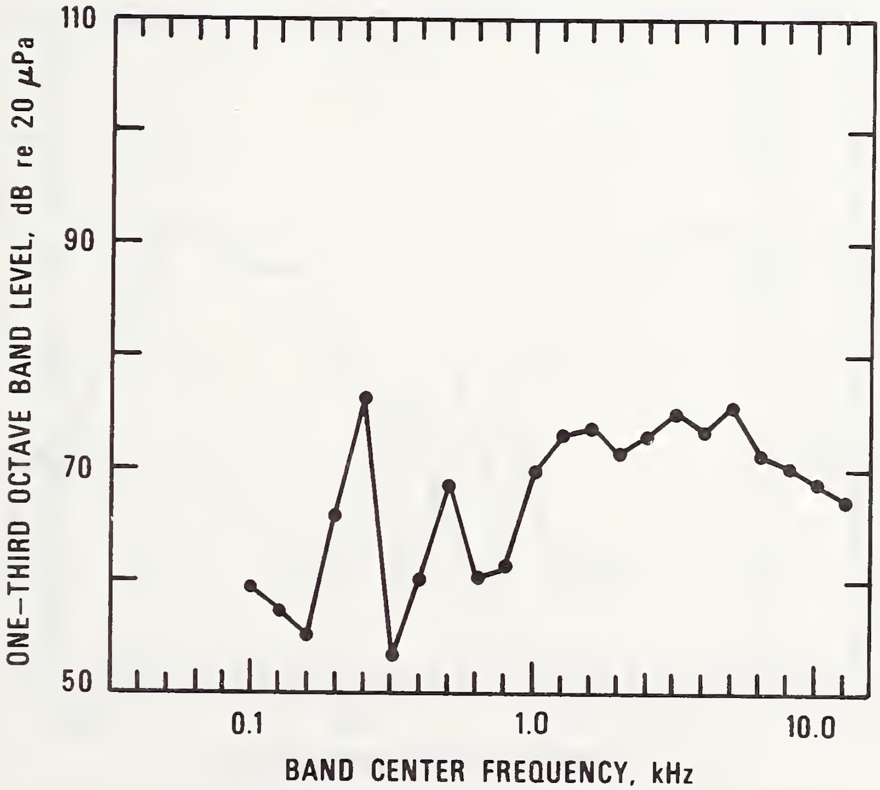

Figure B-3. Noise spectrum produced by airplane engine number 2. The location where the measurement was made is position 5 as shown in Figure B-1.

Table B-4. The A-weighted sound levels (in dB re 20 μPa) produced by airplane engine number 3. Measurements were made at the positions shown in Figure B-1.

Position	A-weighted Sound Level dB	Position	A-weighted Sound Level dB
1	100	11	100
2	99	12	100
3	98	13	100
4	99	14	100
5	100	15	97
6	99	16	97
7	98	17	92
8	97	18	86
9	101	19	80
10	101	20	75

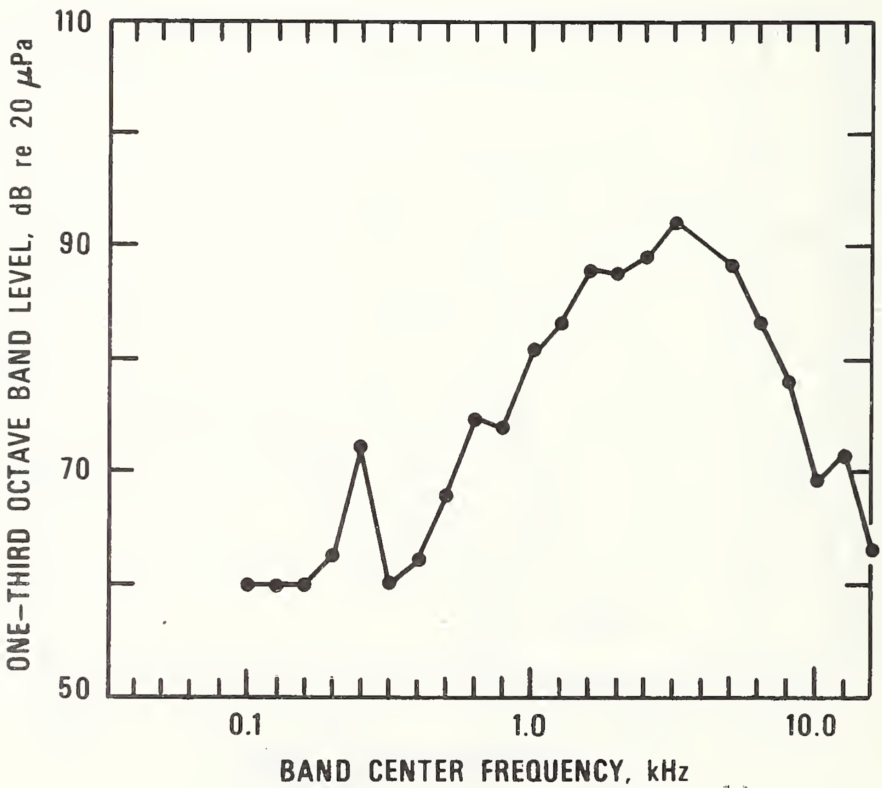

Figure B-4. Noise spectrum produced by airplane engine number 3. The location where the measurement was made is position 5 as shown in Figure B-1.

Table B-5. The A-weighted sound levels (in dB re 20 μPa) produced by airplane engine number 4. Measurements were made at the positions shown in Figure B-1.

Position	A-weighted Sound Level dB	Position	A-weighted Sound Level dB
1	99	11	97
2	99	12	98
3	97	13	99
4	97	14	102
5	99	15	94
6	98	16	98
7	96	17	90
8	96	18	84
9	99	19	78
10	98	20	72

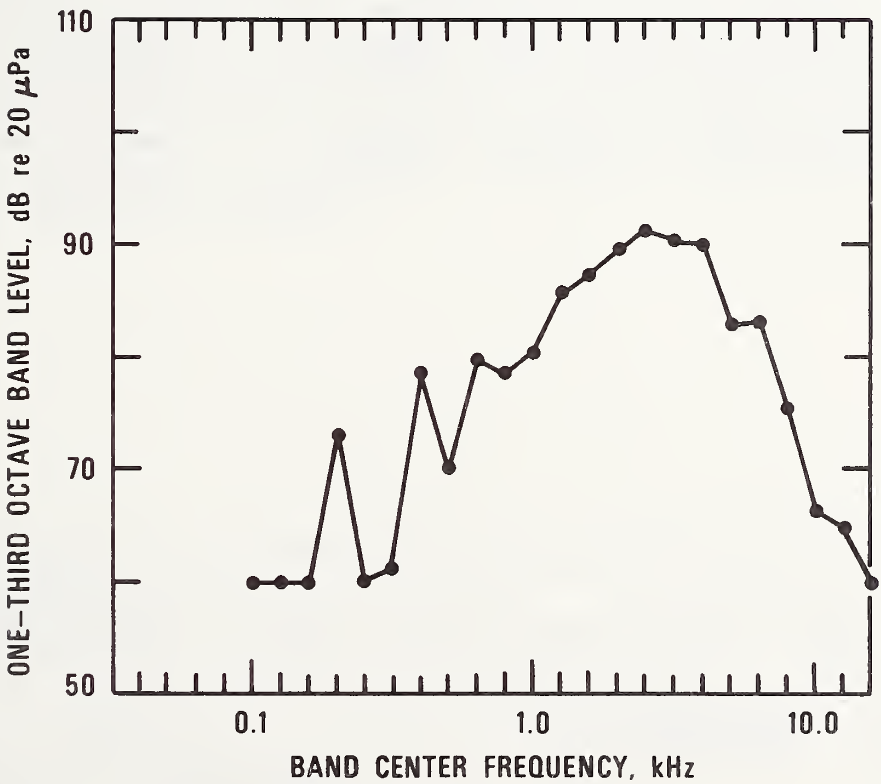

Figure B-5. Noise spectrum produced by airplane engine number 4. The location where the measurement was made is position 5 as shown in Figure B-1.

Acknowledgements

The authors would like to express appreciation to the following members of the Applied Acoustics Section for the contributions they made to this program: Mr. Denzil E. Mathews for his assistance in the conduct of the testing program; Mr. Jack M. Fath for assistance with the model airplane testing program; and Mr. Ronald L. Fisher for his assistance with data analysis.

USCOMM-NBS-DC

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 75-693	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Measurement Methodology for Determining the Sound Output of Model Airplanes and Noise Producing Bicycle Attachments			5. Publication Date April 1975 6. Performing Organization Code
7. AUTHOR(S) Marilyn A. Cadoff and William A. Leasure, Jr.			8. Performing Organ. Report No. NBSIR 75-693
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 2130496 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Bureau of Engineering Sciences Consumer Product Safety Commission 5401 Westbard Avenue Bethesda, Maryland 20014			13. Type of Report & Period Covered Final 7/73-6/74 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

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 Consumer Product Safety Commission under the authority of the Toy Safety Act of 1969. This report outlines a methodology which was developed to measure the noise levels of model airplanes and noise producing bicycle attachments. The technical back-up and rationale for the development of the methodology are discussed. In addition, data taken using the proposed methodology are presented.

17. KEY WORDS *(six to twelve entries, alphabetical order, capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Bicycle attachments; children; consumer safety; model airplanes; noise; toys.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[X] Unlimited [ ] For Official Distribution. Do Not Release to NTIS [ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	24
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $3.25

USCOMM-DC 29042-P74