NBSIR 74-608

Procedure for Measuring Noise Emission From Power Lawn Mowers

Jonathan I. Adler

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

November 1974

Final Report

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Washington, D. C. 20207

NBSIR 74-608

PROCEDURE FOR MEASURING NOISE EMISSION FROM POWER AND LAWN MOWERS

Jonathan I. Adler

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

November 1974

Final Report

Prepared for
Bureau of Engineering Sciences
Consumer Product Safety Commission
5401 Westbard Avenue
Washington, D. C. 20207

U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

ABSTRACT

A procedure is described for measuring the noise emission from power lawn mowers. The procedure covers both walk-behind and riding mowers, including suggestions of maximum noise levels for protection from hearing loss and for reception of emergency messages. The procedure employs a microphone located near the ear of the operator and mounted on a back-pack worn by the operator.

Key Words: Emergency messages; hearing loss; lawn mowers; noise emission; noise pollution; product safety.

I. Introduction

This report outlines a measurement procedure for determining the level of noise emission from power lawn mowers. The measurement technique is designed to estimate the noise level at the ear of the operator. It is similar, in that respect, to the noise measurement technique presented in ANSI B71.1-1972, Safety Specifications for Power Lawn Mowers, Lawn and Garden Tractors, and Lawn Tractors. By contrast, SAE Recommended Practice XJ-1046 (1973), Exterior Sound Level Measurement Procedure for Small Engine Powered Equipment, estimates the noise level at a distance of 7.6 metres (25 feet) from the mower.

The present protocol relies heavily on these earlier documents. Many of the specified test conditions in the present protocol are identical with those specified in the earlier documents. For explanation of the rationale for these test conditions, the reader is referred to those documents. The present technique differs from the earlier protocols primarily in the specification of an operator-mounted microphone to determine the noise level at the ear of the operator while the lawn mower is in motion.

II. Rationale

The present procedure is intended to obtain information similar to that obtained by the noise level measurement procedure in ANSI B71.1-1972. Two provisions of ANSI B71.1-1972 have necessitated the present document: (1) the mower is to be stationary [Section 8.3.4(4)]; and (2) the position of the microphone is specified [Sections 8.1 and 8.2] completely independently of the size or position of the operator [Section 8.3.2(1) states: "An operator shall be in position when readings are taken."].

The use of a stationary power mower can produce underestimates of the noise output. The primary source of noise in a walk-behind mower is the blade (EPA, 1974a). Hence, maximum noise is obtained with maximum blade speed (the maximum governed speed specified by the mower manufacturer). This condition can be met by a stationary mower. However, the primary source of noise in a riding mower is the engine (EPA, 1974a).

Maximum noise is produced when the engine is maximally loaded, within the limits specified by the mower manufacturer (see also SAE XJ-1046), such as by use in tall, wet, or dense grass. Such a maximum is not reached by a stationary mower.

Since riding mowers generally produce higher noise levels than walk-behind mowers, a procedure which underestimates the noise emission of riding mowers would be unsatisfactory. The present protocol attempts to simulate operating conditions by specifying an additional load to be towed while the mower is in motion. (SAE XJ-1046 suggests a brake load as an alternative to a towed load. However, the brakes on the mower in our tests were not adequate to provide sufficient loading.)

The presence of the operator introduces a reflecting surface into the sound field. His body reflects sound both toward and away from the microphone and thus alters the measured level from that obtained in his absence. However, the most accurate measurement of the noise level received at the ear of the operator can be obtained only with the operator present, precisely because of that reflection. Ideally, the microphone should be in the ear of the operator. Realistically, the microphone should be in close proximity to the ear of the operator. If the relationship of the microphone to the ear of the operator is not specified, however, a source of variability is added. Large variations in obtained noise levels can be produced simply by changing the height of the operator. The present protocol avoids this problem by specifying the microphone position relative to the operator's ear.

The specification of microphone position relative to the operator suggests the use of an operator-mounted microphone (Figure 1). Furthermore, a moving mower makes an independently mounted microphone impractical. However, several difficulties with operator-mounted microphones necessitate additional specifications. First, the microphone must be isolated from vibration and sound transmitted through the body of the operator. It was found that a piece of rubber pad, used as a bushing (see Fig. 2) between the microphone and its holder provided sufficient isolation.

Second, the operator-mounted microphone must be no more sensitive to body orientation of the operator than an independently mounted microphone. A requirement that the operator always be facing in the direction of travel throughout the measurements should produce the required insensitivity (see Appendix). Finally, an operator height specification is needed to fix the microphone's position with respect to the mower.

The height range chosen is that for the average adult male. This choice follows ANSI B71.1-1972, in which the microphone height is also based on the average height of adult males. With this specification, however, 50 percent of the adult male population will be exposed to a greater noise level than that measured by these procedures. Furthermore, an even greater proportion of adult females and, especially, teenage children will receive increased exposures. By using a teenage operator, between 1.47 and 1.61 metres (58 and 63 inches) in height, the exposures of at least 50 percent of the teenage population will be limited to the specified level. Even greater protection will be afforded to the population as a whole. Alternatively, any limit based on adult height should be lowered 2 dB to compensate for greater exposures to shorter people (see Appendix).

In addition to the above changes in the ANSI B71.1-1972 specifications, the use of a standardized artificial surface (Figure 3) was required instead of grass. The requirement is substantially the same as that in SAE XJ-1046 (see Fig. 4). A standardized surface is specified to provide comparability of measurement from test site to test site and relative insensitivity to weather changes.

III. Measurement Protocol

1. Instrumentation. The measurements shall be performed with the following instruments:

(1) A precision sound level meter which conforms to the requirements for Type I Sound Level Meters of ANSI S1.4-1971, Sound Level Meters. Alternatively, the noise level may be recorded for later analysis, provided the accuracy of the total system is equivalent to that of a Type I Sound Level Meter.

(2) A sound level calibrator.

(3) A windscreen for use with the microphone. To be acceptable, the screen must not affect the microphone response more than ±1 dB for frequencies from 20 to 4000 Hz and ±1.5 dB for frequencies from 4000 to 10 000 Hz.

(4) An anemometer or other device for measuring wind speed.

(5) A wind direction indicator.

(6) A tachometer or other engine speed indicator.

(7) A thermometer for measuring ambient temperature.

(8) A barometer for measuring barometric pressure.

(9) A wet-bulb thermometer or other relative humidity indicator.

2. Test Site. The test site shall consist of a flat open space free of any large reflecting surfaces, such as signboards, buildings, hillsides, or large trees, located within 30.4 metres (100 feet) of the measurement zone. The measurement zone is defined as follows:

(1) Minimum dimensions: A path of travel 1.2 metres (4 feet) wide by 14.8 metres (48 feet) long flanked on both sides by similar areas, 1.2 metres (4 feet) wide by 14.8 metres (48 feet) long (see Fig. 3).

(2) Surface: Synthetic turf mounted on 19.1 millimetre (0.75 inch) exterior plywood or 12.7 millimetre (0.5 inch) minimum thickness marine plywood with suitable adhesive. The turf shall be 12.7 millimetre (0.5 inch) pile height, 60 denier nylon 6 fiber, approximately 1,085 grams/metre^2 (32 ounces/yard^2) on polypropylene backing approximately 170 grams/metre^2 (5 ounces/yard^2).

Acoustical properties of the surface tested per ASTM C423-66 after mounting on plywood shall be:

Hz	Sound Absorption Coefficient
125	0.04-0.06
250	0.09-0.12
500	0.20-0.28
1000	0.30-0.32
2000	0.40-0.46
4000	0.46-0.62

(3) Placement: The surface shall be placed directly on the ground in the test site as to be approximately level. There shall be no holes in the ground underneath the surface which might cause local areas of high resonance.

(4) Laboratory conditions equivalent to the test site shall be acceptable.

3. Test Conditions. The following conditions shall prevail during the test:

(1) The sound-level measuring equipment shall be located at a point 7.6 metres (25 feet) from the path of travel along a line equidistant from the ends of, and perpendicular to, the path of travel. The observer reading the meter shall also be at that point.

(2) Any person at the test site in addition to the mower operator and the observer reading the meter shall be either directly behind the observer (on the side opposite the path of travel) or more than 15.2 metres (50 feet) from the mower path or the instruments.

(3) The ambient wind speed, the wind direction relative to the path of travel, the ambient temperature, barometric pressure, relative humidity, and the ambient A-weighted sound level shall be measured and recorded. The ambient sound level(A-weighted) due to sources, including wind, other than the lawn mower being tested, must be at least 10 dB lower than the sound level (A-weighted) produced by the lawn mower. It is recommended that measurements not be made in winds exceeding 5.3 metres/second (12 miles/hour).

(4) The cutting height of the mower shall be set as close to 51 millimetres (2 inches) as the mower permits.

(5) The engine (motor) shall be operated at the mower manufacturer's specified maximum governed speed.

(6) For walk-behind mowers, the cutting blades shall be rotating and the self-propelling mechanism, if any, shall be engaged.

(7) For riding mowers, the cutting blades shall be rotating and the clutch engaged. In addition to choosing the appropriate gear, an auxiliary towed load shall be used to produce the maximum sound level obtainable from any gear-load combination within the manufacturer's operating specifications.

4. Test Procedure. The procedure for measuring the sound level produced by a walk-behind mower or riding mower shall be as follows:

(1) An operator shall be in position when readings are taken.

(2) The microphone shall be located on the axis connecting the operator's ears. It shall be 127 millimetres (5 inches) laterally from the side of the operator's head. Measurements shall be taken first on one side and then on the other side of the operator's head, which shall be oriented in the forward direction.

(3) The operator shall be between 1651 millimetres (65 inches) and 1778 millimetres (70 inches) in height.

(4) the microphone shall be mounted on the operator by means of a back-pack frame (see Fig. 1), or its equivalent, in such a way as to minimize the effects of vibration and sound transmitted through the body of the operator. Any auxiliary sound level equipment such as a microphone power supply, tape recorder, etc., to be mounted on the operator shall be placed on the back-pack frame so as to minimize additional reflection of the sound toward or away from the microphone.

(5) The instrument manufacturer's recommendations with regard to microphone orientation shall be followed.

(6) The sound level meter shall be set at the slow response setting and on the A-weighted scale.

(7) The instrument manufacturer's recommended calibration practice shall be followed. Field calibration shall be made immediately before and after each test sequence.

(8) The mower shall be run at least twice in each direction the full length of the specified path of travel for each microphone placement. However, the number of readings at each placement must equal or exceed the range, in decibels, between the highest and lowest A-weighted sound levels obtained. The noise level of the mower shall be the average, rounded to the nearest 0.5 dB, of the two highest readings which are within 1.0 dB of each other.

IV. Implementation

In order to devise a noise emission standard from a measurement protocol, it is necessary to affix a maximum permissible noise level.

The level is, in part, determined by the intended purpose of the standard.

If the goal is prevention of hearing damage to the operator, a level of 85 dB (A-weighted) would be adequate as a maximum limit. With a two-hour exposure, an 85 dB limit is supported by most of the damage-risk literature (Cohen et al.,1970; but see Kryter, 1973, for an opposing view). In addition, from the EPA Levels Document (EPA, 1974b) an 80 dB exposure limit can be computed. It should be noted, however, that even the 85 dB limit may be overly stringent. The 85 dB (A-weighted) limit for a two-hour exposure (Cohen et al., 1970) is based on the assumption that the operator is exposed to continuous noise (or its equivalent) at that level on a daily basis. Given the intermittancy of non-occupational use of lawn mowers, it seems unlikely that, even at 90 dB (A-weighted), any hearing loss could be directly attributable to power mower use. This is not to say that the lower limit should not be adopted. Lawn mowers used by gardeners and free-lancing teenagers are often of the same type used by consumers. These users obviously are subject to longer and more regular daily exposure.

If the goal is prevention of interference with emergency communications directed at the operator, a more stringent limit must be set. Data from Beranek (cited in EPA, 1973) indicate that a shouting speaker will be heard at 2.4 metres (8 feet) if the level is reduced to 75 dB (A-weighted). A pilot experiment conducted at NBS produced similar results (see Appendix). Phonetically-balanced single-syllable words were shouted at operators,from behind, while the operators stood behind a stationary power mower. The noise level of the mower was 84.5 dB (A-weighted). Correct recognition for 50 percent of the words was possible only at distances under 1.5 metres (5 feet) from the operator. These results, however, can only be considered suggestive.

Emergency communications are usually based on a much more restricted vocabulary than ordinary speech. Vocabulary restriction tends to increase the probability of recognition. Furthermore, recognition of the word may not be necessary. To elicit a response of stopping, looking around, etc., a recognition that someone is shouting may be sufficient. Recognition that someone has shouted occurs at greater distances than word recognition. Both of these factors would work to allow a higher noise level.

At the same time, emergency communications are, by definition, unexpected. By contrast, the subject in a speech-intelligibility experiment knows words will be spoken (shouted) to him. An unexpected communication would be more susceptible to interference than ordinary speech, thus indicating a more stringent limit. Clearly, more study of the problem of emergency communications is necessary before an accurate level can be set.

With respect to either goal, there is no justification for setting a level for riding mowers higher than that for walk-behind mowers. Operators of riding mowers are likely to have higher average exposure times than operators of walk-behind mowers. Thus, the possibility of hearing damage, if present at all, is higher for the former. Since riding mowers typically are moving faster than walk-behind mowers, the operator may have less time to react to emergency communications. A larger emergency-communication space, or a lower noise limit, would be necessary to compensate for the higher operating speed. At the very least, equal limits should be set.

Appendix

Several series of measurements were made to test aspects of the measurement protocol. Of primary interest was the robustness of the technique, the extent of its insensitivity to extraneous factors. These included the effects of body and head movement and orientation, and vibration from a moving mower. For comparison, measurements were also taken using the ANSI B71.1-1972 procedure. These tests were performed on grass, rather than on the specified measurement surface, mostly for convenience.

One walk-behind mower and one riding mower were used in these tests. For the walk-behind mower, the results were as follows (all sound level measurements are A-weighted):

A. Variation in body position of the operator resulted in levels between 80.5 dB and 82.5 dB (left side), and between 81.0 dB and 83.0 dB (right side), as measured in accordance with ANSI B71.1-1972. The operator moved from arms-length away, to chest against the handle, to leaning over the handle.

B. With the microphone at a 1.46 metre (56 inch) height, rather than at the 1.68 metre (66 inch) standard height, the ANSI procedure obtained levels from 81.5 dB to 84.5 dB (left side), and from 82.0 dB to 85.0 dB (right side), for the same variations in body position. The 1.46 metre (56 inch) microphone height corresponds to a body height of 1.56 metres (61 inches).

C. Variations in body position of the operator resulted in levels from 83.0 dB to 85.5 dB (right side) as measured with the back-pack microphone. The procedure was identical to that specified in the protocol above, with the exception that the mower was stationary. The range of body positions was the same as in (A). However, in this case the left side measurements were not obtained.

D. Variations in operator head orientation resulted in levels from 82.5 dB to 83.0 dB (right side) as measured by the back-pack microphone with the mower stationary. The operator rotated his head from facing left, to facing forward, to facing right. The operator stood with arms extended from the handle an intermediate distance. No left side measurements were made.

E. Variability of the measurements was determined by measuring the peaks on successive traverses along a previously cut strip of grass. The strip was 14.8 metres (48 feet) in length, equivalent to the measurement zone specified in the protocol. With the microphone on the right side, the range of peaks was from 84.5 dB to 85.0 dB; with the microphone on the left side, the range of peaks was from 85.5 dB to 86.0 dB. By comparison, the average right side level measured in a previous test on the artificial surface was 83.5 dB.

For the riding mower, the results were as follows (all sound pressure level measurements are A-weighted):

A. Variation in body position of the operator resulted in levels from 90.0 dB to 91.0 dB (left side) and from 90.5 dB to 91.0 dB (right side) as measured in accordance with ANSI B71.1-1972. The operator shifted from an upright sitting position to a crouched forward position.

B. With the microphone at a 0.69 metre (27 inch) height, rather than at the 0.76 metre (30 inch) standard height, the ANSI procedure obtained levels of between 90.5 Db and 91.5 dB (left side) and between 91.0 dB and 92.0 dB (right side) for the same variations in body position. The 0.69 metre (27 inch) microphone height corresponds to the average sitting height of boys in their early teens, 0.79 metres (31 inches).

C. Variations in body position of the operator resulted in levels from 89.0 dB to 89.5 dB (left side) and from 90.0 dB to 90.5 dB (right side) as measured by the back-pack microphone. The procedure was identical to that specified in the protocol above, with the exception that the mower was stationary. The range of body positions was the same as in (A).

D. Variations in operator head orientation result in levels of from 89.5 dB to 90.0 dB (both sides), as measured by the back-pack microphone with the mower stationary. The operator rotated his head from facing left, to facing forward, to facing right. The operator sat in an upright position.

E. Variability of the measurements was determined as in (E) above. The range of peaks was from 89.5 dB to 90.0 dB (both sides). In addition to the tests of the protocol, speech intelligibility tests were performed with the walk behind mower used above. The speaker stood at varying distances behind the operator and shouted at the operator lists of 25 monosyllabic phonetically balanced words. The words were obtained from ANSI S3.2-1960, Method for Measurement of Monosyllabic Word Intelligibility. The operator recorded the words on a pad of paper. The number of correct words was as follows:

	Distance		
Operator	2.1 metres (7 ft)	1.5 metres (5 ft)	0.9 metres (3 ft)
J.Z.	6	11	12
J.C.	6	11	14

As the table indicates, 50 percent recognition is achieved only at distances less than 1.5 metres (5 feet), when the operator is standing behind a walk-behind mower with a measured noise level of 83.5 dB (A-weighted).

References

ANSI B71.1-1972. Safety Specifications for Power Lawn Mowers, Lawn and Garden Tractors, and Lawn Tractors. American National Standards Institute, New York, N. Y.

ASTM C423-66 (1966). Method of Test for Sound Absorption of Acoustical Materials in Reverberation Rooms. American Society for Testing and Materials, Philadelphia, Pa.

Cohen, Alexander, Anticaglia, Joseph, and Jones, Herbert H. (1970). "Sociocusis" - Hearing Loss from Non-Occupational Noise Exposure. Sound and Vibration, 4(11), 12-20.

EPA (1973). Public Health and Welfare Criteria for Noise. U.S. Environmental Protection Agency, Washington, D.C., p. 6-5.

EPA (1974a). Lawn Mowers: Noise and Cost of Abatement. U.S. Environmental Protection Agency, Washington, D.C. pp. 17-18.

EPA (1974b). Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. U.S. Environmental Protection Agency, Washington, D.C.

Kryter, Karl D. (1973). Impairment to Hearing from Exposure to Noise. Journal of the Acoustical Society of America, 53(5), 1211-1234.

SAE Recommended Practice, XJ-1046(1973). Exterior Sound Level Measurement Procedure for Small Engine Powered Equipment. Society of Automotive Engineers, New York, N.Y.

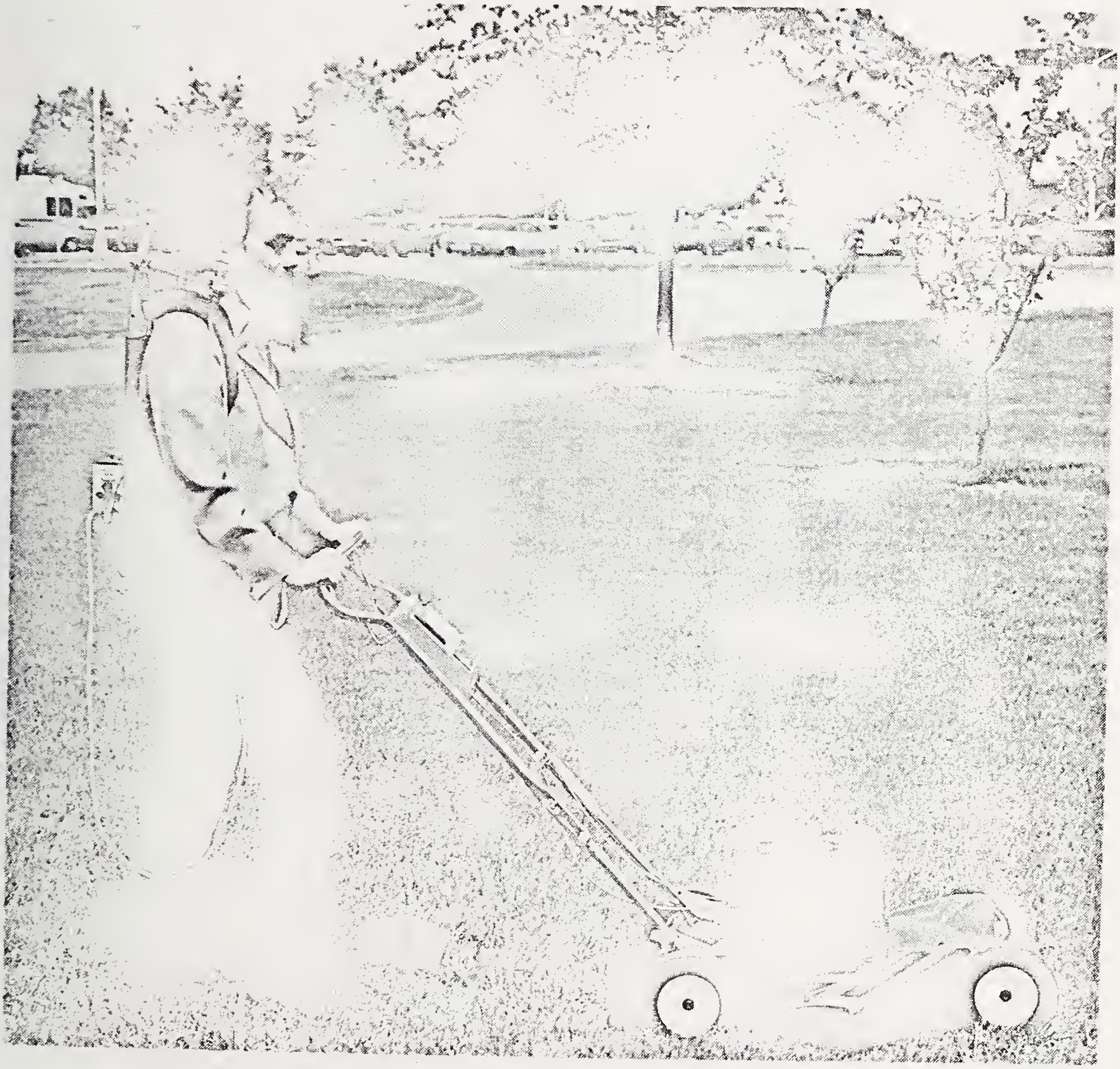

Figure 1. Operator with backpack frame and microphone in position.

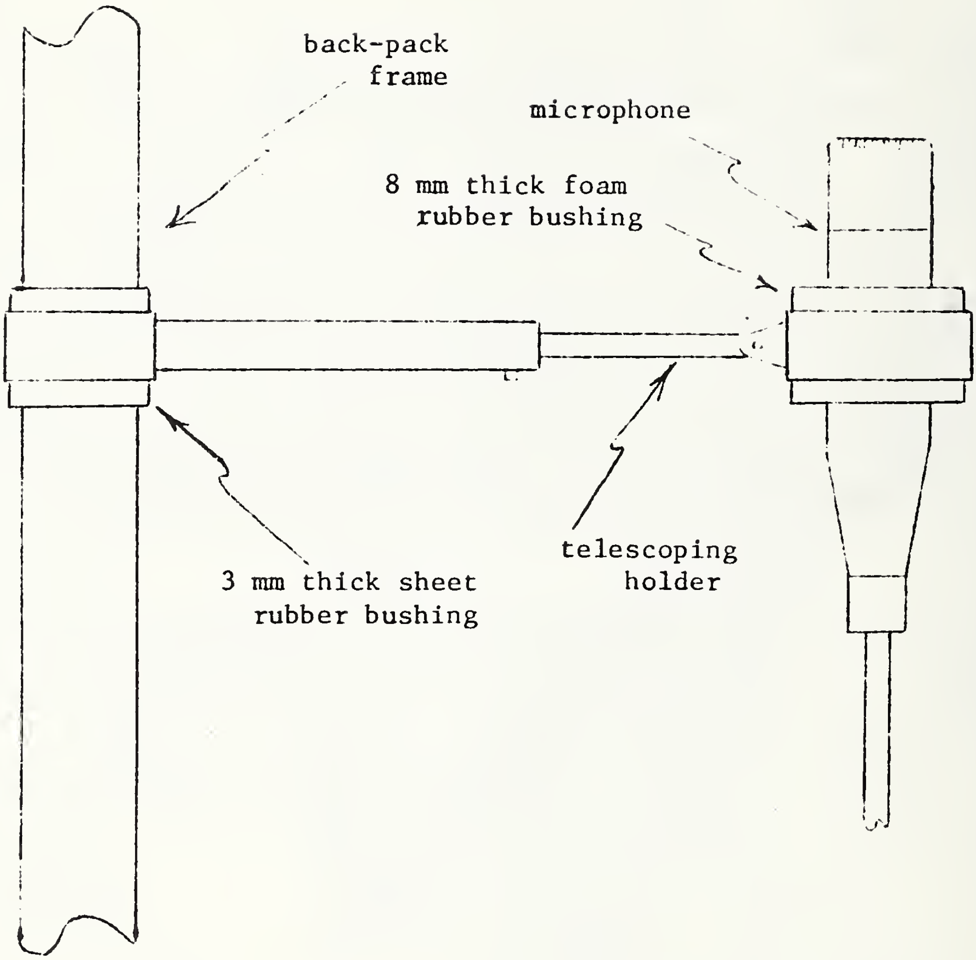

Figure 2. Microphone holder.

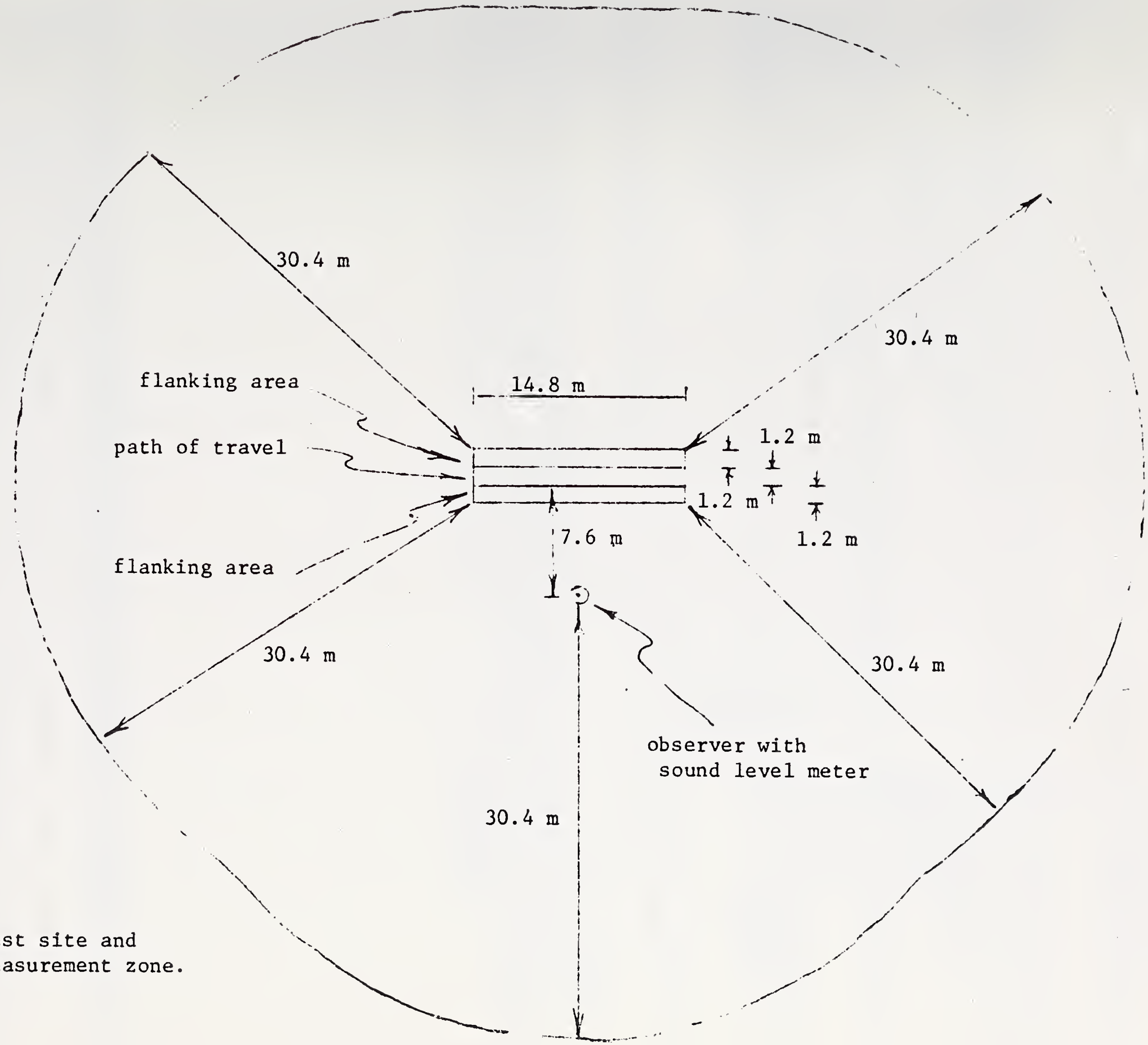

Figure 3. Test site and measurement zone.

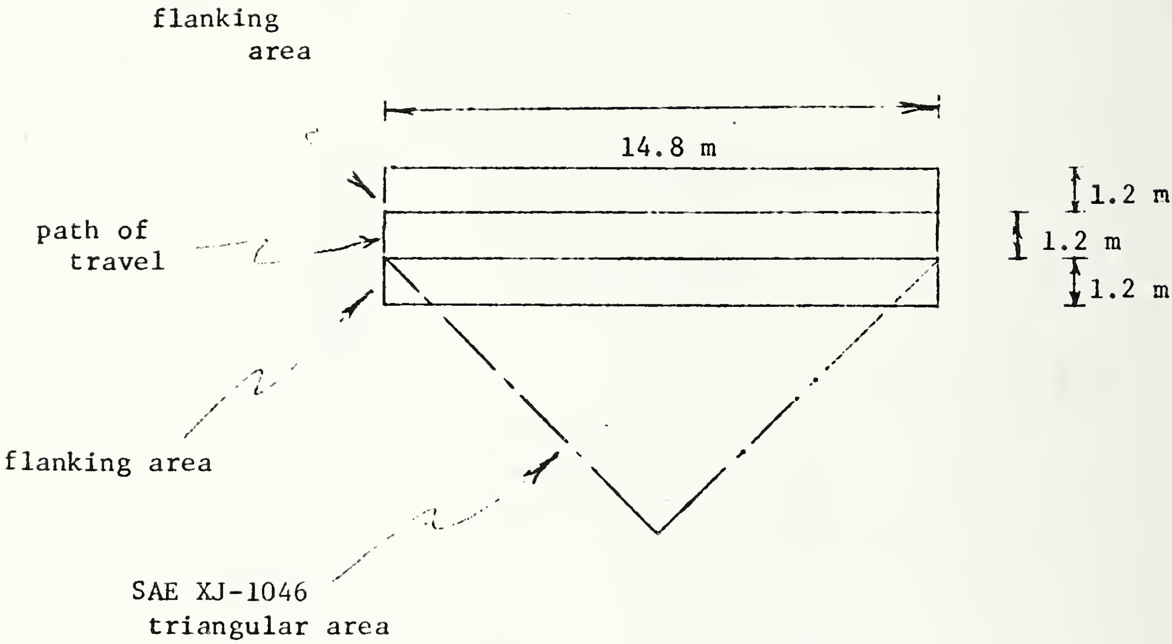

Figure 4. Measurement zones of SAE XJ-1046 and present procedure.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 74-608	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE	5. Publication Date
Procedure for Measuring Noise Emission from Power Lawn Mowers	November 1974
	6. Performing Organization Code
7. AUTHOR(S) Jonathan I. Adler	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 2130114 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 Washington, D.C. 20207	13. Type of Report & Period Covered Final 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.)*

A procedure is described for measuring the noise emission from power lawn mowers. The procedure covers both walk-behind and riding mowers, including suggestions of maximum noise levels for protection from hearing loss and for reception of emergency messages. The procedure employs a microphone located near the ear of the operator and mounted on a back-pack worn by the operator.

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)*

Emergency messages; hearing loss; lawn mowers; noise emission; noise pollution; product safety.

18. AVAILABILITY [X] Unlimited	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[ ] For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	17
[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13	20. SECURITY CLASS (THIS PAGE)	22. Price
[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	

USCOMM-DC 29042-P74