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DEPARTMENT OF THE NAVY
BUREAU OF SHIPS
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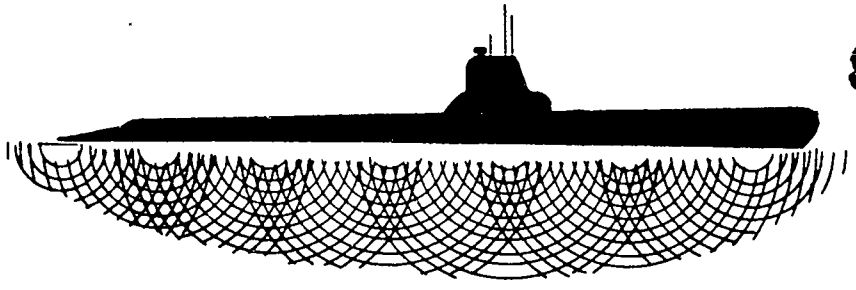
RESEARCH AND DEVELOPMENT REPORT

CRITERIA FOR SETTING AIRBORNE NOISE LEVEL LIMITS IN SHIPBOARD SPACES



JULY 15, 1952
WASHINGTON, D.C.

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CRITERIA FOR SETTING AIRBORNE NOISE LEVEL LIMITS IN SHIPBOARD SPACES

By

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Abstract

In this report criteria are presented to guide the specification writer in the preparation of airborne-noise specifications for ship spaces. The physco-acoustic effects of various levels of noise are described. Measured noise levels in several typical spaces are compared with the criteria. The criteria are summarized in Tables I and II.

Introduction

Noise in ship spaces may be objectionable for several distinct reasons. The noise may be intense enough to result in permanent deafness, the noise may reduce the intelligibility of speech, or the noise may merely result in discomfort. In many ship spaces some of these effects can be tolerated. For example, in an engine room, discomfort and poor speech intelligibility are usually accepted.

Accordingly, the tolerable noise level depends on the function of the space. In the setting of noise level limits, the functions of the space must be known. However, discussion of the functions of various spaces is out of place in this report; it will be assumed that this information is available.

The effects of noise on speech intelligibility, comfort and permanent deafness have been investigated by physco-acoustic research. Although the information cannot, at this time, be considered as completely definite and understood, nevertheless there is sufficient information to permit setting of noise level limits for the various effects of noise.

In the past, noise limits have been set in terms of wide frequency band or "overall" levels. The use of a single wide-band level, although convenient, was a result of insufficient information about the effects of noise. It is now known that a single wide-band level cannot adequately determine the effect of a noise; the frequency spectrum must also be specified. Two noises may have the same wide-band level, yet one can be objectionable and the other not. For example, a noise concentrated at a single frequency with a level of 100 db above 0.0002 microbars may result in some permanent deafness, whereas another noise with the same wide-band level, but distributed uniformly over the audio-frequency spectrum will not result in deafness.

Accordingly, the noise level limits described in this report are in terms of spectra. This may result in some inconvenience and complexity, since instead of a single number, a group of numbers must be specified as a limit. However, this added complexity is necessary if the limits are to have significance.

No consideration is given in this report to the practicability of achieving the limits. The point-of-view taken is that if certain noise levels are necessary to enable a space to perform its function adequately, then these limits must be met. Only after a strong showing of impracticability should the limits be waived.

Noise Level Limits

The noise level limits for avoiding various objectionable effects are given in Tables I and II. Although these tables are intended to be self explanatory, some additional discussion of their application may be useful. The basis for the derivation of the limits is given in the Appendix to this report.

The deafness-avoidance criteria in Table I are determined to avoid any abnormal permanent hearing loss in 95% of all individuals. The indicated levels should not be exceeded in any octave band. Permanent hearing loss, as used in these criteria, is a hearing loss, indicated by an audiogram, which persists for months or years after the exposure to the noise. It should be noted that audiograms can indicate small values of hearing loss (less than 30 db) which do not result in social handicaps; accordingly, the deafness-avoidance criteria may be considered to be conservative.

The comfort criteria in Table I are somewhat arbitrary, as the tolerable level of noise depends on an individual's expectation of noise and the extent to which he had become accustomed to it. For this reason two distinct criteria have been set. It should be noted that noise does not effect the ability of an individual to perform an assigned task, if the task does not require speech communication. However, excessive noise may be a morale problem since it may effect the incentive required to perform a task, or may result in nervous fatigue and a lowering of the "threshold of irritability."

The criteria for speech interference in Table II are based on the concept of the "speech interference level." The speech interference level is the arithmetic average of the decibel levels for the octave bands 300 to 600, 600 to 1200, 1200 to 2400, and 2400 to 4800 cps. The effect of noise on speech intelligibility does not depend on the level in any individual octave band, but instead on their averaged level. The permissible speech interference level depends on the loudness of the speaking voice, on the distance from the speaker, and on the acoustical characteristics of the space. The pertinent characteristic of the space

is the amount of acoustic absorption present; since absorption reduces the amplifying effect of reverberation on the speech, the more absorption, the lower the speech-interference level must be. The levels listed in Table II are the maximum noise levels which will permit good speech intelligibility under the stated conditions.

Comparison with Measured Levels

It is of interest to compare the levels actually measured in spaces with the listed criteria. This will be done for a typical submarine engine room and for a destroyer combat information center (C. I. C.).

The octave band levels measured in an engine room of a fleet submarine, the USS REDFISH, are listed below and compared with the levels given in Table I as the deafness-avoidance criteria for repeated exposure to noise. The comparison indicates that with the engines at full speed, the levels exceed the criteria by about 5 db in the bands from 300 to 4800 cps, but with the engines idling, the criteria are not appreciably exceeded.

Measured Levels on USS REDFISH vs Deafness-Avoidance Criteria

Frequency Band in cps	Octave Band Level in db above 0.0002 microbars		
	Measured Levels (Ref. 2)		Deafness-Avoidance
	650 RPM	No Load	Criteria
75-150 cps	104	98	110
150-300	106	103	110
300-600	111	106	105
600-1200	105	102	100
1200-2400	97	93	95
2400-4800	94	87	90

Accordingly, some abnormal hearing loss may be found in personnel assigned to the engine rooms of fleet submarines.

The octave band levels in the C.I.C. on USS BORIE (DD 703) with all equipment operating, calculated from data in reference (7), are listed below. The speech interference level calculated from these octave band levels is 64 db above 0.0002 microbars.

Measured Levels in USS BORIE C.I.C.

Frequency Band in cps	Octave-Band Level db above 0.0002 microbars
300-600	70
600-1200	67
1200-2400	61
2400-4800	58

In the comparison of this speech interference level with the criteria in Table II, it will be assumed that the space has a quantity of acoustic absorption between 100 and 400 sabines. The table indicates that for good intelligibility at distances of 4 feet or greater a very loud voice will be required, whereas a normal voice will provide good intelligibility only as far as 1 foot.

Recommended Noise Level Limits

As stated previously, the acceptable noise level depends on the function of the space. Based on present usage of spaces, noise level limits can be recommended as a guide for the specification writer. Recommended maximum levels are given below.

1. All accessible points in all spaces:
   Deafness-avoidance criteria for occasional exposures in Table I.

2. All watch stations in all spaces, no speech communication required.
   Deafness-avoidance criteria for repeated exposures in Table I.

3. All watch stations, only minimal speech communication required:
   (a) Deafness avoidance criteria for repeated exposures in Table I.
   (b) Speech interference level less than 90 db.

4. Spaces requiring close-up speech communication without strain, and communication possible to all parts of the space:
   Speech interference level below 72 db.

5. Small spaces (less than 5000 cubic feet) requiring speech communication to all parts of the space without excessive strain:
   Speech interference level below 60 db.

6. Noisy Berthing Spaces.
   Higher comfort criteria in Table I.

7. Social spaces such as messing spaces:
   Speech interference level below 60 db.

8. Special quiet ship spaces such as sick bay:
   Lower comfort criteria in Table I.

It should be understood that these recommended limits may require modification to suit the requirements of specific spaces.

APPENDIX
DERIVATION OF CRITERIA

A spectrum analysis in octave bands has been chosen as a compromise between the oversimplified wide-band level and the ultimate analysis in band widths equal to the aural critical bands. The latter analysis is, for physco-acoustic purposes, the most complete description of a noise, but such an analysis is considered to be inconvenient for routine use. The setting of limits for octave bands is satisfactory if the noise has continuous spectrum or many peaks distributed through each octave, but errors may result if the noise consists of only a few discrete frequencies.

The deafness-avoidance criteria for repeated exposures are based on the limit of 100 sones per octave band suggested by reference (1). The levels of deafness-avoidance criteria in references (1) and (2) agree for the band 2400 to 4800 cps, but at lower frequencies the levels of reference (1) and Table I are higher than those suggested by reference (2); it is believed that reference (2) is too conservative at the lower frequencies. For occasional exposures the 15 db increase in permissible level suggested by reference (2) has been used above 300 cps; below 300 cps only 10 db increase has been used.

The comfort criteria are rather arbitrary. The higher limit is based on the levels indicated by reference (3) as the limit for a comfortable commercial aircraft. The lower limit has been set to provide a speech interference level of about 50 db, with a gradual rise in level at frequencies below 600 cps; there are indications that comfort is related to ease of speech communication.

The concept of "speech interference level" is used in reference (4). This concept is a simplification of the procedure for estimating interference of noise with speech described in reference (5). The simplification is based on several assumptions and approximations; the important ones are 1) the levels in the various bands do not differ among each other by more than about 30 db. 2) the relation between articulation index and the speech-noise ratio in decibels is linear, 3) the octave bands are assumed to contribute equally to the articulation. A weighted average, based on the unequal contribution of the octave bands to articulation, has been suggested by reference (6), however, such refinements are not considered necessary for the accuracy required here. In the preparation of Table II, the levels were separated by 6 db intervals, as this was considered to be the practical limit of accuracy; if nothing else, the level of speech varies by this amount among individuals. A 6-db interval corresponds to a spread of about 0.2 in articulation index. The following data was used in the preparation of Table II: 1) The averaged octave-band

speech level, for the bands 300-600, 600-1200, 1200-2400, and 2400-4800 cps, was assumed to be 66 db above 0.0002 microbars in 1% of 1/8 second intervals, at 1 foot for a normal voice level; 2) In the calculation of the effect of reverberation, a directivity index of 3 db was used; 3) For an articulation index of 0.5 it was assumed that the speech level in 1% intervals must be 8 db higher than the long-time average noise level.

References

(1) Hardy, H. C.: Paper A4 presented at meeting of Acoustical Society of America on May 8, 1952.

(2) Kryter, K. D.: "The Effects of Noise on Man" (Monograph Supplement 1, 1950, of the Journal of Speech and Hearing Disorders) Part II.

(3) Lippert and Miller: JASA Vol 23 p 478 (July 1951). Journal of the Acoustical Society of America.

(4) Bolt, Beranek and Newman: Paper unpublished at M. I. T. Symposium on Building Acoustics and Noise Control, on 8.9 April, 1952.

(5) French and Steinberg: JASA Vol 19, P 90 (January 1947)

(6) Unpublished letter from D. E. Bishop, Armour Research Foundation, to Bureau of Ships dated 3 June 1952.

(7) Material Laboratory, N. Y. Naval Shipyard, Final Report on Project 5280-1, dated 5 March 1952.

TABLE I
CRITERIA FOR
DEAFNESS AVOIDANCE AND COMFORT

Maximum Permissible Sound Pressure Levels in Individual Octave Bands
in Decibels above 0.0002 microbars

	OCTAVE BAND (Lower cut off, cps. / (Upper cut off, cps.	38 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600
DEAFNESS	Occasional exposures (less than 1 hour each)	125	120	120	120	115	110	105	110
	Repeated exposures (over periods of months)	115	110	110	105	100	95	90	95
COMFORT	Noisy Environment (Inhabitants expect noise)	100	95	90	85	75	65	60	55
	Normal Environment (Inhabitants expect moderate quiet)	80	70	60	55	50	50	50	45

TABLE II

CRITERIA FOR SPEECH INTERFERENCE

NOTES:

1. The table gives the maximum permissible speech interference level for good speech intelligibility under the indicated conditions.

2. The speech interference level is the arithmetic average of the decibel levels for the octave bands 300-600, 600-1200, 1200-2400, and 2400-4800 cps. Levels are in decibels above 0.0002 microbars.

3. Good intelligibility is defined as an articulation index of 0.5 or higher, corresponding to an intelligibility of 97% for sentences, 90% for isolated words, and 70% for syllables.

4. If excellent intelligibility is desired, corresponding to an articulation index of 0.7 or higher (90% intelligibility for syllables), the speech interference levels should be set 6 db lower than indicated.

5. Very loud speech is defined as the loudest speech possible without shouting or excessive strain. It is sometimes called "full-effort speech", and has a long-time average rms. sound pressure level of 87 db above 0.0002 microbars at 1 foot.

6. In the absence of more definite values of acoustic absorption the following values may be assumed--below 100 sabines for a space less than 500 cubic feet in volume; 100-400 sabines for 500-5000 cubic feet; 400-1600 sabines for space above 5000 cubic feet.

Maximum Permissible Speech Interference Levels

		VOICE LEVEL			
Distance to Talker in feet	Acoustic Absorption of Space in sabines	Shout	Very Loud	Raised Voice	Normal
½	Any value	90	84	78	72
1	Any value	84	78	72	66
2	Any value	78	72	66	60
4	Below 100	78	72	66	60
	above 100	72	66	60	54
8 or more	Below 100	78	72	66	60
	100-400	72	66	60	54
	400-1600	66	60	54	48

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