NVIC 12-82
2 Jun 1982

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 12-82
Electronic Version for Distribution Via the World Wide Web

Subj: Recommendations On Control of Excessive Noise

Ref: (a) 46 CFR 32.40-15
(b) 46 CFR 72.20-5
(c) 46 CFR 92.20-5
(d) International Maritime Organization (IHO) Resolution A.468(XII), "Code On Noise Levels On Board Ships".
(e) U.S. Naval Ocean Systems Center, "Study of Airborne Noise On Merchant Ships" (see enclosure (9), reference 1).

1. PURPOSE. This Circular contains the Coast Guard's recommended guidelines to the U.S. maritime industry for addressing conditions of high noise. The guidelines were developed in consideration of the need for protecting crewmembers from noise exposures which may produce permanent noise induced hearing loss; for providing crewmembers with suitable conditions for recuperation from the effects of exposure to high noise levels; and for providing a safe working environment by giving consideration to the need for effective speech communication and for hearing audible alarms and warnings. Amplifying information in attached enclosures is provided as guidance in addressing key aspects of noise control.

2. APPLICATION.

a. The recommendations of this Circular apply to all commercial vessels inspected by the Coast Guard except Mobile Offshore Drilling Units.

b. Although these guidelines are not directed specifically to uninspected commercial vessels, the Coast Guard considers them to be appropriate guidelines should any owner of uninspected vessels also choose to follow them.

c. At the time of this publishing, the Coast Guard is collecting data to determine whether separate guidelines would be appropriate for inspected offshore drilling units and fixed structures. However, in lieu of separate guidelines, these guidelines are recommended for the interim.

3. DISCUSSION.

a. According to a recent Coast Guard-sponsored study (enclosure (9), ref. 1), noise exposures of certain personnel aboard U.S. merchant vessels were found to be in excess of those considered to be safe. The study also indicated that high noise levels aboard ship interfere with speech intelligibility) internal shipboard communications and the audibility of warning signals, which potentially impairs the safety of some operations on the vessel. Additional studies from foreign countries and information from other sources overwhelmingly support these findings for virtually all classes of commercial vessels. The studies also demonstrate that unlike shoreside workers who can retreat to a quiet environment after their work shift, merchant seamen are part of a mobile environment and may not have the opportunity to retreat to a quieter) relaxed atmosphere. Crew quarters, recreation areas, mess rooms, etc. are sometimes as noisy as the working environment. Similar problems are also widely reported in the offshore drilling industry. (NOTE: At the time of this publishing, the Coast Guard is still conducting a study on the particular noise problems in the offshore drilling industry.)

b. The effect of noise on hearing is a function of the actual noise level, its component frequencies and the duration of exposure. An excessive combination of these elements results in a shift in a person's threshold of hearing, i.e., an elevation in the lowest level of sound detectable to the ear. A threshold shift may be recoverable to varying degrees, depending upon its magnitude, provided the person retreats to a quiet environment (generally accepted as below 75 db(A)) for a sufficient time. While small threshold shifts may be totally recovered, large shifts are only partially recoverable leaving with each occurrence a small permanent threshold shift, known as hearing loss. The minimum goal of a noise control program should be to insure that an exposure (noise level over a certain duration) is not so great that the temporary threshold shift cannot be recovered during the following rest period.

c. After careful study, the Coast Guard has concluded that the most meaningful method of evaluating excessive noise in the maritime industry is by measuring the cumulative noise exposure during the complete 24-hour day. In addition to consideration of the normal work time noise exposure, the 24-hour exposure measurement considers the time after exposure to high noise to evaluate whether sufficient quiet time is provided to allow for recovery from temporary threshold shift. The term which will be used to express this measurement is the "24-hour effective exposure level," or $L_{eff}(24)$, and is defined in technical terms in enclosure (1). The L_{eff} (24)concept differs somewhat from the criteria proscribed by the Occupational Safety and Health Administration (OSHA) because of several factors which distinguish the maritime industry from industry ashore. However, the $L_{eff}(24)$ criteria would afford similar protection.

d. The exposure limit recommended herein (82 dB(A)) is, like almost all exposure limits, based upon an evaluation of a certain degree of risk to some personnel and does not insure that all personnel will not incur hearing damage. For this reason a hearing conservation program containing a system for periodic audiometric testing of personnel is necessary to detect those susceptible persons at the initial outset of a hearing impairment before any appreciable damage is accrued. Since, such a program would generally not be necessary if exposure levels (computed without regard to attenuation contributed by hearing protective devices) were further reduced to 77dB(A), the Circular suggests that new vessels be designed so that the 77dB(A) level may be achieved.

e. The control methods, i.e., engineering controls, administrative controls or hearing protective devices, selected by the owner/operator of a unit to achieve the recommended exposure limits, would depend upon economic and other considerations. Based upon data obtained from the study conducted by the Coast Guard and the state of the art in present noise control technology, the recommendations could be implemented on most units without retrofitting, principally through the use of hearing protectors. Other units may additionally need to administratively limit the time of exposure, and/or install soundproof control booths. Ultimately, however, installation of permanent engineering controls to reduce noise levels is the best means of assuring effective hearing protection. Although this technology may be young in marine applications (in the United States), the Coast Guard has seen several examples where significant reductions in noise levels in engineering compartments through modest engineering controls were achieved. The exposure levels in this proposal are such that they may be economically achieved on many vessels by using these engineering controls. It is encouraged that engineering controls be used whenever economically feasible.

f. In November 1981 the International Maritime Organization (IMO, formerly IMCO) approved a standard on shipboard noise entitled "Code On Noise Levels On Board Ships," which applies basically to new ships of 1600 gross tons or more. The Coast Guard participated in the development of this Code and endorses its recommendations. As the preamble to the Code makes clear however, it was not intended that the Code be adopted verbatim by member nations. Rather, each nation was permitted the flexibility to implement the principles of the Code through a method suited to the maritime industry of that nation. The Coast Guard believes therefore, that the recommendations in this Circular are a satisfactory implementation of the IMO Code. (NOTE: The IMO Code contains a section suggesting recommended noise level limits for various types of spaces on a unit. It is believed that this list offers guidance which would be useful to the designers of U.S. vessels and is therefore incorporated verbatim as an enclosure to this Circular. These levels are provided primarily as guidelines which might be useful for design specifications for suitable types of new vessels.)

g. It is considered that implementation of the recommendations in this Circular will involve an ongoing process encompassing a time frame of several months to years, depending upon the vessel. It is anticipated that phases involving measurement, provision of hearing protection devices, installation of some engineering controls, implementation of the hearing conservation program and other administrative aspects could be completed within two years. However, it may take up to four years before complete engineering solutions can be designed and installed.

h. The limits and procedures set out in these guidelines are regarded as minimum acceptable precautions against high noise conditions. For a greater margin of safety, owners and operators may wish to provide higher levels of protection. Also, as technology improves and as more scientific information becomes available, consideration will be given to amending these guidelines accordingly.

4. ACTION.

a. The following paragraphs b through i contain recommended guidelines for protecting crewmembers from conditions of high noise. Additional information in the attached

enclosures (1) through (9) are provided to amplify certain provisions of the recommendations. Definitions of terms used are contained in enclosure (1).

b. Recommended Exposure Limit.

(1) Each crewmember's 24-Hour Effective Exposure Level, $L_{eff}(24)$, as defined in enclosure (1), should be constrained to a maximum of 82 dB(A).

(2) If exposure levels were further reduced, through engineering and administrative controls alone, to an $L_{eff}(24)$ criteria of 77 dB(A), the hearing conservation program outlined below would no longer be necessary in most cases. The Coast Guard believes that the technology to accomplish this objective will be feasible on most deep-sea vessels, over 1600 gross tons, constructed after 1985 and recommends designing to the 77 dB(A) criteria at that time.

(3) NOTE: The exposure limits specified above are based upon the findings that exposures to high noise in the maritime industry are normally intermittent, as defined in enclosure (1). If work shift noise exposure is continuous, vice intermittent, then exposure levels should be reduced even further.

(4) $L_{eff}(24)$ can be achieved by any combination of engineering controls, administrative controls or hearing protective devices. However, because engineering controls provide the most positive means of assuring adequate protection, it is recommended that engineering controls be given first consideration and evaluated for feasibility before opting for other methods. Discussions on engineering controls and hearing protective devices are included in enclosures (4), (7) and (8).

(5) The Coast Guard realizes that reducing noise levels generally becomes increasingly more difficult on smaller vessels. It was for this reason that the IMO noise level limits referred to in subparagraph c.(2) below were restricted to vessels over 1600 gross tons. On many existing vessels of less than 500 gross tons, the incorporation of effective structural and engineering alterations to attenuate structure-borne noise may be economically prohibitive. However, through the use of hearing protective devices, administrative controls and selective engineering changes, the recommended 24-hour exposure limit, $L_{eff}(24)$, of 82db(A) should still be attainable.

c. Recommended Noise Limits.

(1) Where practicable, maximum noise levels in berthing spaces, and in mess spaces of units over 500 gross tons, should be no greater than 75 dB(A) on existing units and 70 dB(A) on new units.

(2) Annex III, paragraph (l)(e), of the International Regulations for Preventing Collisions at Sea, 1972 (commonly called the 72 COLREGS) contains the following requirements: "The sound pressure level of the vessel's [fog whistle] at listening posts shall not exceed 110 dB(A) and so far as practicable should not exceed 100 dB(A)." The 72 COLREGS are U.S. law and are mandatory for all U.S. vessels navigating on the high seas.

(3) As stated in Discussion paragraph 3.f., the "Code On Noise Levels On Board Ships," a noise standard published in November 1981 by the International Maritime Organization (IMO), contains a listing of suggested noise level limits for various spaces on ship. The Coast Guard considers that these limits would generally be appropriate for adoption as minimum design specifications for ocean-going vessels over 1600 gross tons which would be subject to the IMO Code. This list of limits is in enclosure (6). It is not intended that the list supplant any other recommendation in this paragraph 4., nor is it meant to imply that, if followed, would any exposure limit recommended herein be automatically achieved.

d. Rearing Protective Devices.

(1) Unless the $L_{eff}(24)$ computed or measured for a crewmember accounts for and allows such an exposure, crewmembers should be required to wear hearing protective devices whenever entering spaces with noise levels greater than 85 dB(A).

(2) NOTE: Any exposure of persons not wearing hearing protection to noise levels over 105 dB(A) should be avoided. However, if such exposures are unavoidable, they should be constrained to the principle of intermittent exposure (see definition in enclosure (1)) such that each exposure duration is one-seventh of the total allowable exposure at that noise level.

(3) At no time should the unprotected ears of crewmembers be exposed to non-impulse noise levels over 115 dB(A) or to impulse noise levels over 140 dB(A).

e. Evaluation of Noise Conditions.

An evaluation of noise conditions should be conducted on each unit and the results documented. The evaluation should consider noise conditions during all normal operations underway and in port. Enclosure (3) should be consulted with regards to proper equipment and measurement procedures.

f. Warning Notices.

(1) Where the noise level in spaces exceeds 85 dB(A), entrances to such spaces should carry a warning notice advising personnel of the noise hazard and the need for hearing protection. (A guide for design of this sign is the ANSI Specification for Accident Prevention Signs, Z35.1-1972.) If only a minor portion of the space has such noise levels the particular location(s) or equipment should be identified at eye level, visible from each direction of access.

(2) Where hand tools, galley and other portable equipment produce high noise levels in normal working conditions, warning information should be provided, preferably on the device.

g. Instruction to Crewmembers.

(1) Crewmembers should be instructed in the hazards of high and long duration noise exposure and the risk of noise induced hearing loss. Instruction should also include

a description of the unit's noise control program, the types of hearing protection devices provided and their proper use and care, and the unit's hearing conservation program.

(2) Appropriate crewmembers should receive such instruction as is necessary in the correct use and maintenance of machinery and silencers or attenuators in order to avoid the production or transmission of unnecessary noise.

h. Hearing Conservation Program.

(1) All crewmembers having 24-Hour Effective Exposure Levels (computed, in this case, without regard to attenuation contributed by hearing protective devices) greater than 77 dB(A) or routinely exposed to noise levels greater than 85 dB(A) should be included in a hearing conservation program as outlined in enclosure (5).

(2) Much of the maritime industry utilizes a highly mobile labor force of which individual personnel work a vessel or rig for a limited period and then move on to another unit. Consequently, it is often impractical for operators of these units to individually implement portions of hearing conservation programs involving audiometric testing and recordkeeping. In such cases it is recommended that a program of audiometric testing be coordinated on a group basis between the owner/operators and the employees.

i. Responsibilities.

(1) The owner/operator of a unit should be responsible for ensuring that means for noise reduction and control are applied and maintained according to the recommendations of this Circular. Particular attention should be paid to insuring that the unit's officers are informed of the provisions of the unit's noise control program and the need for instructing crewmembers as provided in paragraph f, and to insuring that hearing protectors are provided and maintained.

(2) Crewmembers should be responsible for complying with the unit's noise control program, as instructed, paying particular attention to wearing provided hearing protectors in the proper manner while working in the prescribed locations.

CLYDE T. LUSK, JR.
Chief, Office of Merchant Marine Safety

End: (1) Definitions
(2) Determining the Effective Exposure Level (Examples)
(3) Equipment and Measurement
(4) Hearing Protective Devices
(5) Hearing Conservation program
(6) IMO Noise Limits
(7) Suggested Engineering Methods for Controlling Noise
(8) Noise Reduction On Towboats and Other Small Vessels
(9) References

DEFINITIONS

1. A-weighted sound pressure level or noise level: The quantity measured by a sound level meter in which the frequency response is weighted according to the A-weighting curve, as per ANSI Sl.4-1971. The A-weighting values for Octave Bands 31.5 to 8000 Hz are as follows:

Frequency (Hz)	31.5	63	125	250	500	1K	2K	4K	8K
A-Weighting (dB)	-39	-26	-16	-8	-3	0	+1	+1	-1

2. Hearing protector: A device worn to reduce the level of noise heard by the wearer; hearing protective device (HPD).

3. Effective Exposure Level, $L_{eff}(24)$: The constant sound level that produces the same noise exposure as the actual time-varying noise over a 24-hour period within the prescribed sound level limits. Leff is based on a 5 dB exchange rate which assumes that personnel exposures at high noise levels are intermittent. In calculating this level all noise less than 80 dB(A) may be disregarded.

   a. The Effective Exposure Level, measured from continuous A-weighted sound pressure signals, is defined as follows (Note: This formula is mainly for use of equipment manufacturers.):

$$L_{eff} = \left(\frac{5}{\log 2}\right) \log\left[\frac{1}{T}\int_0^T \left[\frac{p(t)}{p_0}\right]^{4\log 2} dt\right]$$

   where: p(t) = time-varying A-weighted sound pressure, N/m^2
   p_0 = reference sound pressure, $2x10^{-5}$ N/m^2
   t = time, in hours
   T = total time interval, 24-hours
   log = logarithm to the base 10

   b For practical purposes, the Effective Exposure Level can be calculated by the following approximate formula:

$$L_{eff} = 16.61 \log\left[\frac{1}{T}\sum_{i=1}^{n} 10^{L_{Ai}/16.61}\Delta t_i\right]$$

   where: L_{Ai} = A-weighted sound level during the i^{th} time interval, Δt_i
   Δt_i = i^{th} time interval, in hours
   $T = \sum_{i=1}^{n} \Delta t_i$ = total time interval, 24-hours

4. Exchange rate: The amount of decrease in noise level which would allow doubling of the exposure time.

5. Impulse noise: Noise of less than 1 second's duration which occurs as an isolated event, or as one of a series of events with a repetition rate of less than 15 times per second.

6. Integrating sound level meter: A Bound level meter designed or adapted to measure the level of the time-averaged A-weighted sound pressure. It is used when sound level fluctuations are too large or erratic to permit accurate readings with a standard sound level meter.

7. Intermittent noise exposure: A daily personnel noise exposure during which the normally encountered noise exposure is interspersed with periods in low level noise, i.e. below 80 dB(A), which are conducive to auditory rest. (Paragraph 4.d.2 of the main text discourages the exposure 6f personnel not wearing hearing protection to noise levels over 105 dB(A). If such exposures are unavoidable, under the principle of intermittent exposure the individual exposure duration should not exceed the times listed below:

Noise level (dB(A))	106	107	108	109	110	111	112	113	114	115
Time (min)	7.4	6.5	5.7	4.9	4.3	3.7	3.2	2.8	2.5	2.1

8. New unit: A unit contracted for on or after 1 January 1986.

9. Noise: For the purposes of this Circular, all unwanted sound.

10. Noise dosimeter: A personal sampling device which automatically measures the wearers cumulative noise exposure over a prescribed period of time.

11. Noise level: See A-weighted sound pressure level.

12. Sound: Energy that is transmitted by pressure waves in air or other materials and is the objective cause of the sensation of hearing.

13. Sound pressure level: The level of sound pressure, L, measured on a logarithmic scale and given by the formula:

$$L = 20\log_{10}\frac{(p)}{(p_0)}dB$$

where: p = rms value of measured sound pressure
$P_0 = 2 \times 10^{-5}$ N/m^2 (the reference level)

14. Steady noise: A sound where the level fluctuates through a total range of less than 5 dB(A) as measured on the "slow" response of a sound level meter in one minute.

15. Vessel: includes every description of watercraft used, or capable of being used, as a means of transportation on water.

DETERMINING THE EFFECTIVE EXPOSURE LEVEL (EXAMPLES)

1. $L_{eff}(24)$ can be determined through direct readout from personnel noise dosimeters or through manual calculation, comparing measured noise levels against time-motion profiles of the crewmember, or by combining the two methods. Since exposure levels normally vary from day-to-day, it will be necessary to measure several days of exposures to determine the maximum exposure levels unless background data such as from an identical sister-ship is available and is proven to duplicate that vessel's noise conditions. This would apply both to the use of dosimeters and to time-motion profiling.

2. Dosimetry is normally the easier method of determining exposure levels, particularly in jobs where personnel visit various locations of differing noise levels on an unscheduled basis. Commercial noise dosimeters vary in the descriptions and criteria which they are programmed to measure and only those programmed to perform the Leff measurement (i.e. 82 dB(A) criterion level, 80 dB(A) threshold level, 5dB exchange rate) should be utilized for this determination. However, since this criteria is similar to the OSHA hearing conservation criteria, except for the longer evaluation period, proper dosimeters should be readily available. This equipment can also be rented which may be more cost effective for some companies.

3. Examples of performing the L_{eff} calculation are as follows:

Example 1: The $L_{eff}(24)$ limit of 82 dB(A) was determined by calculating the exposure level resulting from the combination of an 8-hour exposure of 90 dB(A), OSHA's current standard, and 16 hours at less than 80 dB(A) (which is disregarded because it is below the threshold level). Using the equation in enclosure (1), this is repeated as follows:

$$L_{eff} = 16.61\log\left[\frac{1}{T}\sum_{i=1}^{n} 10^{L_{Ai}/16.61}\Delta t_i\right]$$

$$L_{eff}(24) = 16.61\log\left[1/24\left(\left(10^{90/16.61}\times 8\right)+\left(0\times 16\right)\right)\right] = 82\,dB(A)$$

Example 2: A noise survey is conducted on a 25,000 dwt steam vessel. The results indicate high noise levels in several machinery spaces and a noise level of 78 dB(A) on the mess deck.

Further analysis is performed to determine the actual exposures of the crew. An overview reveals that only engineering personnel are sufficiently exposed to high noise to be in danger of overexposure, so the analysis is limited to this group. At this point the noise consultant must decide whether to measure exposures using (a) personal noise dosimeters or (b) time motion study.

The consultant decides to measure the exposures by performing a time motion study while the vessel is on a 10-day trip. He profiles the various routines of the affected personnel and relates the respective noise levels. An example of the incremental exposures determined over a 24-hour period for the First Assistant Engineer are tabulated as follows:

1 hr. @ 95 dB(A) 5 hrs. @ 93 dB(A) 2 hrs. @ 88 dB(A)

2 hrs. @ 85 dB(A) 12 hrs. @ less than 80 dB(A)

The effective exposure level resulting from these incremental exposures is computed from the formula in enclosure (1) as follows:

$$L_{eff} = 16.61\log\left[\frac{1}{T}\sum_{i=1}^{n} 10^{L_{Ai}/16.61}\Delta t_i\right]$$

$$L_{eff}(24) = 16.61\log\left[1/24\left(\left(10^{95/16.61}\times 1\right)+\left(10^{93/16.61}\times 5\right)+\left(10^{88/16.61}\times 2\right)+\left(10^{85/16.61}\times 2\right)+0\right)\right]$$

$$L_{eff}(24) = 85 dB(A)$$

The analysis indicates that the exposures of most of the engineroom personnel are, like the First Assistant, in the vicinity of 85 to 89 dB(A), exceeding the 82 dB(A) recommended limit.

(Note: The analysis of exposure levels described above could also have been accomplished using personal noise dosimeters, probably with much less effort. A problem sometimes experienced with dosimeters is in obtaining the cooperation of the crew, some of whom may be reluctant to wear the device or may want to bias the readings. However, if this can be resolved (many experts do not find this to be a problem), dosimeters offer a more accurate and less time consuming method of determining exposure levels.)

The consultant presents three options for resolving the overexposures, listed as follows:

Option I: Require personnel to wear hearing protection in all machinery spaces where noise levels exceed 90 dB(A).

Option 2: Construct a sound-proof booth around the operator's station in the engineroom.

Option 3: Apply engineering controls at several key noise emitting sources in the engineroom.

The owners decide to implement Option 1. The recommendations of this Circular for warning notices, crew instruction and hearing conservation program are instituted. The crew is offered three models of hearing protectors to choose from. A system of audiometric testing and recordkeeping is developed.

Finally; the consultant also designs a treatment for reducing the mess deck noise level to 68 dB(A) which is subsequently installed.

Example 3: Using dosimetry to evaluate on watch exposure and doing time motion study to profile the remaining 16-hours off watch, another crewmember' 5 exposure is determined as follows:

on watch: L_{eff} (8 hours) = 85 dB(A)

off watch: 2 hrs @ 81 dB(A)
14 hrs @ less than 80 dB(A) (disregard)

$$L_{eff}(24) = 16.61\log\left[1/24\left(\left(10^{85/16.61}\times 8\right)+\left(10^{81/16.61}\times 2\right)+0\right)\right] = 78 dB(A)$$

(Note: Computing work shift exposures of personnel by time/motion survey is normally more complex than indicated in the above examples as noise levels will vary considerably.)

EQUIPMENT AND MEASUREMENT

1. Equipment.

   a. Use of the following equipment is recommended: sound level meter, personal noise dosimeter, octave band analyzer, integrating sound level meter with peak and maximum hold capacity, and acoustic calibrator.

   b. Sound level meters should meet the Type II requirements of the ANSI Specification for Sound Level Meters, S1.4-1971 (R1976). For critical measurements which determine compliance with recommended limits, a Type I precision sound level meter should be used.

   c. Personal noise dosimeters should meet the Class 2A requirements of the ANSI Specification for Personal Noise Dosimeters, Sl.25-l978. The dosimeter should measure L_{eff} utilizing the criteria specified in Definition 3 in enclosure (1).

   d. Other measuring equipment should meet appropriate national or international standards.

   e. Only equipment certified intrinsically safe should be used in areas where flammable gas/air mixtures may be present.

2. Measurement.

   a. All physical measurements should be made following the applicable procedures of ANSI Sl.13-1971 (R1976), Methods for Measurement of Sound Pressure Levels, and ANSI 51.21962 (R1976), Method for the Physical Measurement of Sound, and accepted practice. Use of ISO Standard 2923-1975(E), "Acoustics-Measurement for Noise On Board Vessels" is also suggested.

   b. Noise measurement equipment should be calibrated initially, at subsequent intervals of approximately four hours, at the end of tests and at any other time when tests are interrupted due to battery replacement, etc.

   c. Noise measurements should be taken in decibels using an A weighting filter (dB(A)). The meter should be set to "slow" response and the readings made only to the nearest decibel. A measuring time of at least 5 seconds should be allowed. If a meter fluctuates in level within a range of 5 dB maximum to minimum, an estimate of the level may be made by averaging the excursions of the needle with the eye. It is suggested that C-weighted levels also be taken. Furthermore, to facilitate analysis of noise in certain areas where engineering controls may be applied, measurement of noise by octave band levels should be considered. A form found convenient for recording the noise data is attached. A wind screen on the microphone should be used in locations where air motion is noticeable, such as bridge wings, lookout positions, and near fans and ventilators.

   d. Measurements of intermittent and transient sources, such as ship's horn or whistle at bridge and lookout locations are best made with meters with "maximum-hold" and "peak-hold" capability. Certain machinery, such as steering motors, etc. may also need measurements of this type.

e. Measurement of exposure levels at manned and intermittently manned locations is most convenient with an integrating sound level meter. This instrument may be used in two ways: (1) at locations where the sound level fluctuates, perhaps due to a cyclic operation of a machinery item, and the meter is used to measure the average sound level. For this the meter is operated at a fixed location for a period of at least one full cycle of the machine; (2) to assess the average level over a space such as that transited by an oiler on his rounds, the meter is operated while it is carried over the actual path and at an equivalent rate of the oiler, and the average sound level is read at the completion of the path. If an integrating sound level meter is not available, the average sound level may be calculated by averaging the set of sound level measurements on a pressure squared basis.

3. Survey.

When evaluating noise exposures, all operating conditions underway and in port should be considered. For standardization however, a noise survey should normally be conducted under the following conditions:

a. Measurements underway should be taken with ship in the loaded or ballast condition, operating at normal design service speed and with all auxiliary machinery and electrical equipment which is normally in use in operation. Particulars of machinery in operation should be noted.

b. Noise level measurements in spaces containing emergency diesel engine-driven generators, fire pumps or other emergency equipment that would normally be run only in emergency, or for test purposes, should be taken with the equipment operating. Adjoining spaces need not be measured with such equipment operating, however, unless it is likely that the equipment will be operated for periods other than those mentioned above.

c. Measurements in port should be taken with the ship[1]s cargo handling equipment in operation, in those areas and accommodation spaces affected by their operation.

d. Measurements should be made at the principal working and control stations of crewmembers in the machinery spaces and in the adjacent control rooms, if any, with special attention being paid to telephone locations and to positions where voice communication and audible signals are important. Measurements should be taken in all workshops, at points on all normally used access routes and at all other locations which would normally be visited during routine inspection, adjustment and maintenance.

e. In addition to the spaces referenced above, noise levels should be measured in all areas where work is carried out and in all locations with high noise levels where crewmembers may be exposed, even for relatively short periods. Noise levels need not be measured for normally unoccupied spaces, holds, deck areas and other spaces which are remote from noise and where a preliminary survey shows that noise levels are below 70dB(A).

SAMPLE NOISE SURVEY FORM

Vessel Name: Hull No.

Type: Owner:

Built by: Year Built:

Dimensions

Length: Breadth: Depth:

Maximum draft (summer load line): Gross Tonnage:

Machinery

Engines - Type: manufacturer:

number: Normal design service shaft speed:

Generators - Type: manufacturer:

number: Output: kw

Main reduction gear:

Type of propeller: number of Propellers:

Auxiliary engines:

Other machinery notes:

Conditions During Measurement

Vessel's proximate position: Type of voyage:

Draft forward: Draft aft: Depth of water:

Weather - Wind speed: Seas:

Vessel's direction in relation to seas:

Vessel's speed: Shaft speed: r.p.m.

Propeller pitch:

Summary of machinery status: _____

_____

_____

_____

_____

_____

2 JUN 1982

SAMPLE NOISE SURVEY FORM

VESSEL _____

DATE ___/___/___

Data taken by (name) _____

Sound level meter _____

Octave band analyzer _____

Acoustic calibrator _____

Other _____

Calibration time (before)_____(2)_____(3)_____(after)_____

COMPARTMENT NAME	COMPARTMENT No. (deck-frame-stb/pt)	TIME	MIC LOC	SOUND PRESSURE LEVELS (dB) WEIGHTED (A)	(C)	OCTAVE BAND ANALYSIS 32	63	125	250	500	1k	2k	4k	8k	NOISE SOURCE (propulsion, ventilation, etc.); and NOTES.

HEARING PROTECTIVE DEVICES

1. Hearing protective devices (HPD's) must be effective in providing the necessary protection and be acceptable to the individual. Selection, fit and instruction in proper use are critical to effective performance. HPD's come in three basic types, i.e. ear muffs, ear plugs and canal caps (partial inserts); sometimes, for protection in particularly high noise levels, muffs and plugs will be worn together. HPD's should be carefully chosen from the hundreds of models now available. It should be noted that HPD's often differ in effectiveness at different frequencies whereby one device may be especially effective in high frequency noise, another in mid-frequency and another in low frequency.

2. For many reasons, the HPD attenuation (reduction of noise to the ear) realized in actual field use may be substantially less than the attenuation listed by the HPD manufacturer. Manufacturers ratings are computed in a controlled, supervised, laboratory situation, using motivated test subjects and for a short specific time period. However, in actual use wearers of HPD's are not often as well instructed or motivated to obtain such good results. Unless a crewmember is completely motivated, through training and supervision, to wear the device properly, actual attenuations will not often attain to manufacturers ratings. An evaluation of HPD attenuation, therefore, must consider two factors: (1) calculation of attenuation based on the manufacturer's attenuation data; and (2) adjustment of this calculation to compensate for real world use.

3. Several methods of calculating the actual noise level under an HPD have been suggested by various sources. The National Institute for Occupational Safety and Health (NIOSH) lists three methods which are detailed in the NIOSH publication "List of Personal Hearing Protectors and Attenuation Data" (enclosure (9), ref. 12). Essentially, however, there are two common methods for this calculation. The preferred method is the one which looks at the frequency spectrum of the noise (by octave band) and applies the corresponding attenuation at that frequency for the HPD. This can be termed the "long method", or NIOSH method #1 in the above reference 12. A rougher method, which is based on several general assumptions which can allow an error of as much as +8 dB depending on the frequency breakdown of the noise, is based on the single-number Noise Reduction Rating (NRR) which is provided with each device. Although the NRR can be useful as a quick method of evaluating an HPD, the best professional method of evaluating HPD attenuation is the "long method." These two methods of calculation are described as follows:

   a. "Long method" (NIOSH Method #1) calculation: After correcting the sound level at each octave band from 125 to 8000 Hz for "A"-weighting (see Definition #1), subtract the HPD's listed attentuation at that frequency band and add 2 times the HPD's listed standard deviation. These resultant levels are summed logarithmically to yield the calculated A-weighted noise level under the HPD.

   b. NRR Calculation: Very simply, the NRR is subtracted from the actual noise level, measured on the C-weighted scale, to yield the estimated A-weighted noise level under the HPD. (Note: If only the actual A-weighted noise level is known, the NRR may still be applied by adding an estimate of the C-A difference, normally approximately 5 dB, to the A-weighted level and then subtracting the NRR.)

4. Adjusting the calculated HPD noise reduction to compensate for real world use is a controversial issue since the HPD effectiveness is directly related to the motivation and understanding of the employee. The Coast Guard recommends that in normal circumstances, where employees are instructed in the importance and use of HPD's, a correction factor of 5 dB less than manufacturers

stated attenuation should be applied. If it is not desirable to apply this safety factor, the owner should insure that the audiometric test program is strengthened to detect ineffective HPD performance.

5. As we address the problem of HPD's not achieving desired results, we must hastily add that this problem is not automatically corrected simply by getting the best attenuating devices available. Overprotecting workers may present problems just as serious as underprotecting. When RPD's attenuate more-noise than necessary, they also filter out wanted sound such as that from conversation, audible signals and alarms, and operating machinery. In order to hear these sounds, workers will often deliberately misfit or tamper with their HPD's. If they do not, they may miss important communications and signals, endangering the vessel or operation. This is why it is important to select the HPD which protects mainly at the frequency levels necessitated by the particular noise encountered and then train and motivate the personnel to properly wear the devices to attain the calculated attenuation.

6. Once HPD's are properly selected and issued, care must be taken to maintain them. Manufacturers y instructions concerning sanitation, maintenance and replacement should be followed. For example, cushions on ear muffs often harden and crack after a few months use, reducing the effectiveness of the muff, and must be replaced.

HEARING CONSERVATION PROGRAM

1. A Hearing Conservation Program should be designed to prevent hearing damage to crewmembers and to detect and treat, at an early stage, those persons who are beginning to experience a loss in hearing acuity due to workplace noise. Some basic elements of a Hearing Conservation Program are as follows:

   a. A well-designed plan for controlling the noise exposures of crewmembers through administrative controls and hearing protective devices (HPD's).

   b. Instruction of exposed persons on the hazards of high noise exposure, the design and goals of the unit's Hearing Conservation Program, and the proper use of hearing protective devices.

   c. Initial and periodic audiometric tests administered by a trained and appropriately qualified person and reviewed according to accepted practice.

   d. Maintenance of audiometric test records.

   e. Follow-up analysis of records to detect individuals incurring a significant shift in hearing acuity and subsequent action to prevent further hearing damage to those individuals.

2. As important as the design of a Hearing Conservation Program is, a factor just as critical is the effort spent on convincing the affected personnel of the reasons behind the program and the purpose of the procedures chosen. The pivotal characteristics of a successful Hearing Conservation Program can be broken down as follows:

   - motivation
   - comfortable and effective HPD's
   - support by all levels of supervision
   - enforcement feed-back

   When- a hearing Conservation Program is well designed and implemented, the proper use of HPD's can become quickly established and accepted by the crew. Popular misconceptions concerning noise and HPD's can be dissolved through an effective educational program. Many short films are available which are useful in highlighting the pertinent topics and maintaining the interest of personnel (enclosure (9), ref. 13).

NOISE LIMITS RECOMMENDED BY IMO

(Reference paragraph 4.C.2 of main text.) The following are noise level limits recommended by the International Maritime Organization (IMO) in its "Code On Noise Levels On Board Ships" (Enclosure (9), ref. 2) for new vessels over 1600 gross tons.

		dB(A)
1	Work Spaces	
.1	Machinery spaces (continuously manned)	90*
.2	Machinery spaces (not continuously manned)	110
.3	Machinery control rooms	75
.4	Workshops	85
.5	Non-specified work spaces	90*
2	Navigation spaces	dB(A)
.1	Navigating bridge and chartrooms	65
.2	Listening post, including navigating bridge wings and windows	70
.3	Radio rooms (with radio equipment operating but not producing audio signals)	60
.4	Radar rooms	65
3	Accommodation spaces	dB(A)
.1	Cabins and hospitals	60
.2	Mess rooms	65
.3	Recreation rooms	65
.4	Open recreation areas	75
.5	Offices	65
4	Service spaces	
.1	Galleys, without food processing equipment operating	75
.2	Serveries and pantries	75
5	Normally unoccupied spaces	dB(A)
	Spaces not specified	90*

* Coast Guard Note: Reduction to this level will not automatically preclude need for hearing protective devices.

SUGGESTED ENGINEERING METHODS FOR CONTROLLING NOISE

1. General

a. Reducing shipboard noise levels is a complex endeavor which requires careful consideration. This enclosure presents a short discussion of the many practices which are commonly used today.

b. Design and construction of noise control measures should be supervised by persons skilled in noise control techniques. The references listed in enclosure (9) also, offer a wealth of expertise on the subject. Attention is drawn in particular to reference 5, the SNAME Design Guide for Shipboard Airborne Noise Control.

c. Some of the measures which can be taken to control noise levels or reduce the exposure of crewmembers to potentially harmful noise are indicated in paragraphs 2 through 10 of this enclosure. It is emphasized that it will not be necessary to implement all or any of the measures recommended in this enclosure on all ships. The enclosure does not provide detailed technical information needed for putting constructional noise control measures into effect, or for deciding which measures are appropriate in particular circumstances.

d. In applying noise control measures, care should be taken to ensure that rules and regulations concerning ship structure, accommodation and other safety matters are not infringed and that the use of sound reduction materials does not introduce fire or health hazards.

e. The need for noise control should be taken into account in the design stage of a unit, when deciding which of different designs of structures, engines and machinery are to be installed, the method of installation, the sitting of machinery in relation to other spaces, and the acoustical insulation and sitting of the accommodation spaces.

f. Due to the normal methods of ship construction, it is most probable that noise originating from machinery and propellers reaching the accommodation and other spaces outside the machinery spaces will be of the structure-borne type.

g. When designing efficient and economical measures for controlling noise from machinery installations in existing ships, the A-weighted noise measurements must normally be supplemented by some form of frequency analysis.

2. Isolation of Sources of Noise

a. Where practicable, any engines or machinery producing excessive noise levels should be installed in compartments which do not require continuous attendance.

b. Accommodations should be sited both horizontally and vertically as far away as is practicable from sources of noise such as propellers and propulsion machinery.

c. Machinery casings should, where practicable, be arranged outside superstructures and deck houses containing accommodation spaces. Where this is not feasible, passageways should be arranged between the casings and accommodation spaces, if practicable.

d. Consideration should be given, where practicable, to the placing of accommodation spaces in deck houses not in superstructures extending to the ship's side.

e. Consideration may also be given where applicable to the separation of accommodation spaces from machinery spaces by unoccupied spaces, sanitary and washing rooms.

f. Suitable partitions, bulkheads, decks, etc. may be needed to prevent the spread of sound. It is important that these be of the correct construction and location in relation to the source of sound and the frequency of the sound to be attenuated.

g. Sound absorbing material is useful in preventing the increase of noise level due to reflection from partitions, bulkheads, decks, etc.

3. Exhaust and Intake Silencing

a. Air intake systems to machinery spaces, accommodation spaces and other spaces and exhaust systems from internal combustion engines should be arranged so that the inflow or discharge orifices are remote from places which are normally frequented by crewmembers.

b. Silencers and attenuators often provide effective noise reduction. Lining of ventilation ducts at strategic locations with sound absorbing material (with due regard to structural fire protection standards) can also be extremely effective.

c. To minimize noise levels in accommodations, it is normally necessary to isolate exhaust systems and certain pipework and ductwork from bulkheads) casings, etc.

4. Machinery Controls

a. In continuously manned spaces or spaces where crewmembers might reasonably be expected to spend lengthy periods of time on maintenance or overhaul work, consideration may have to be given to the fitting of sound insulating enclosures or partial enclosures to engines or machinery producing excessive sound levels. When sound insulating enclosures are fitted, it is important that they entirely enclose the noise source.

b. Although it may seem that noise in high noise areas such as engineerooms and machinery spaces eminates from a vague multitude of noise contributing sources, it has been found that most of this noise is usually traceable to a few specific components on certain systems or machinery. These components can usually be traced systematically and then economically treated, substantially reducing engineroom noise levels, often to levels where hearing protectors would not be necessary. A partial list of these major noise elements are as follows:

Steam Turbine Plants
Gear boxes
M-G sets
Valves
Boiler fans
Hydraulic systems
Ventilation system fans
Turbines

Diesel Plants
M-G sets
Gear boxes
Hydraulic systems
Ventilation system fans
Engine components
- Turbo chargers
- Valve covers

Couplers (high speed only)	- Inspection plates - Exhaust system - Expansion joints - Intake system

5. Reduction of Noise in the Aft Body

To reduce the noise influence in the aft part of the vessel, especially in the accommodation spaces, consideration may be given to the various noise/vibration contributions of propeller, shaft, wave action, etc. during the procedures of designing the aft body, propeller, etc.

6. Enclosure of the Operator

In many machinery spaces it may be desirable to protect operating or watchkeeping personnel by providing a sound reducing control room or other similar space.

7. Controls in Accommodation Spaces

a. To reduce noise levels in accommodation spaces it may be necessary to consider the isolation of deck houses containing such spaces from the remaining structure of the ship by resilient mountings.

b. Consideration may also be given to the provision of flexible connections to bulkheads, linings and ceilings and the installation of floating floors within accommodation spaces.

c. The provision of curtains to side scuttles and windows and the use of carpets within accommodation spaces assists in absorbing noise.

8. Selection of Machinery

a. The sound produced by each item of machinery to be fitted should be taken into account at the design stage. It is often possible to control noise by selecting the machine which produces the least airborne, fluid-borne or structure-borne sound.

b. Manufacturers should be requested to supply information on the sound produced by their machinery and also to provide recommended methods of installation in order to keep noise levels to a minimum.

9. Inspection and Maintenance

All items of machinery, equipment and associated working spaces should be regularly inspected with respect to noise by a competent person. Should such inspection reveal defects in the means for noise control, or other defects causing excessive noise, these should be rectified as soon as practicable.

10. Vibration Isolation

a. Where necessary, machines should be supported on specially designed and fitted resilient mountings.

b. Where structure-borne sound from auxiliary machinery, compressors, hydraulic units, generating sets, vents, exhaust pipes and silencers produces unacceptable noise levels in accommodation spaces or on the navigating bridge, resilient mountings should be fitted to isolate the equipment from the structure.

c. When sound insulating enclosures are fitted it is desirable that the machine should be resiliently mounted and that all pipe, trunk and cable connections to it be flexible.

NOISE REDUCTION ON TOWBOATS AND OTHER SMALL VESSELS

1. The problem of noise on small vessels such as towboats, offshore supply boats, crewboats, etc. is in many ways more difficult and complex than on larger vessels. Although enclosure (7) discusses most of the practiced methods of noise control on vessels, a separate enclosure speaking particularly to the problem on small vessels was considered necessary.

2. Small vessels usually incorporate high horsepower propulsion systems into very small frames. Consequently, mechanical vibration from the machinery is not effectively dampened by the mass of the vessel, but rather is transmitted through the light structure and converted to noise as it vibrates about the vessel. This structure-borne noise is the predominant problem on most small vessels and is difficult to control. Because of the magnitude of the problem, it has been accepted that high noise levels are usually unavoidable. As a result, crewmembers are exposed to very high noise levels not just in working areas, but in mess, lounge and berthing areas as well.

3. Despite the difficulties, there is potential for substantial noise reductions on small vessels. Other countries and a few companies in the United States have successfully developed several noise control techniques over the last decade. The techniques are somewhat expensive, but generally not prohibitively so. Investments made in developing and implementing these techniques will afford substantial benefits in days ahead.

4. When considering the application of noise controls, it is suggested that first priority generally be placed upon reducing noise to acceptable levels in accommodation spaces and in those areas where personnel cannot wear protective devices because of operational necessity. This should not discourage application of engineering controls to machinery spaces, since such controls are often the best method of reducing noise in other areas of the vessel. Noise reductions can be more easily achieved on new vessels, incorporated into the vessel design, than retrofitted into existing vessels. Because of the complexity of noise control, it is important that persons having expertise in shipboard noise control be consulted particularly throughout the design and construction phases of new vessel construction and before attempting expensive noise controls on existing vessels.

5. No attempt will be made to describe in detail the various means for reducing noise levels on small vessels. Literature such as that listed in references 6.j. thru 10 of enclosure (9) should be researched for this information. However, the following is a partial List of several methods, most of which are discussed in enclosure (7), which should be considered:

   - maximizing distances and providing buffer spaces (voids, tanks, etc.) between accommodation and machinery spaces;

   - room isolation, e.g. floating decks and resiliently suspended bulkheads and deckheads;

   - resilient mounting of all vibrating machinery;

   - effective noise barrier around high noise spaces, to prevent noise transmission to adjacent spaces, and sound absorbing material around high noise spaces, to reduce contribution of reverberant noise within the space;

   - flexibly mounting exhaust, ventilation and other service lines;

   - insuring that all fit-ups are tight and that all penetrations through spaces are sealed;

- silencers or attenuators on air intakes and exhaust;

- sound absorbtion treatment of accommodation spaces;

- use of low noise components, e.g. hydraulic pumps with low fluid-borne noise levels.

6. The use of room isolation is expensive and can possibly present stability problems by affecting a vessel's center of gravity. However, the results in reducing noise levels can be dramatic. Now that better techniques are being refined and standardized, room isolation should be given serious consideration.

7. The use of resilient mounts on main propulsion engines can also have dramatic results in reducing transmission of noise through the structure to outside spaces. They do however, present substantial problems for shaft alignment and maintenance and in most cases require use of flexible couplings. At the present time the use of resilient mounts for main propulsion engines may not be feasible on many vessels. However, the technology is certainly feasible and should be developed by the industry.

8. The technology for reducing noise on small vessels is feasible; much is already developed. There is an immediate need for an industry forum for guiding this technological development and providing standards and information which could then be disseminated back to the industry. It is believed that if enough interest were expressed to an appropriate technical society a committee would be established to perform this function.

REFERENCES

1. "Study of Airborne Noise on Merchant Ships", performed for U.S. Coast Guard by U.S. Naval Ocean Systems Center (NOSC), San Diego, CA. Five volumes: NOSC technical documents #243 (NTIS/AD-A075 356), 254 (NTIS/AD-A075 000/0), #257 (NTIS/AD-A075 001/8), and #267 (NTIS/AD-A080 631/5) and technical report #405 (NTIS/AD-A075 002/6). Available through the National Technical Information Service (NTIS), Springfield, VA 22161, Tel. 703-557-4650.

2. "Code On Noise Levels On Board Ships," International Maritime Organization (IMO) Resolution A.468 (XII); after it is published this code will be available through: New York Nautical Instrument and Service Corp., 140 W. Broadway, New York, N.Y. 10013, Tel. 212-962-4650.

3. "Noise Control In Ships," handbook, 1976, NTNF Report B.0930.4502.l Norwegian Council for Technical and Scientific Research (NTNF), Gaustadalleen 30, Blindern, Oslo 3, Norway. Available through: Selvig's Publishing House, Ltd., Oslo, Norway.

4. "Noise Abatement On Ships," Report 118, 1976, The Swedish Maritime Research Center, Box 24001, S40022 Gothenburg, Sweden.

5. "SNAME Design Guide for Shipboard Airborne Noise Control", (scheduled for publication in summer 1982) Society of Naval Architects and Marine Engineers, Publications Division, 1 World Trade Center, Suite 1369, New York, NY 10048; Tel. (212) 432-0310.

6. The following references, reports and other literature are available from Det norske Veritas at this address: Det norske Veritas, Chrysler Building, 49th Floor, 405 Lexington Ave., New York, NY 10017; Tel. (212) 697-2056:

   a. "Acoustical Planning In Ship Design," E. Brubakk.
   b. "Noise Prediction and Planning In Ships," A.C. Nilsson, Rpt. No. 78-030.
   c. "Controlling the Noise Problem - Prediction, Measurement and Remedies," pamphlet.
   d. "Prediction of Vibration at the Design Stage - Excitation and Response," pamphlet.
   e. "Prevention of Harmful Vibration In Ships," 2nd Ed. (1982).
   f. "Handbook of Vibration Control In Ships," (1982).
   g. "Propeller Induced Hull Plate Vibration," A.C. Nilsson (1980).
   h. "Propeller Induced Noise In Ships", Nilsson, Persson and Tyvand, SNAME Symposium (1981).
   i. "Modelling Aspects for Finite Element Analysis of Ship Vibration," Computers and Structure, Skaar & Carisen (1980) Vol. 12, pp. 409-419.
   j. "Noise Control On Small Ships," E. Brubakk, paper presented at Inter-Noise 1979.

7. "Feasible Noise Levels In Accommodation of Vessels Engaged In Towing," a report for the Ministry of Transport, Canada, by Jackson-Talbot and Associates Ltd. Available through: Hull Inspection and Standards Div., Canadian Coast Guard, Tower A, Transport Canada Building, Place de Ville, Ottawa, Ontario K1A 0N7. COST: $25.00.

8. "Noise Control On Diesel Tugs - A Sequel," by T. R. Dyer and B. Lundgaard; presented to Pacific Northwest Section of the Society of Naval Architects and Marine Engineers, November 1, 1980; available though SNAME, See reference (e) for address.

9. "Sound Attenuation - Towboats," Steven Roik, Chairman, Council of Marine Carriers Sound Committee; presented at the British Columbia Towboat Industry Conference, March 1981.

10. "Design Practices for Silencing Diesel Powered Small Boats," NAVSEA 0902-038-1010.

11. "Compendium of Materials for Noise Control," NIOSH, DHEW (NIOSH) Pub. No. 80-116, May 1980. Available through: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402; Stock #017-033-00359-9; Cost: $9.00.

12. "List of Personal Hearing Protectors and Attenuation Data," NIOSH, HEW Pub. No. 76-120. Available through: National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, ph. 703-557-4650; Stock No. PB 267 461, Cost: $7.50.

13. A list of approximately 20 films on hearing and hearing protection, produced by both manufacturers and professional organizations, is available upon request from E.A.R. Division, Cabot Corporation, Indianapolis, Indiana, 46268; telephone (317) 872-1111.

14. The following ANSI standards, referenced in this Circular may be ordered from The American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018:

Specification for Accident Prevention Signs, z35.1-1972;
Specification for Sound Level Meters, Sl.4-1971(R1976);
Specification for Personal Noise Dosimeters, Sl.25-1978;
Methods for Measurement of Sound Pressure Levels, Sl.13-1971(R1976);
Method for Physical Measurement of Sound, Sl.2-1962(R1976).

15. "Acoustics-Measurement of Noise On Board Vessels", International Organization for Standardization, ISO Standard 2923 - 1975(E); can be ordered through ANSI (see reference 14).