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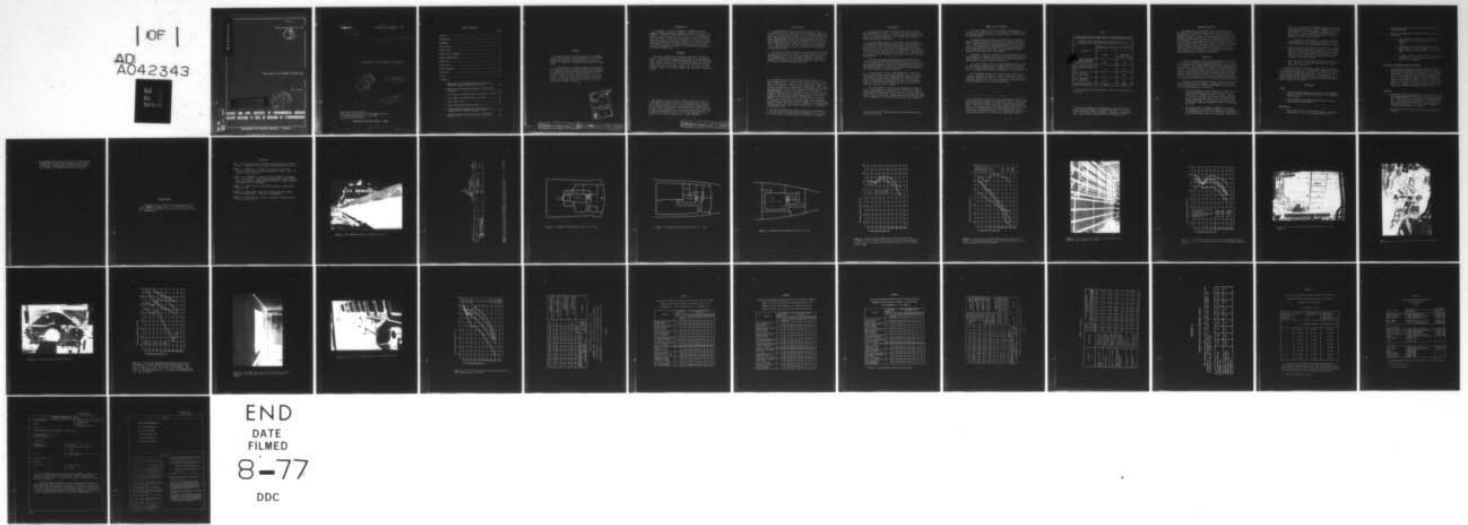
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A NOISE SURVEY OF THE CORMORANT, PROPOSED FDSS.(U)  
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A NOISE SURVEY OF THE CORMORANT, PROPOSED FDSS

R.B. Crabtree

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ABSTRACT

A noise survey was conducted on board the CORMORANT, proposed FDSS (Formerly the ASPA QUARTO), in her original trawler configuration to determine if noise would be a habitability, health or operational problem after the FDSS refit.

It was found that in sleeping quarters adjoining the main machinery spaces, noise will probably cause sleep and rest disturbance unless adequate noise reduction measures are implemented, and that a hearing hazard exists for persons occupying the main machinery spaces on a routine basis. In addition, the proposed communications/control complex will require considerable quieting of the Diesel Generator Room exhaust blowers.

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## INTRODUCTION

In response to tasking from NDHQ, the Human Engineering Section of DCIEM conducted an ergonomics investigation of the CORMORANT<sup>1</sup> (formerly the ASPA QUARTO) (Figure 1), an Italian stern trawler, as a prerequisite to her refit as a CF Fleet Diving Support Ship (FDSS). As part of this evaluation, the Sonics Section performed a study of the noise environment of the ship in her original configuration to determine if noise, as it existed, would be a habitability, health, or operational problem after the refit. This report presents the results of the noise survey and makes appropriate recommendations.

## PROCEDURE

The noise evaluation was conducted in February 1976 during trials at the Underwater Range off Halifax and at the Halifax Dock Yards. Overall and octave-band sound pressure levels were measured using a Bruel and Kjaer, type 2209, precision sound level meter and a type 1613 octave filter set. In addition, the noise in certain compartments was recorded with a Nagra, type IV-S, precision tape recorder. Results of the noise analysis are tabulated in Appendices A to E.

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<sup>1</sup> ASPA QUARTO, a 240-foot fishing trawler purchased by DND is to be refitted into a mother ship for the Submersible Diver Lockout (SDL) research submarine, and a base for related diving activities. She is powered by three 900 hp turbocharged diesel engines, each driving a 730 kva alternator. These units can be switch-connected to either the propulsion buss or the service buss as required. The variable-pitch propeller is driven at 200 rpm (nominally) by two 950 hp electric motors operating into a common gearbox.

## NOISE PROFILE

The distribution of A-weighted<sup>2</sup> sound pressure levels throughout the ship is shown in profile in Figure 2. Plan views of Nos. 01, 1 and 2 Decks (Figures 3, 4 and 5 respectively) illustrate this distribution in greater detail in the vicinity of the Diesel Generator Room casing. The main machinery spaces (the Diesel Generator Room and Propulsion Machinery Room) contain the most intense noise found on the ship. Noise in the areas adjacent to the Diesel Generator Room, although not intense enough to be a serious hazard to hearing, interfere with conversation and may disturb sleep.

The type of propulsion system<sup>3</sup> used on the ship is such that the noise from the diesel generators changes minimally with ship speed/engine loading. The octave-band noise levels observed at the Switchboard (in the Diesel Generator Room) increase only slightly, for example, from zero ship speed with engines idling to 11 knots at nearly full power (Figure 6).

.....

<sup>2</sup> A sound having energy which is concentrated in the 20- to 500-Hz range produces a sensation that is less loud than a sound with an equal amount of energy in the frequency range 500 to 5000 Hz. In addition, a high-intensity low-frequency sound causes less hearing damage than a sound with an equivalent amount of mid-frequency energy. Thus, when an estimate of the loudness or hearing-damage potential of continuous noise is required, its low-frequency components are de-emphasized. One particular frequency weighting, the A-weighting, applies approximately 30 dB of de-emphasis at 50 Hz, and decreases to 5 dB at 500 Hz and 0 dB at 1000 Hz. The C-weighting, on the other hand, applies virtually no de-emphasis in the audible-frequency range. The sound pressure level of a sound, expressed in dB, is assumed to be C-weight unless otherwise specified. Sound pressure levels that are A-weighted are expressed as dBA.

<sup>3</sup> The diesel generators and propulsion motors on this ship run at nominal speeds of 600 and 1800 rpm respectively, with propulsion thrust being controlled solely by propeller pitch angle.

## HABITABILITY

The high levels of noise existing in the Diesel Generator Room will present a problem in the areas directly adjacent to it. The C2 and P2 Quarters on Nos. 2 and 3 Decks respectively, designated as sleeping accommodation, will contain noise likely to cause sleep and rest disturbance.

The noise levels measured on both sides of the bulkhead immediately aft of the diesel generators are illustrated in Figure 7. Also shown is the PNC-60 Preferred Noise Criterion Curve (Beranek et al, 1971), which describes the maximum recommended octave-band noise levels (65 dBA) for shipboard sleeping quarters<sup>4</sup>. It can be seen that considerable noise reduction is required, particularly in the low frequency octave-bands, in order to meet this specification.

Since the low frequency attenuation of the bulkhead (3 to 5 dB) is less than might be expected from this type of barrier, it appears that acoustic energy is being transmitted around it by the structural members of the ship, to which the diesel generators are rigidly mounted. Resilient supports would substantially reduce structureborn noise from this source.

In areas where a lobby or companionway will separate the Diesel Generator Room from sleeping quarters (e.g., the officers' accommodation on No. 1 Deck), additional noise reduction would result from the double barrier (Appendix E). However, where sleeping accommodation is located over a part of the machinery room, the section of decking separating the two areas will undoubtedly require acoustic treatment.

It is interesting to note that the refrigeration insulation in No. 1 Hold (Figure 8), consisting of a thick wall of foam sandwiched between steel plating and concrete, provides a better noise barrier (subjectively, the noise is far less obtrusive) than does the plating, air-space, composition-board construction found in the corridor on No. 2 Deck and in most other areas (Figure 7).

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<sup>4</sup> Noise Criteria for Sleeping Quarters Onboard Canadian Forces Ships (Forshaw, 1975).

## DAMAGE RISK TO HEARING

The noise produced by the main engines is sufficiently intense to be a definite risk to the hearing of crew members without hearing protection who must occupy the Diesel Generator Room on a routine basis.

For hearing conservation purposes, CFAO 34-22 specifies noise exposure limits in terms of ISO Noise Rating Numbers<sup>5</sup> (Forshaw, 1970). Maximum continuous exposure times vary from eight hours per day for noise having a Noise Rating Number not greater than N-85 to only four minutes per day for noise of N=125 (Appendix F). Noise exposures within these limits are considered to be non-hazardous in the long term for most people.

Accordingly, the noise hazard to hearing for Diesel Generator Room personnel is summarized in Table 1, for cruise-speed and zero-speed conditions. The Switchboard and No. 1 Diesel Generator are illustrated in Figures 10 and 11 respectively.

The levels of noise in the Propulsion Machinery Room are such that unprotected exposure should be limited to 22 or 45 minutes per day. However, this space is occupied only during outer round duties and maintenance operations (Appendices A to E and Figure 12).

The octave-band spectra of the noise at the locations listed in Table 1 are shown in Figure 9. With the exception of the Engineers' Workshop and areas very close to the engines (within the near sound field), the noise levels throughout the Diesel Generator Room are similar in both intensity and spectrum.

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<sup>5</sup> The International Organization for Standardization (ISO) Noise Rating Curves are an agreed set of empirical curves relating octave-band sound pressure levels to the centre frequency of the octave-bands. Each curve is characterized by a Noise Rating Number (N), which is numerically equal to the sound pressure level of the curve at 1000 Hz. The Noise Rating of a given noise can be found by plotting the octave-band spectrum on the Noise Rating Curves and selecting the highest curve to which the spectrum is tangent.

TABLE 1

MAXIMUM DAILY NOISE EXPOSURE LIMITS FOR DIESEL GENERATOR ROOM PERSONNEL WITHOUT EAR PROTECTION, BASED ON CFAO 34-22 <sup>6</sup>		
LOCATION	MAXIMUM DAILY EXPOSURE TIME IN MINUTES	
	8 KNOTS	ZERO KNOTS (engines idling)
Switchboard (principal watchkeeping station)	45*	45
No. 4 deck aft, between Diesel Generators Nos. 2 and 3	22	22
Access platform, No. 2 deck level	45	120
Access platform, No. 1 deck level	120	120
Engineers' Workshop	No data	480

\* Noise exposure at the Switchboard is reduced to 22 minutes at high speed.

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<sup>6</sup> When noise exposures are interrupted by sufficiently long recovery periods in which the ambient noise does not exceed ISO Noise Rating Number N=85, or 90 dBA, considerably longer cumulative exposures may be tolerated by the ear (Forshaw, 1970).

## HEARING CONSERVATION

The unprotected noise exposure limits specified above for machinery space personnel are impractical, given that normal watchkeeping routines are of three- or four-hour durations. For prolonged exposures, therefore, hearing protection must be worn throughout these areas if the risk of significant hearing loss is to be minimized. The estimated levels of noise under the CF standard issue earmuffs (SSC 258), worn by a person stationed at the Switchboard, are illustrated in Figure 13 (Clark et al, 1967). Clearly, hearing protection reduces the noise at the ears to levels which are non-hazardous in the long term. All machinery space personnel should therefore be provided with effective hearing protectors on a personal issue basis.

## OPERATIONS

In order to determine if noise might affect the efficiency of the ship's operations, measurements were made on No. 1 Deck in areas proposed for the FDSS Communications/Control complex (Figure 3). Levels of noise ranged from 85 dBA in the proposed Red Area (presently the XO's washroom), to 61 dBA on the Bridge (Figures 14 and 15). The principal sources of noise in this area are the main machinery-space exhaust blowers which generate spectra characterized by a large pure tone component in the 250-Hz octave-band. This can be seen (Figure 16) in the noise observed on the Bridge, in the Lobby, and particularly in the washroom (proposed Red Area).

Obviously, the noise measured in these areas will be affected by the planned structural changes. Although it is difficult to predict exactly what the resultant noise levels will be after re-fit, some generalizations can be made:

1. The sound absorptive layer proposed for the walls of the Red Area should insure that noise inside the room is below levels considered hazardous to hearing. However, the whine-like character of the noise will undoubtedly annoy the man stationed there. Noise treatment of the blower compartment, or the blowers themselves (perhaps by Helmholtz absorptive resonators), would further reduce this noise.
2. The curtain which is planned to separate the Red Area and Communications Area will be acoustically transparent to low frequency noise and will therefore be ineffective in preventing blower noise from entering the Communications

Area. It is noted that the maximum allowable noise level for manned radio rooms is 63 dBA, as specified in the DND Noise Criteria for Shipboard Spaces (CDA/MS/NVSH 1-0-1, Anon, 1972). Unless an effective noise attenuating partition is installed between these areas, it will be impossible to meet this criterion.

An additional noise barrier, constructed along the Diesel Generator Room casing, would attenuate the mid- and high-frequency noise transmitted through the casing.

3. Levels of noise will be lower in the Underwater Tracking Area than in the Communications Area due to the barrier partition between them. It is unlikely that the former will be as quiet as the Bridge in its original configuration or that it will meet the NVSH specification of 58 dBA for sonar control rooms.
4. The noise levels on the Bridge did meet the NVSH requirement. There is no reason to believe that this will change after the refit.

Observations made on the Bridge suggest that the telephone system used on the ship is not adequate for communicating in areas containing high ambient levels of noise (e.g., the Diesel Generator and Propulsion Machinery Rooms) due to distortion of the speech signals and masking by the noise. Noise-excluding hoods should be installed at telephone locations in high noise areas to improve speech intelligibility.

## CONCLUSIONS

### General

1. The most intense levels of noise found on the CORMORANT exist in the Diesel Generator Room and in the Propulsion Machinery Room.
2. Noise levels in the Diesel Generator Room do not vary appreciably with ship speed.

### Habitability

1. Areas that adjoin the main machinery spaces, and/or are directly over a part of the main machinery spaces,

contain high levels of noise and will be unacceptable as sleeping quarters.

2. Sizable noise reductions in noise-critical areas can be achieved by:
  - a) the construction of effective noise barriers, particularly at the Diesel Generator Room casing,
  - b) separation of the sleeping quarters from the Diesel Generator Room by means of a corridor or lobby, thereby forming a double noise barrier, and
  - c) resilient mounting of the diesel generator units to reduce the transmission of structure-born noise from the engines.

#### Damage Risk to Hearing and Ear Protection

1. Noise produced by the main engines or propulsion motors and gearing is sufficiently intense under most operating conditions to be hazardous to the hearing of crew members who routinely occupy the main machinery spaces for more than 22 to 45 minutes per day. Since watchkeeping routines in these areas are usually of three to four hours duration, effective ear protection must be worn by these people if the risk of significant hearing loss is to be minimized. All machinery space personnel should be provided with their own CF standard issue ear muffs.

#### Operations

1. The noise levels at locations that will form part of the FDSS operations/communications area are presently as much as 22 dBA in excess of recommended levels (CDA/MS/NVSH 1-0-1). The main source of this noise is the exhaust blowers for the Diesel Generator Room, located adjacent to the proposed Red Area. It is clear that substantial quieting of these blowers is necessary.
2. Noise levels on the existing bridge meet the NVSH specification.

3. The telephone system on the ship may not provide adequate communication in areas where the ambient level of noise is very high. The use of noise-excluding hoods around the telephones is recommended for such compartments.

ACKNOWLEDGEMENT

The author wishes to thank the acting Commanding Officer of the CORMORANT, LCDR Dale Gibb, for the excellent support and co-operation provided by the ship's officers and men during this investigation.

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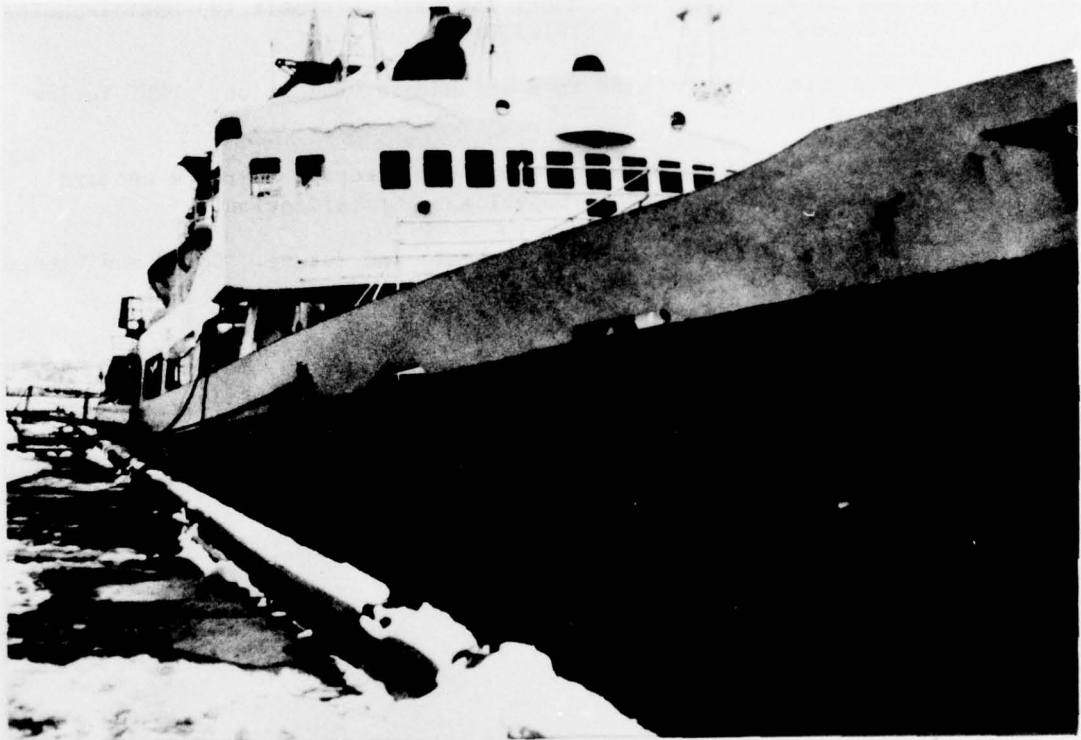


Figure 1: The CORMORANT moored at the Halifax Dockyards.

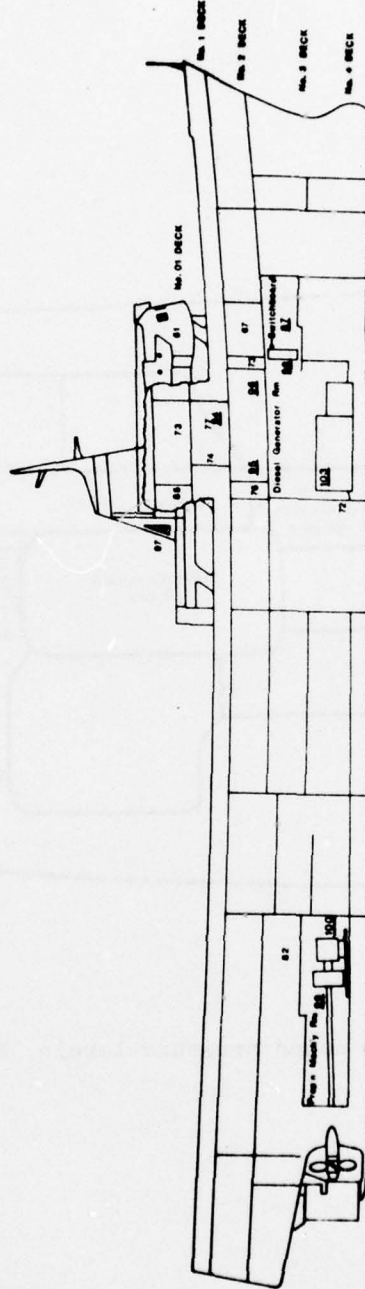


Figure 2: Noise profile of the CORMORANT in A-weighted sound pressure levels. Underlined numbers indicate measurements taken within the main machinery spaces.

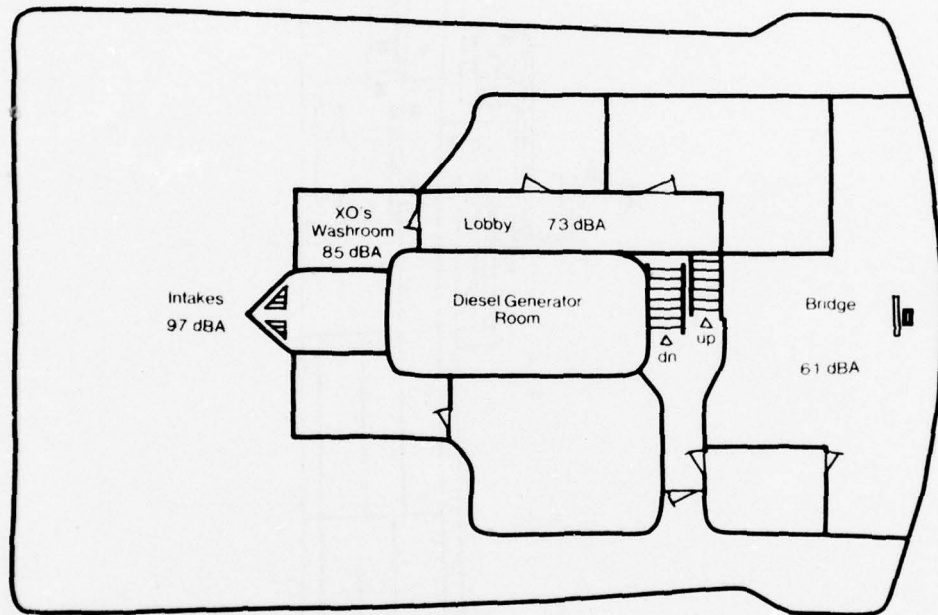


Figure 3: A-weighted sound pressure levels, No. 01 Deck.

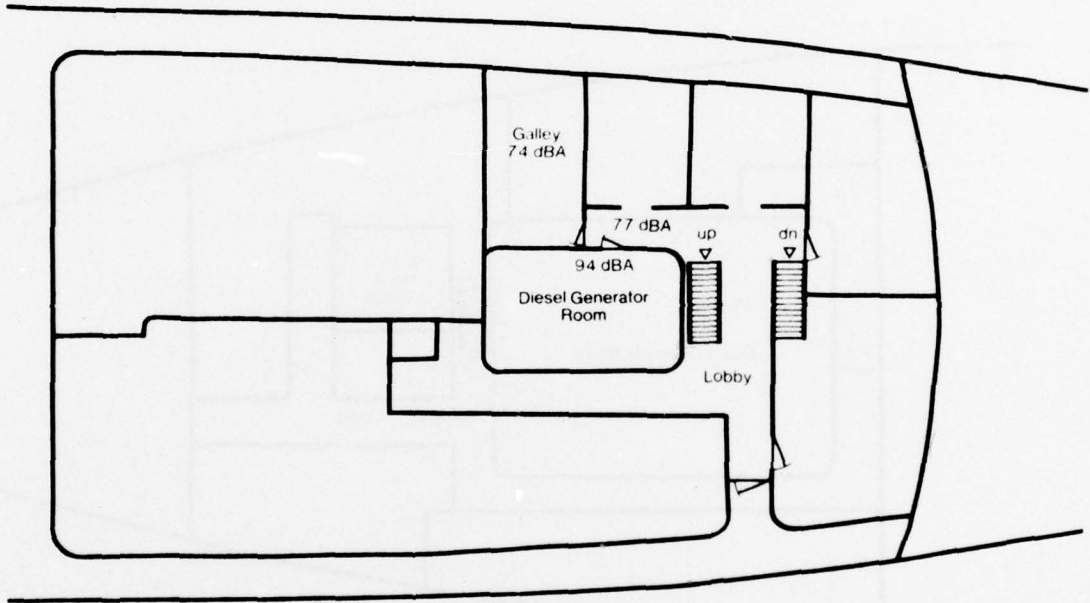


Figure 4: A-weighted sound pressure levels, No. 1 Deck.

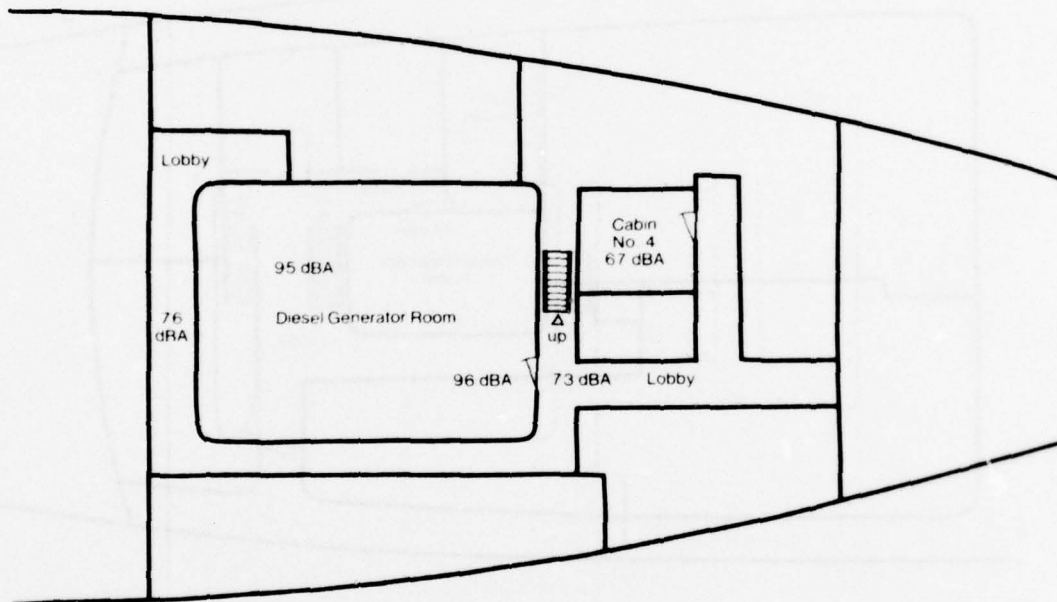
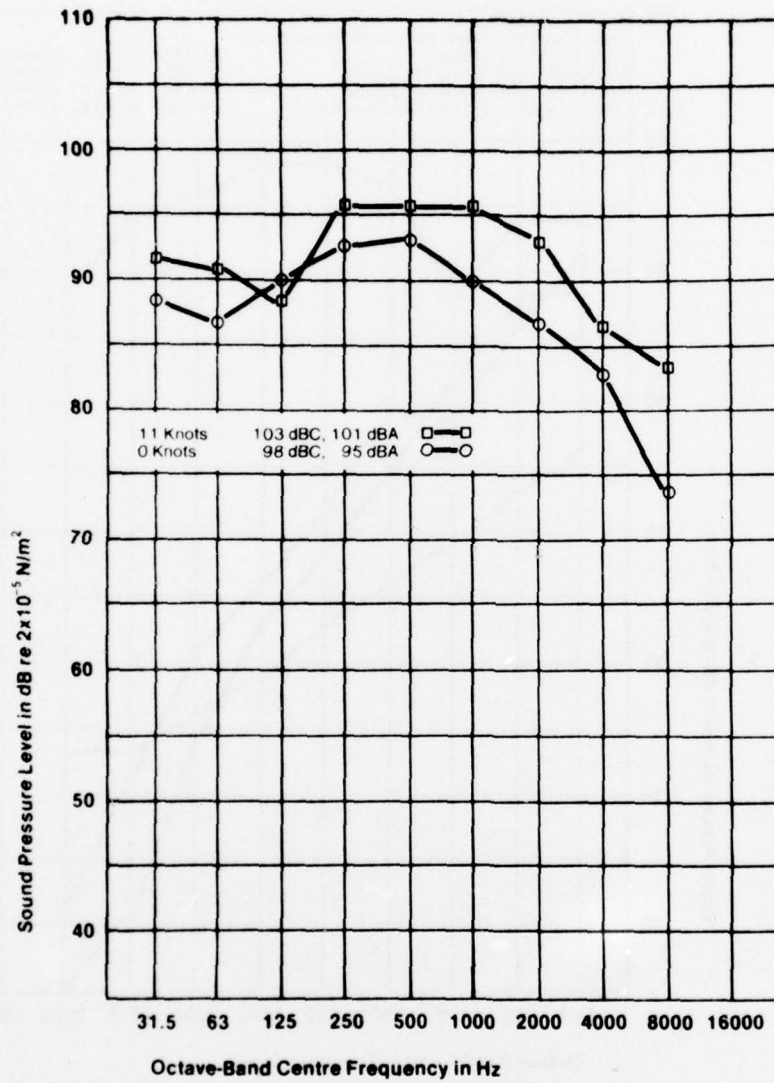


Figure 5: A-weighted sound pressure levels, No. 2 Deck.



**Figure 6:** Overall and octave-band sound pressure levels at the Switchboard 1) at 11 knots, 90% propeller pitch (all diesel generators running), and 2) at dockside (diesel generators Nos. 1 and 2 running with no load).

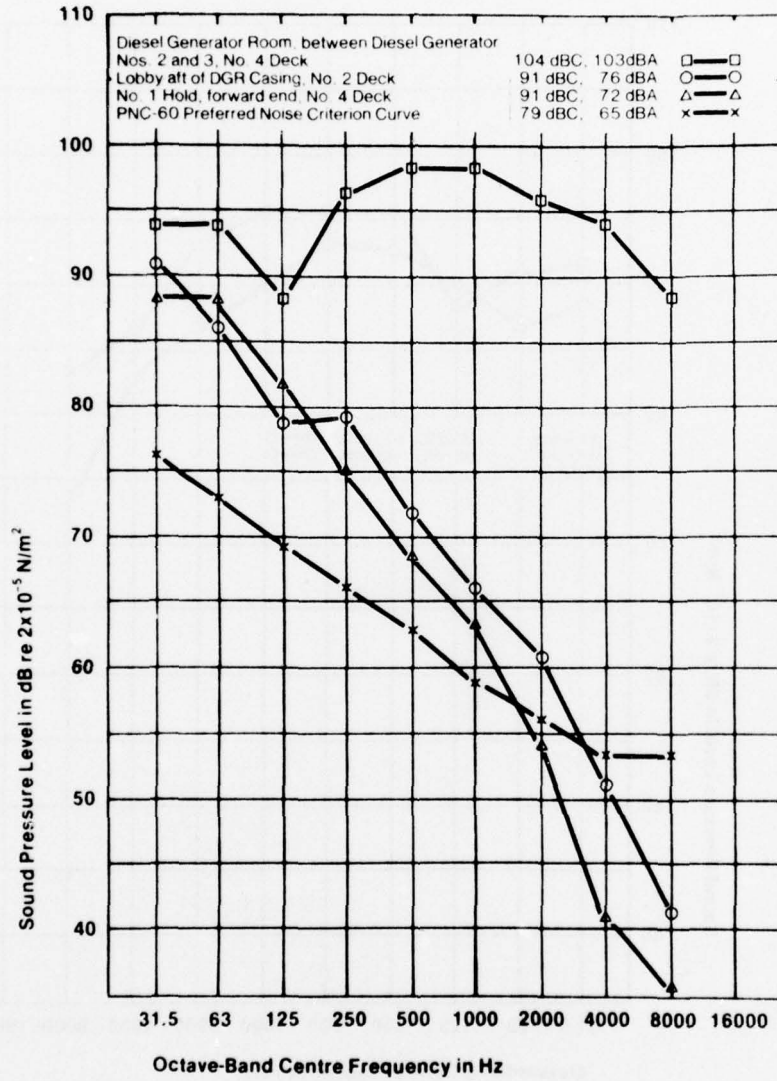


Figure 7: Overall and octave-band sound pressure levels at both sides of the bulkhead immediately aft of the diesel generators, and Preferred Noise Criterion Curve PNC-60.

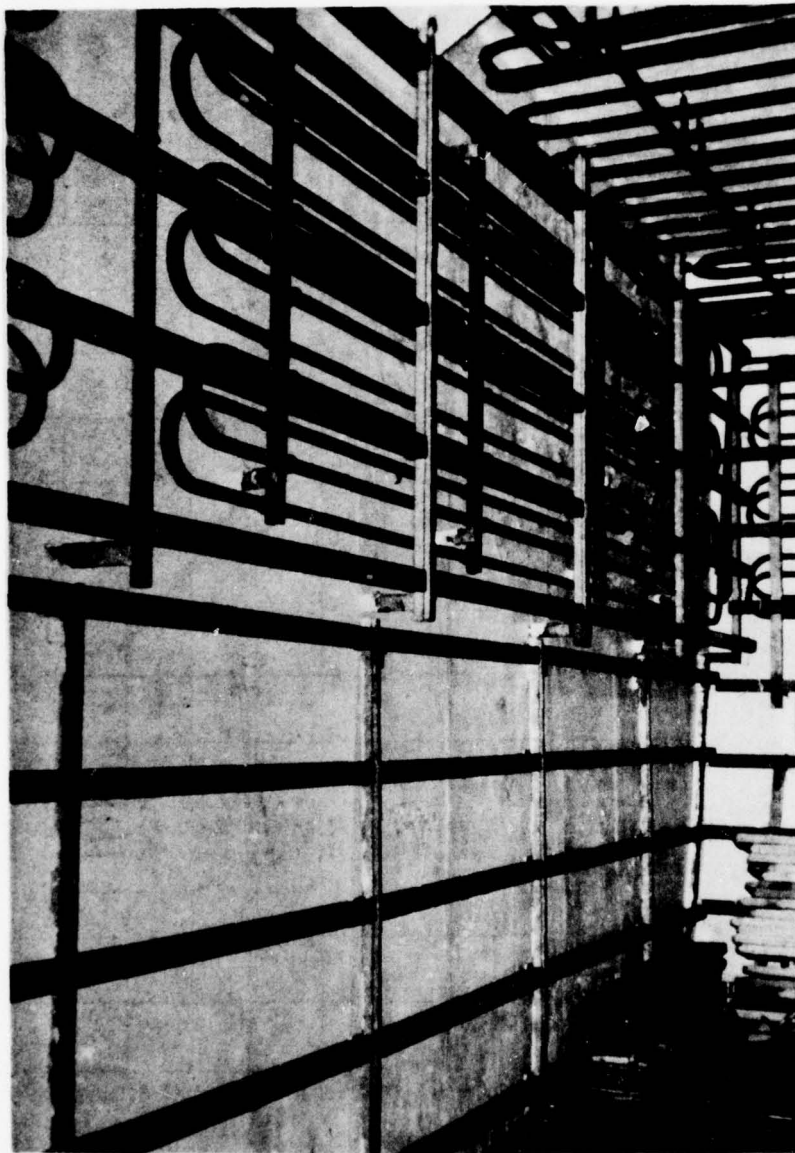


Figure 8: The refrigeration insulation covering the Diesel Generator Room casing in No. 1 Hold.

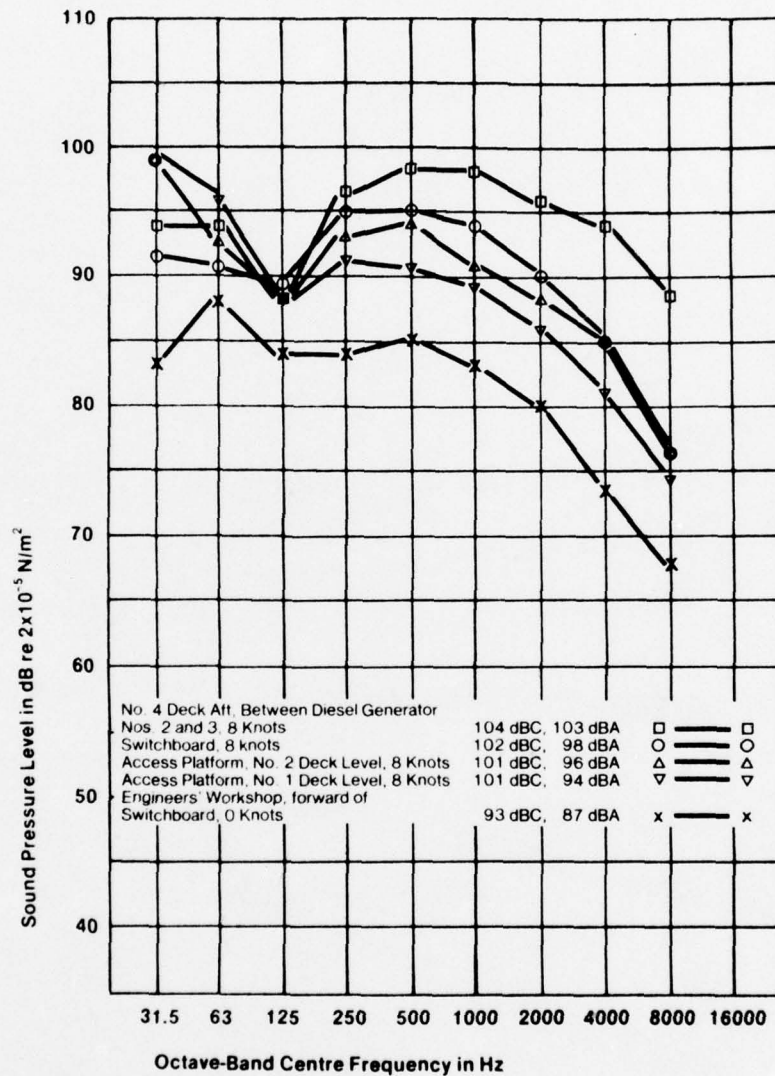


Figure 9: Overall and octave-band sound pressure levels at various locations in the Diesel Generator Room with all three diesel generators running.

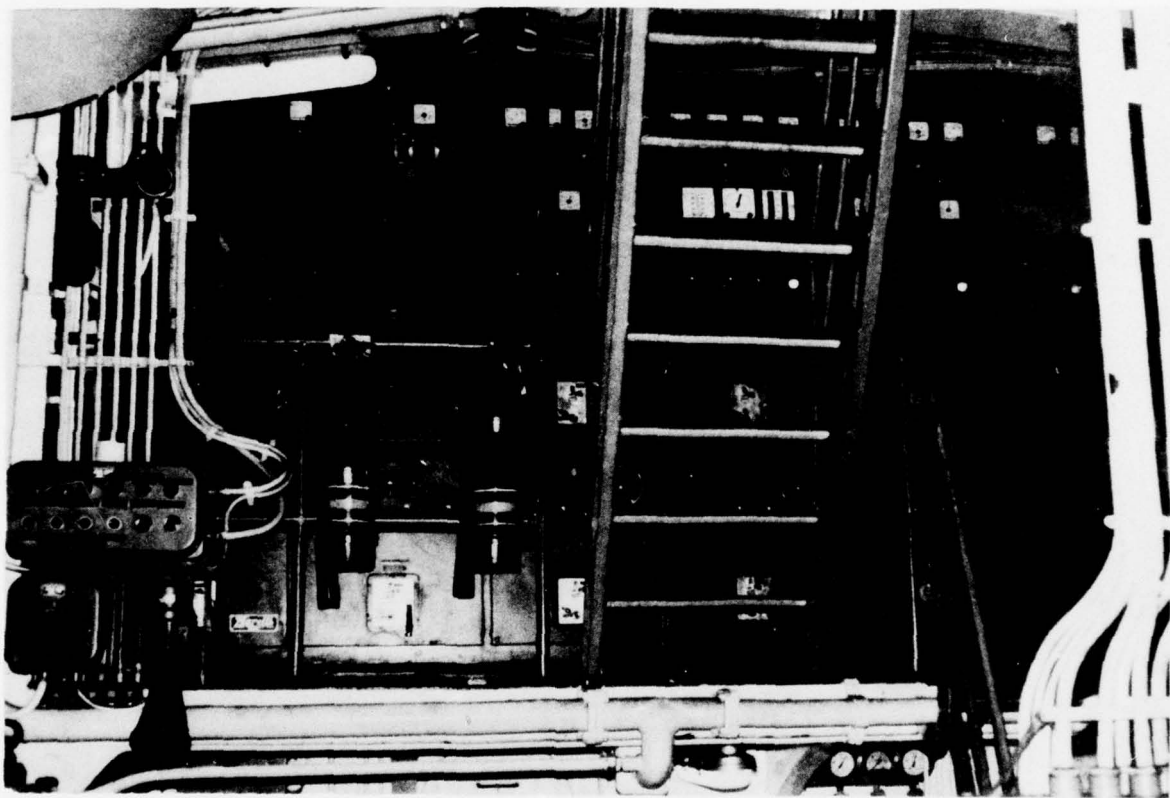


Figure 10: The main Switchboard viewed from beside No. 2 Diesel Generator.

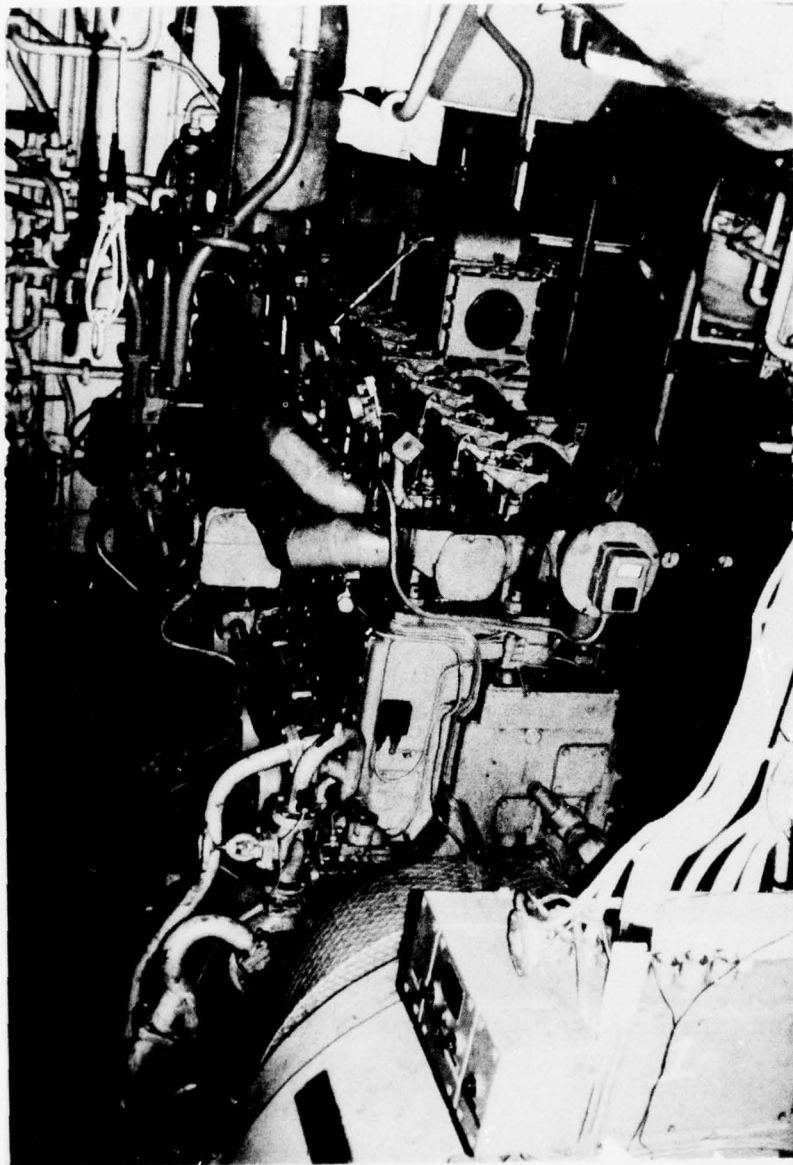


Figure 11: No. 1 Diesel Generator viewed from the Switchboard.

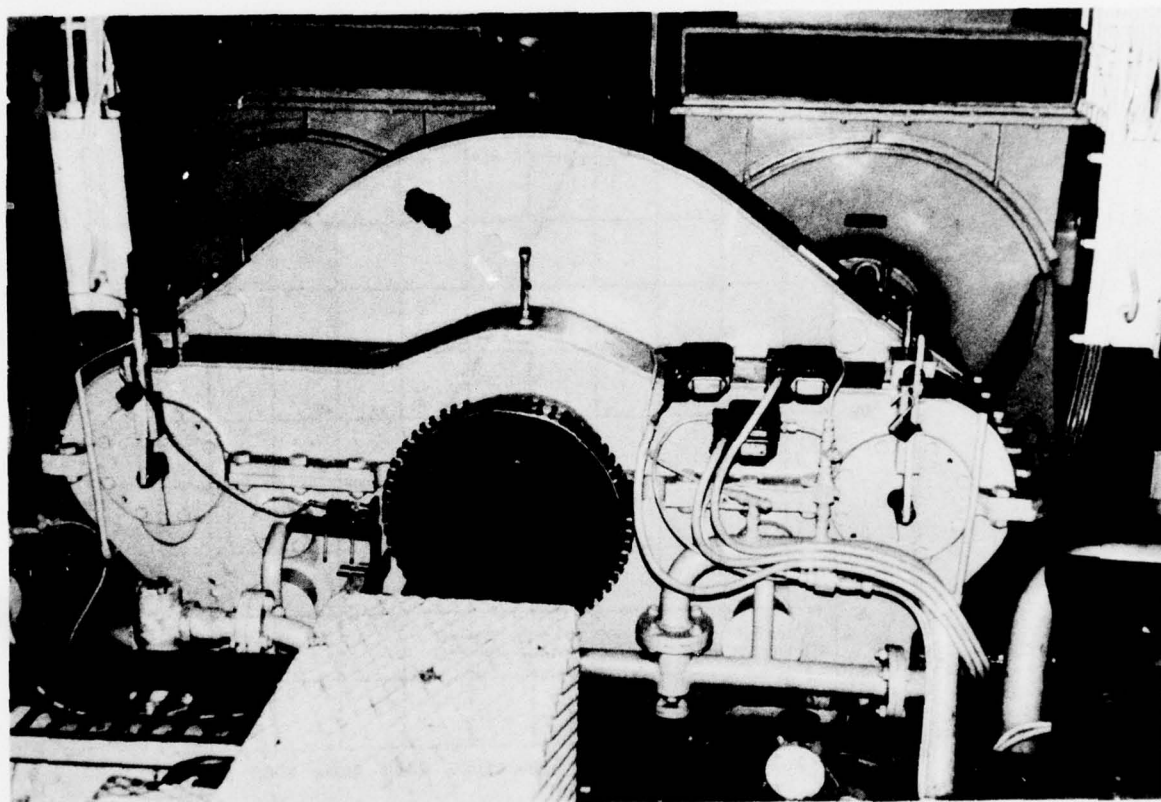


Figure 12: The propulsion motors and main gearing.

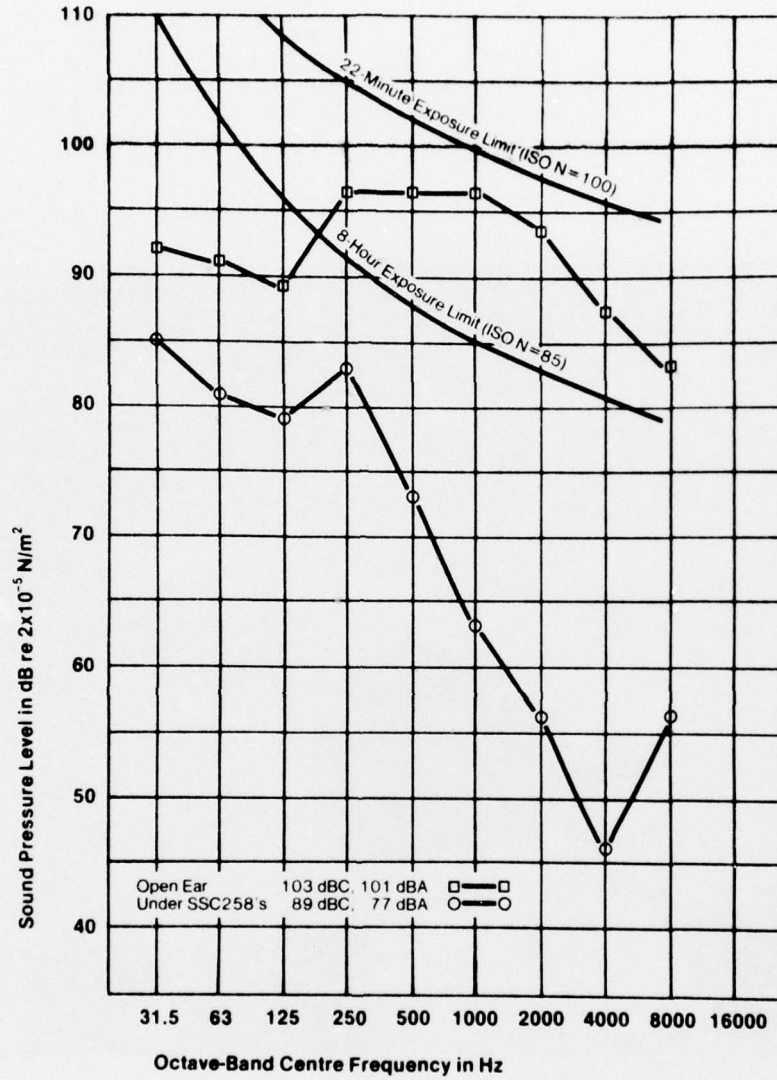


Figure 13: Overall and octave-band sound pressure levels at the Switchboard at 11 knots showing 1) actual levels, and 2) those expected under a set of SSC 258 standard issue earmuffs. (The earmuff attenuation shown in each octave band is the mean attenuation less one standard deviation). Also shown are ISO Noise Rating Curve Nos. 100 and 85.



Figure 14: The Lobby, port side of the Diesel Generator Room Casing, No. 01 Deck looking towards the Executive Officer's Washroom.

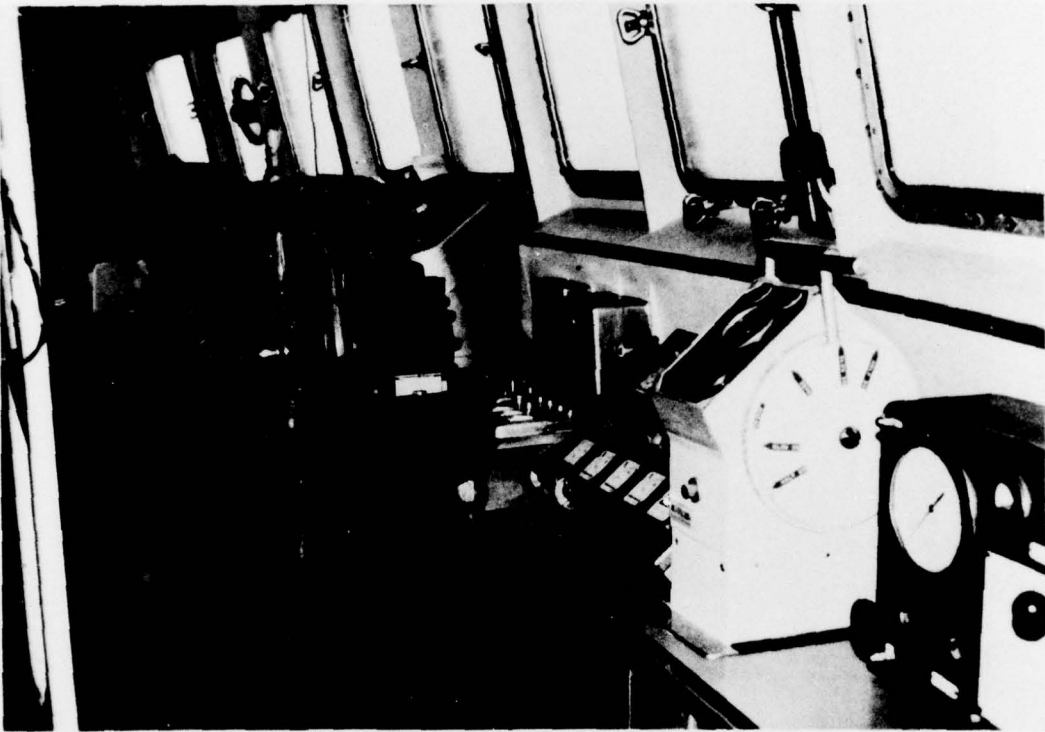


Figure 15: A view of the command position on the Bridge, from the starboard side.

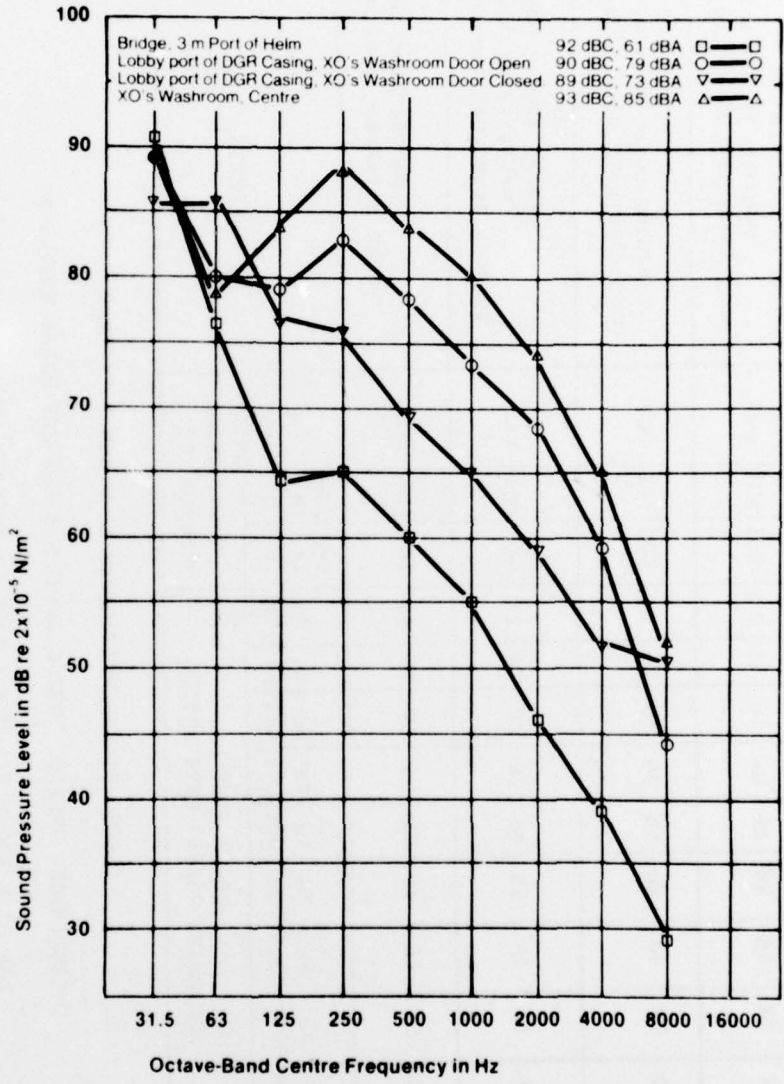


Figure 16: Overall and octave-band sound pressure levels at three locations on No. 01 Deck.

APPENDIX A

OVERALL AND OCTAVE-BAND SOUND PRESSURE LEVELS IN THE MAIN MACHINERY SPACES OF CORMORANT RUNNING AT HIGH SPEED (11 KNOTS WITH 90Z PROPELLER PITCH AND 200 RPM SHAFT SPEED. DIESEL GENERATORS NOS. 1, 2 AND 3 ON PROPULSION/SERVICE BUSS)

LOCATION	ISO NOISE RATING NO. N	OVERALL SPL			OCTAVE BAND CENTRE FREQUENCY SPLs IN dB									
		C Wt dBC	A Wt dBA		31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
Diesel Generator Room at Switchboard	100	103	101		92	91	89	96	96	96	96	93	87	83
Diesel Generator Room at Access Platform No. 2 Deck Level	95	102	100		97	91	87	95	94	95	91	87	84	
Propulsion Machinery Room 1 m forward of Motors	100	104	103		97	92	92	90	94	98	96	85	79	
Propulsion Machinery Room 1 m aft of Gearbox	100	104	102		94	91	91	90	97	98	95	84	76	

## APPENDIX B

OVERALL AND OCTAVE-BAND SOUND PRESSURE LEVELS IN SELECTED LOCATIONS OF CORMORANT  
 RUNNING AT CRUISING SPEED (8 KNOTS WITH 70% PROPELLER PITCH. DIESEL  
 GENERATORS NOS. 1 AND 2 ON PROPULSION BUSS, NO. 3 ON SERVICE BUSS)

LOCATION	ISO NOISE RATING NO. N	OVERALL SPL		OCTAVE BAND CENTRE FREQUENCY SPLs IN dB									
		C Wt dBC	A Wt dBA	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
Diesel Generator Room at Switchboard	95	102	98	92	91	89	95	95	94	90	85	77	
Diesel Generator Room at Access Platform, No. 2 Deck level	95	101	96	99	93	88	93	94	91	88	85	77	
Diesel Generator Room at Access Platform, No. 1 Deck level	90	101	94	99	96	87	92	91	89	86	82	74	
Propulsion Machinery Room, 1 m forward of Motors	100	102	100	92	90	88	90	92	96	94	82	77	
Propulsion Machinery Room, 1 m aft of Gearbox	95	102	99	92	94	91	90	91	95	92	82	72	
Lobby aft of DGR Casing, No. 2 Deck		91	76	91	86	78	79	72	66	60	52	42	
Lobby outside DGR Access Door, No. 1 Deck		88	77	83	86	79	76	75	71	68	56	50	
Lobby port of DGR Casing, No. 01 Deck, 2 m aft of Stairway		89	73	86	86	77	76	69	65	59	52	51	
No. 1 Hold, 1 m aft of Forward Bulkhead,		91	72	88	88	82	75	68	63	54	41	36	

## APPENDIX C

OVERALL AND OCTAVE-BAND SOUND PRESSURE LEVELS IN SELECTED LOCATIONS OF CORMORANT  
 RUNNING AT LOW SPEED (4 KNOTS WITH 85% PROPELLER PITCH AND SHAFT SPEED  
 REDUCED TO 120 RPM, DIESEL GENERATORS NO. 1 ON PROPULSION BUSS (SPEED  
 REDUCED TO 350 RPM), 2 AND 3 ON SERVICE BUSS, NORMAL SPEED (600 RPM))

LOCATION	ISO NOISE RATING NO. N	OVERALL SPL		OCTAVE BAND CENTRE FREQUENCY SPLs IN dB									
		C Wt dBC	A Wt dBA	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
Diesel Generator Room at Swtichboard	90	98	95	88	89	87	92	92	90	86	78	70	
Diesel Generator Room at Access Platform No. 2 Deck level	90	100	94	95	97	97	93	90	89	86	81	70	
Diesel Generator Room at Access Platform, No. 1 Deck level	90	100	93	96	94	89	91	88	87	84	79	69	
Propulsion Machinery Room, 1 m forward of Motors	95	96	94	77	80	83	87	91	91	86	79	70	
Propulsion Machinery Room, 1 m aft of Gearbox	95	96	95	83	80	84	86	89	92	88	80	72	
Lobby aft of DGR Casing, No. 2 Deck		91	73	89	88	81	77	69	63	58	49	39	
Lobby outside DGR Access Door, No. 1 Deck		87	75	82	84	80	79	74	70	66	59	45	
Lobby port of DGR Casing, No. 01 Deck, 2 m aft of Stairway		92	74	89	82	78	77	70	66	60	51	41	
No. 1 Hold, 1 m aft of forward Bulkhead, No. 4 Deck level		90	70	88	86	80	72	66	60	51	40	35	

## APPENDIX D

OVERALL AND OCTAVE-BAND SOUND PRESSURE LEVELS IN SELECTED LOCATIONS OF  
CORMORANT AT DOCKSIDE (PROPELLER FEATHERED, 200 RPM SHAFT SPEED.  
DIESEL GENERATORS NOS. 2 AND 3 RUNNING)

LOCATION	ISO NOISE RATING NO. N	OVERALL SPL		OCTAVE BAND CENTRE FREQUENCY SPLs IN dB									
		C Wt dBC	A Wt dBA	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
Diesel Generator Room at Switchboard	95	98	95	88	87	90	93	93	90	87	83	74	
Diesel Generator Room at Access Platform, No. 2 Deck level	90	99	94	96	88	87	92	92	89	87	83	74	
Diesel Generator Room at Access Platform, No. Deck level	90	98	92	96	90	86	90	90	86	85	81	71	
Propulsion Machinery Room, 1 m forward at Motors	95	100	97	88	92	91	91	92	93	89	86	78	
Propulsion Machinery Room, 1 m aft of Gearbox	100	103	100	93	96	97	95	94	96	91	95	78	
Lobby aft of DGR Casing, No. 2 Deck		89	73	88	86	78	77	70	65	62	52	40	
Lobby outside DGR Access Door, No. 1 Deck		82	75	76	76	76	77	73	69	66	61	49	
Lobby port of DGR Casing, No. 01 Deck, 2 m aft of Stairway*		90	79	90	80	79	83	78	73	68	59	44	
No. 1 Hold, 1 m aft of forward Bulkhead, No. 4 Deck level		87	68	84	84	76	72	67	60	52	38	25	

\* The door of the XO's washroom was open during this measurement

APPENDIX E

OTHER OVERALL AND OCTAVE-BAND SOUND PRESSURE LEVELS RECORDED IN CORMORANT

LOCATION	CONDITIONS	ISO NOISE RATING NO.	OVERALL SPL		OCTAVE BAND CENTRE FREQUENCY SPLs IN dB								
			C Wt DBC	A Wt DBA	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Diesel Generator Room, between Diesel Generators Nos. 1 and 2, on Catwalk, No. 2 Deck	0 Knots, Diesel Generators Nos. 2 and 3 Running	95	99	95	86	90	89	93	92	91	88	84	75
Diesel Generator Room, between Diesel Generators Nos. 2 and 3 No. 4 Deck level, 1 m from aft bulkhead	0 Knots, Diesel Generators Nos. 1 and 3 Running	100	102	100	90	90	88	95	96	94	93	92	85
Diesel Generator Room, Engineers' Workshop Centre	0 Knots, Diesel Generators Nos. 1, 2 & 3 Running	85	93	87	83	87	84	84	85	83	80	73	67
Propulsion Machinery Room, 1 m forward of Motors	4 Knots, 70% Pitch 150 RPM Shaft	90	95	93	80	82	82	86	90	90	86	78	70
Propulsion Machinery Room, 1 m aft of Gearbox	4 Knots, 70% Pitch 150 RPM Shaft	90	96	95	84	83	83	85	88	93	87	80	72
Outside, No. 01 Deck 1 m aft of Diesel Generator Room, Air Intakes	4 Knots, Diesel Generators Nos. 1, 2 & 3 Running 85% Pitch, 120 RPM Shaft	95	101	97	95	88	86	98	94	92	88	83	73

APPENDIX E (CONTINUED)

LOCATION	CONDITIONS	OVERALL SPL		OCTAVE BAND CENTRE FREQUENCY SPLs IN dB									
		C Wt dBC	A Wt dBA	31.5	63	125	250	500	1000	2000	4000	8000	
				Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz	Hz
Bridge, 3 m port of Helm	0 Knots, Diesel Generators Nos. 2 & 3 Running	92	61	91	77	64	65	60	55	47	39	29	
Galley Centre	0 Knots, Diesel Generators Nos. 1 & 3 Running	82	74	78	73	72	75	72	70	65	55	41	
Cabin No. 4, Centre	0 Knots, Diesel Generators Nos. 1, 2 & 3 Running	79	67	73	76	73	70	68	63	56	44	31	
Lobby outside Diesel Generator Room Access Door,	0 Knots, Diesel Generators Nos. 1 & 3 Running, Access Door closed	88	73	88	82	75	73	70	66	63	55	42	
No. 2 Deck	Access Door Open	94	85	93	87	80	82	83	82	78	73	63	
XO's Washroom Centre	0 Knots, Diesel Generators Nos. 1, 2 & 3 Running	93	85	90	78	84	88	84	80	74	65	52	

## APPENDIX F

## STEADY-STATE NOISE EXPOSURE LIMITS

The maximum allowable time per day that an individual may be exposed to a continuous noise of given Noise Rating Number is presented below (CFAO 34-22).

ISO NOISE RATING NUMBER (N)	85	90	95	100	105	110	115	120	125
MAXIMUM ALLOWABLE EXPOSURE PER DAY IN MINUTES	480	120	45	22	14	11	8	6	4

## APPENDIX G

VOICE LEVEL AND DISTANCE BETWEEN SPEAKER AND LISTENER FOR  
SATISFACTORY FACE-TO-FACE COMMUNICATION, AS LIMITED BY  
AMBIENT NOISE LEVEL (dBA)

(After Webster, 1969)

DISTANCE IN FEET BETWEEN SPEAKER AND LISTENER	NORMAL VOICE	EXPECTED VOICE LEVEL (1)	LIMIT FOR UN-AIDED FACE-TO-FACE SPEECH COMMUNICATION (2)
A-WEIGHTED AMBIENT SOUND PRESSURE LEVEL			
0.5	82 dBA	94 dBA	117 dBA
1	76 dBA	85 dBA	111 dBA
2	70 dBA	77 dBA	103 dBA
3	66 dBA	72 dBA	101 dBA
4	64 dBA	69 dBA	99 dBA
6	62 dBA	62 dBA	95 dBA
8	60 dBA	61 dBA	93 dBA
10	56 dBA	57 dBA	91 dBA
12	54 dBA	54 dBA	89 dBA

1. The expected voice level is that to which normal-hearing persons would be expected to increase their vocal efforts to overcome masking effects of ambient noise upon their auditory feedback. This increase in vocal effort is about 3 dB for each 10 dB increase in ambient noise level, at a level starting at about 50 dB.

2. Limited by maximum vocal effort.

## APPENDIX H

DND SPECIFICATION FOR AIRBORNE NOISE CRITERIA  
FOR SHIPBOARD SPACES<sup>1</sup>

(Anon, 1972)

Operational Spaces	SHIP'S SPEED			SHIP'S SPEED	
	CRUISE <sup>2</sup>	FULL <sup>3</sup>		CRUISE <sup>2</sup>	FULL <sup>3</sup>
Command Position, Bridge	63 dBA	65 dBA	Operations Room	58 dBA	63 dBA
Sonar Control Room	50 dBA	58 dBA	Wheelhouse	63 dBA	68 dBA
Target Indication Room	63 dBA	63 dBA	Radar Office (Manned)	63 dBA	63 dBA
Radio (Manned)	58 dBA	63 dBA	Radar Office	77 dBA	77 dBA
Radio (Unmanned)	68 dBA	77 dBA	Gun Fire Control Room	63 dBA	63 dBA
Message Centre	68 dBA	68 dBA	Crypt Centre	68 dBA	68 dBA
			Gyro Room, Unmanned	77 dBA	91 dBA

## Manned Working Spaces

Engine Room (general)	91 dBA	121 dBA	Boiler Room (general)	91 dBA	121 dBA
Engine Room (control console)	77 dBA	91 dBA	Boiler Room (control console)	77 dBA	91 dBA
Diesel room (general)	121 dBA	121 dBA	Switchboard	77 dBA	77 dBA
Diesel room (control console)	91 dBA	91 dBA	Magazines	77 dBA	77 dBA
Main Mach. Control Room	68 dBA	68 dBA	Electronic Workshop	68 dBA	68 dBA
Workshops	91 dBA	91 dBA	A/S Mortar handling rooms	77 dBA	77 dBA
Ordnance Spares Compt	91 dBA	91 dBA			
Torpedo House	77 dBA	77 dBA			
Galley	77 dBA	77 dBA			

## Living Spaces

C.O.'s Cabin	63 dBA	63 dBA	Sick Bay (Consult)	58 dBA	63 dBA
Officers Cabins	68 dBA	68 dBA	Sick Bay (Hospital)	63 dBA	68 dBA
Offices	68 dBA	68 dBA			
Ward Room	63 dBA	68 dBA			
Ward Room ante room	63 dBA	68 dBA			
Crews Dining Hall	68 dBA	77 dBA			
P.O.'s Dining Hall	68 dBA	77 dBA			
Seamens Mess Spaces	68 dBA	73 dBA			

<sup>1</sup> Criteria have been converted from Air Noise Control (ANC) levels in dB to A-weighted Sound Pressure Levels in dBA.

<sup>2</sup> Cruising speed: up to 15 knots.

<sup>3</sup> Full Speed: 20 knots upwards.

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KEY WORDS

Ship noise/habitability

Ship noise/operations

Ship noise/hearing

Ship engine room noise

Noise/Naval vessels

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