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INVESTIGATION INTO NOISE EXPOSURE OF ENGINE ROOM PERSONNEL ABOARD M.S. "TRIDENT AMSTERDAM"

by

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Summary

The noise exposure in terms of equivalent continuous sound level L_{eq} of engine room personnel was determined aboard the freighter m.s. "Trident Amsterdam" during ordinary trade voyages by means of two methods: the first by making use of dosimeters, the second by measuring the sound levels in the engine room at 165 positions and the exposure times of the engineers involved for three operating conditions of the ship. The two methods gave results which were in good agreement.
A further conclusion is that a simplified calculation method may offer a reliable alternative for determining the value of L_{eq}.

1 Introduction

Aboard ships engine room personnel is often exposed to high noise levels during the working hours.

Without any countermeasure this would sooner or later result in hearing impairment for a great percentage of the exposed persons.

Because this has become widely known the personnel involved wear hearing protectors and feel themselves quite safe by doing so. However this may only be expected to be justified for the great majority of the personnel if the sound level, to which the ear is exposed, is lower than 90 dB (A).

The sound level at the position of the ear is the result of the sound level in the environment minus the sound level difference introduced by the ear defender. The maximum permissible level in the environment, e.g. the engine room could be determined if the insertion loss of the ear defender is known.

However, this is less simple than it seems to be because:

1. there are many types of protection items
2. the sound level difference introduced by a certain protector depends on the physical shape of the wearer's head or ear.

Nevertheless an idea can be obtained of the permissible sound levels, if the investigation is restricted to earmuffs using caps.

The insertion loss (IL) of a great number of earmuffs is given e.g. in [1]. The influence of the wearer on the average value of the IL can be expressed by its standard deviation (s). The average IL may be supposed to be reached for 50% of the wearers. However a greater protection rate is frequently required e.g. 80%. In this case the average IL has to be decreased by the standard deviation. A protection rate of 98% is reached when twice the standard deviation is subtracted from the average IL data. Using the spectrum as may be expected to be typical for engine room noise the attenuation of an earmuff expressed in dB(A) can be calculated. Doing this for the earmuff with the highest and for the one with the lowest IL given in [1] the following data is obtained:

	ΔL_A	$\Delta L_A - s$	$\Delta L_A - 2s$
earmuff 1	32	29	26
earmuff 2	18	13	8

So, starting with the limit of 90 dB(A) at the ears, the highest permissible sound level in the engine room could be within the range 98–119 dB(A), depending on the desired protection rate and on the acoustical properties of the earmuffs used. The lowest level of this range is well below the limit of 110 dB(A) proposed, among others, by the Dutch authorities.

However, the 90 dB(A) limit is valid for a continuous exposure during an eight-hours' working day, 40 hours per week. This is not the case aboard modern ship because it is common practice and required by many authorities, to install a control room if the levels in the engine room exceed 90 dB(A).

So the personnel will only be exposed to high levels during a part of their duty hours. In that case the exposure is not continuous and higher levels, depending on exposure time, are permissible following [2]. When the levels to which a person is exposed vary in relation to time they may be described by a so-called equivalent continuous level (L_{eq}) being the continuous level which would result in the same amount of sound energy as it would be the case for the varying level during the same time.

The aim of the investigation reported in the next chapters was to obtain some insight into the relation between the sound levels existing in the engine room and the L_{eq}. Furthermore it would be profitable if the L_{eq} could be calculated from the sound levels and the exposure times. In that case the L_{eq} could be obtained in the future by executing only sound level measure-

ments in the engine room or even be obtained from calculated levels.

However the exposure time is in fact unknown and therefore it was also necessary to obtain this quantity aboard the ship under investigation. Because the measurement of L_{eq} and the determination of exposure times asked a great amount of organisation and accompaniment, the investigation aboard the m.v. "Trident Amsterdam" were used to test the system of data collection and to obtain experience about the necessity of the accompaniment of the measurement L_{eq} during long sailing times.

2 Data of the ship

The measurements were carried out aboard the freighter the m.v. "Trident Amsterdam" during ordinary trade voyages. Some general data of the ship and the propulsion system are:

Length between perpendiculars	156.00 m
Breadth moulded	23.30 m
Depth moulded	12.50 m
Loaded draft	8.26 m
Service speed during measurements	20 knots
Propulsion diesel engine (1):	
manufacturer	Schelde Sulzer
type	8 RND – 2 stroke
output	12 MW
speed	125 rpm
Auxiliary diesel engines (3):	
manufacturer	Smit – B & W
type	8 T 23 HH – 4 stroke
output	3 × 0.72 MW
speed	750 rpm

3 General conditions during the measurements

The operating conditions during the measurements were:

- sound pressure level measurements:
  - at sea : main engine 6 MW at 124 rpm and auxiliary diesel engines no. 2 and 3
  - in the harbour: auxiliary diesel engines no. 1 and 2.
- equivalent continuous sound level measurements:
  - at sea : main engine output about 10.5 MW at 122 rpm and two of the auxiliary diesel engines; output varying between 150–225 kW each
  - in the harbour: auxiliary diesel engines no. 2 and 3; output varying between 150–225 kW each.

4 Measuring equipment

The sound pressure levels were recorded via a 1″ microphone, manufactured by General Radio, on magnetic tape using a recorder manufactured by Kudelski, type Nagra IV SJ.

For determining the equivalent continuous sound levels the 1944-1 noise monitors were worn on duty hours by the persons who were exposed to noise. The measured noise-exposure indexes, which were read with the aid of a 1944-1 noise exposure indicator, were further converted into equivalent continuous levels. The monitor as well as the indicator are manufactured by General Radio.

5 Measuring procedure

5.1 *Measurement of sound pressure levels*

Surveys of noise measurements have been carried out during two voyages of the ship. On a coastal trip, sailing from Rotterdam to Hamburg, the sound pressure levels were recorded on magnetic tape at a large number of positions in the engine room. Since the noise levels in the harbour and at sea are quite different, measurements were taken under both conditions viz. with only the auxiliary diesel engines in operation and at service speed whereas the propulsion engine was also running.

The measuring positions were chosen at places at which the engineers probably spent a large part of their time and of course at quite a number of places along the route which has to be taken when the watch keeping engineer makes his round through the engine room.

For the determination of the measuring positions the surfaces of the tanktop and platform decks in the engine room were divided into rectangular sections with dimensions of about 1.50 × 1.50 m. The measuring locations were chosen at 1.65 m perpendicular above the middle of these sections.

The number given to a measurement is composed of seven figures, see the Table in the Appendix, indicating the location of the rectangular section in which the particular data is measured, the operating condition of the ship during the measurements and the quantity of the measured value, the last one only to enable the calculations to be performed with the aid of a computer.

5.2 *Measurement of noise doses*

During the crossing of the North Atlantic from Hamburg to Baranquilla the equivalent continuous sound levels, L_{eq} to which the engineers during their presence in the engine room are exposed, were measured. Aboard this ship two four-hour watches are kept from 8.00–12.00 hours and from 13.00–17.00 hours, the time between these periods the ship sails with an unmanned engine room except at short periods before arriving and after leaving a harbour.

During a watch the engineer in charge was provided with a noise exposure monitor. From the measurements

and the observations made during the watch the following data were obtained:

- the noise exposure index measured during the round through the engine room
- the duration of the round through the engine room
- the route of the rounds through the engine room
- the arrival times at several positions.

The other available noise-exposure monitors were distributed to the engineers who executed maintenance in the engine room during the mentioned watches. At places where these engineers mainly spent their time the duration of the exposure was measured.

6 Results of measurements and calculations

6.1. *Sound pressure level measurements*

The recordings have been analysed with a 1/3-octave band-analyser and from the results octave band levels and sound levels-A have been calculated. These data and the NR-numbers which are obtained from the octave band spectra are given in Table 1 of the Appendix. Additionally the sound levels-A calculated for the operating conditions "service speed" and "harbour" are given at the measuring positions on the general arrangements of the Floor and the several platform decks, see the Fig. 1–8 of the Appendix.

At about 1 m from the main engine on deck no. 1 (= Floor) and deck no. 2 the averaged sound level-A is about 95 dB(A) and on deck no. 3: 93 dB(A). In the vicinity of the auxiliary diesel engines the space averaged sound level-A is about 97 dB(A). The highest levels, 100 dB(A), have been measured between two operating auxiliary diesel engines and in the vicinity of the turbocharger. In the control room and in the workshop the averaged sound levels are 80 and 88 dB(A) respectively. In the Tables 1 and 2 a survey of the sound levels averaged per deck is given.

6.2. *Noise doses*

In the Tables 3, 4 and 5 the results of the noise dose measurements, the L_{eq}'s and the exposure times are given. From the routes, the exposure time and the measured sound levels L_{eq}'s are calculated, which was only possible with respect to the inspection watches. The results are given in Table 6.

Two different types of L_{eq} are used in the Tables 3–6: L_{eq_m} and L_{eq_8}. L_{eq_m} is the L_{eq} for the time T which equals the exposure time and L_{eq_8} where for the time T eight hours is chosen:

$$L_{eq} = 10 \log \left\{ \frac{1}{T} \int_0^T p^2(t)\,dt \right\} \quad (1)$$

where p = rms-value of the sound pressure at the time t
T = total time taken into consideration.

When using for T the duration of the measuring period L_{eq} is proportional to the time-averaged energy of the sound, supposing the integration time is sufficiently long. This quantity is used to investigate if space-averaged sound levels can be used in stead of L_{eq}.

The calculated L_{eq} are obtained by using the relation

$$L_{eq} = 10 \log \left\{ \frac{1}{T} \int_0^T 10^{L_t/10} \cdot dt \right\} \quad (2)$$

where L_t = sound level at time t
T = total time $= \sum t_i$.

Table 1. Averaged values of the sound levels in dB(A) at various areas in the engine room. Operational condition of the ship: service speed

area	number of measuring positions	average value of sound levels ($\overline{L_A}$)	standard deviation	level of the mean-square space averaged A-weighted sound pressure ($L_{\overline{A}}$)
deck 1 (floor)	53	94.5	2.7	95.3
deck 2	39	92.6	3.2	93.4
deck 3	42	90.0	4.2	91.8
deck 4	1	88.0	–	88.0
deck 5	5	89.0	2.1	89.4
deck 6	9	87.0	1.3	87.2
deck 7	9	85.6	1.1	85.7
shaft tunnel	4	85.8	1.5	86.0
control room	4	79.8	1.0	79.8
workshop	2	87.0	0	87.0
store	6	77.3	2.9	78.2
deck 1, near aux. diesel engines	20	97.2	1.7	97.4
decks 1–3	134	92.5	3.9	93.9

Table 2. Averaged values of the sound levels in dB(A) at various areas in the engine room. Operational condition of the ship: in the harbour

area	number of measuring positions	average value of sound levels ($\overline{L_A}$)	standard deviation	level of the mean-square space averaged A-weighted sound pressure ($L_{\overline{A}}$)
deck 1 (floor)	37	91.3	4.5	93.6
deck 2	19	87.5	2.7	88.3
deck 3	24	83.2	2.6	83.8
deck 4	1	84.0	–	84.0
deck 5	4	81.8	2.1	82.1
deck 6	7	82.3	1.6	82.6
deck 7	9	80.9	0.8	81.0
control room	3	78.0	0.0	78.0
workshop	2	81.5	0.7	81.5
deck 1, near aux. diesel engines	16	94.7	4.1	96.1
decks 1–7	101	86.7	5.2	90.3
decks 1–3	80	88.0	5.0	91.1

For the normal watches reported in Table 3, L_{eq_m} could be calculated very precisely because the exposure times during the rounds at each of the measuring positions in the engine room were known (Table 7).

Additionally the L_{eq_m} was calculated using a less fine division e.g. the exposure per deck (Table 6).

For the assessment of the noise exposure in relation to hearing impairment L_{eq} must be known for a period of 8 or 40 hours. The L_{eq} to which an engineer is exposed during an 8-hour working day can be obtained by addition of two L_{eq_8} each of which being obtained during a 4-hour watch following the power law

$$L_{eq_{tot}} = 10 \log (10^{L_{eq_1}/10} + 10^{L_{eq_2}/10})$$

The L_{eq_8}'s given in the Tables 3, 4 and 5 are thus giving

Table 3. Survey of the measured L_{eq_m} and L_{eq_8} in dB(A) to which the watch keeping engineers are exposed during their inspection rounds through the engine room. The integration times used are the round duration time (L_{eq_m}) and 8 hours (L_{eq_8}) respectively.
Operational condition of the ship: service speed

measure-ment no.	round no.	round duration time (min)	total watch keeping time (min)	L_{eq_m} (dB(A))	L_{eq_8} (dB(A))
6	1	25	162	94.8	82.7
9	2	49	250	92.3	83.3
14	3	88	270	95.6	88.5
16	4	21	250	96.8	84.1
26	5	25	135	–	–
27	6	127	240	–	–
31	7	18	250	96.3	83.1
33	8	21	250	94.8	82.5
41	9	20	245	95.0	82.9
45	10	77	260	96.0	88.3
48	11	24	215	98.4	85.8
53	12	60	160	94.4	86.6
56	13	21	120	94.7	82.3
68	14	18	210	94.4	81.5
74	15	84	210	95.1	87.7
83	16	25	210	94.9	83.0
59	17	73	210	94.6	86.7
119	18	19	210	–	–
127	19	57	210	92.6	83.9
128	20	13	210	–	–
133	21	44	255	95.3	85.5
137	22	27	210	95.2	83.1
140	23	57	210	93.4	84.6
144	24	17	210	96.7	83.1
145	25	86	210	95.4	88.1
146	26	22	227	94.5	82.3
147	27	69	180	94.8	86.6
149	28	20	210	95.9	83.0
152	29	66	180	92.8	84.5
157	30	17	210	93.9	81.0
160	31	57	150	92.4	83.5
167	32	23	210	90.5	79.6
172	33	14	201	90.7	78.5
total number n =		33	33	29	29
average value $\bar{x}$ =		41.9	210.3	94.6	84.0
standard deviation s =		28.8	35.8	1.7	2.5

Table 4. Survey of the measured L_{eq} of engineers who kept watches and executed maintenance in the engine room. Operational condition of the ship: service speed

measure-ment no.	exposure time (min)	L_{eq_m} (dB(A))	L_{eq_8} (dB(A))	location where maintenance is executed *
4	165	91.8	82.2	–
5	218	93.9	90.5	–
8	240	91.5	88.5	–
15	265	98.3	95.7	aux. diesel engines
17	220	99.3	95.9	aux. diesel engines
19	215	96.0	92.5	aux. diesel engines
22	240	94.5	91.5	–
23	245	99.4	96.5	aux. diesel engines
25	253	98.6	95.8	aux. diesel engines
29	245	94.9	92.0	–
30	290	98.3	96.1	–
32	250	97.0	94.2	–
34	250	98.3	95.5	–
35	185	89.6	85.5	deck 6
36	185	88.8	84.7	deck 6
37	185	94.3	90.2	–
38	200	92.9	89.1	–
39	245	98.9	93.7	–
40	245	87.2	82.0	–
42	120	100.0	94.0	aux. diesel engines
46	240	98.2	95.2	–
47	260	95.9	93.2	–
49	215	98.1	94.6	aux. diesel engines
50	215	100.0	96.5	aux. diesel engines
51	240	94.7	91.7	–
54	155	98.1	93.2	aux. diesel engines
58	120	97.4	91.4	–
60	210	92.2	88.6	–
64	235	90.7	87.6	deck 7
66	235	94.6	91.5	deck 1
69	60	88.8	79.8	deck 1, 2
70	235	95.1	92.0	–
71	235	94.7	91.6	–
72	235	97.2	94.1	–
73	240	94.6	91.6	–
75	185	95.9	91.8	deck 1
76	185	96.1	92.0	deck 1
77	180	90.4	86.1	deck 3
129	210	99.4	95.8	aux. diesel engines
130	210	98.1	94.5	aux. diesel engines
131	210	97.9	94.3	aux. diesel engines
134	255	98.8	96.1	main engine
135	240	97.3	94.3	main engine
138	210	99.1	95.5	aux. diesel engines
139	210	97.9	94.3	aux. diesel engines
141	180	98.0	93.7	aux. diesel engines
142	180	98.2	93.9	aux. diesel engines
143	180	89.7	85.4	deck 6, 7
150	210	92.4	88.8	deck 3
151	210	91.0	87.4	workshop
153	180	91.7	87.4	workshop
154	180	86.4	82.1	–
155	210	94.2	90.6	–
159	210	90.3	86.7	–
161	155	93.6	88.7	deck 1
162	210	94.0	90.4	deck 1
163	210	88.7	85.1	deck 3
164	210	99.0	95.4	deck 1
166	210	99.6	96.0	deck 1
168	210	94.3	90.7	–
170	210	92.6	89.0	–
171	210	95.0	91.4	–
n =	62			
$\bar{x}$ =	210.5	95.1	91.2	
s =	38.0	3.6	4.1	

* When the location is not given the maintenance was carried out throughout the entire engine room.

no complete information about the noise exposure because only one four-hour watch was considered whereas the additional duty time, spent in the engine room performing maintenace, was neglected.

7 Discussion of the results

7.1

The highest sound levels measured in the engine room of the m.v. "Trident Amsterdam" appear to be 100 dB(A) (Table 1, Appendix).

During sailing conditions only at tanktop and at the decks 2 and 3 the averaged values of the levels per deck exceed 90 dB(A) (Table 1). For the harbour condition this is only at tantop the case (Table 2). The highest levels occur near the auxiliary diesel engines and in the vicinity of the turbocharger of the propulsion engine. The averaged value of the measured L_{eq} of the inspection watches appears to be 94.6 dB(A), or rounded to the nearest whole decibel: 95 dB(A) (Tables 3 and 9).

The similar values of the calculated data are (rounded) 94 dB(A) which is in good agreement with the measured value. The standard deviations are low for the measured as well as for the calculated data and from the Table 7 it appears that the L_{eq}'s deviate very little from round to round. This is mainly caused by the fact that about 18 minutes of the round duration time of 42 minutes (averaged values, see Table 6) are spent at tanktop, where the highest levels are present.

Also from Table 7 it appears that, from a statistical point of view, it makes little difference (0.3 dB(A)) if the L_{eq} is obtained by using observations about the position of an engineer, made every 30 seconds or less, or by using the exposure time per deck combined with the level of the mean-square space averaged A-weighted sound pressure $L_{\bar{A}}$ per deck (Table 6). The calculated L_{eq_8} equals $L_{\bar{A}}$ when the latter is obtained from the sound pressures measured at the three lowest levels in the engine room (93.9 dB(A), see Table 1). This certainly will not be a coincidence but will probably differ slightly from ship to ship.

Table 5. Survey of the measured L_{eq} of engineers who kept watches and executed maintenance in the engine room. Operating condition of the ship: in the harbour

measurement no.	exposure time (min)	L_{eq_m} (dB(A))	L_{eq_8} (dB(A))	location where maintenance is executed
10	260	92.9	90.2	–
11	260	90.9	88.3	entire engine room
12	260	93.6	90.9	deck 1, main engine
13	252	89.4	86.6	–
78	210	94.8	92.1	–
79	210	94.2	90.6	–
81	210	97.3	93.7	deck 2, compressor
88	215	92.5	89.0	entire engine room
89	215	92.7	89.2	deck 1, 2
90	210	91.9	85.9	entire engine room
96	210	91.2	85.2	prop. shaft tunnel
98	240	92.4	89.4	deck 1, 2
101	210	91.7	85.7	deck 3, main engine
102	210	86.5	80.5	entire engine room
104	210	86.2	80.2	workshop
108	240	90.8	84.8	engine room
112	210	89.4	83.4	–
116	210	93.1	87.1	deck 2, location 02/50-51
117	210	90.0	84.0	–
118	210	89.3	83.3	deck 3, location 01/51-54
123	280	92.7	90.3	deck 1, location 01-02/51-54
124	280	90.6	88.3	deck 1, location 01-02/51-54
$n =$	22			
$\bar{x} =$	228.3	91.6	87.2	
$s =$	25.4	2.6	3.6	

Table 6. The L_{eq_m} to which watch keeping engineers are exposed during their rounds through the engine room, calculated by using the exposure times per deck and the averaged sound levels $L_{\bar{A}}$ at each of the decks in the engine room; obtained from Table 1.
Operational condition of the ship: service speed

round no.	time spent (min) during round at deck no. 1 (floor)	2	3	6	7	shaft tunnel	total time at a round (min)	calculated L_{eq_m} (dB(A))
1	12	3	10	0	0	0	25	94.0
2	0	32	17	0	0	0	49	92.9
3	45	22	15	4	2	0	88	94.1
4	9	4	8	0	0	0	21	93.9
5	5	10	10	0	0	0	25	93.3
6	51	23	35	12	2	4	127	93.5
7	6	8	4	0	0	0	18	93.9
8	7	5	9	0	0	0	21	93.6
9	8	6	6	0	0	0	20	93.4
10	39	23	13	4	2	6	77	94.3
11	13	5	6	0	0	0	24	94.3
12	33	9	9	2	2	5	60	94.0
13	12	3	6	0	0	0	21	94.3
14	9	4	5	0	0	0	18	94.4
15	37	23	16	2	1	5	84	93.8
16	10	7	8	0	0	0	25	93.9
17	42	14	8	2	2	5	73	94.1
18	6	9	4	0	0	0	19	93.9
19	26	13	10	0	0	8	57	93.6
20	6	4	3	0	0	0	13	94.1
21	18	10	9	2	2	3	44	93.5
22	18	4	5	0	0	0	27	94.6
23	26	12	9	1	2	7	57	93.7
24	8	4	5	0	0	0	17	94.1
25	37	20	16	2	2	8	86	93.7
26	12	8	2	0	0	0	22	94.4
27	31	10	14	5	4	0	69	93.5
28	11	5	4	0	0	0	20	94.3
29	31	17	7	2	2	7	66	93.8
30	8	4	5	0	0	0	17	94.1
31	13	17	16	3	1	7	57	92.9
32	13	4	6	0	0	0	23	94.3
33	5	4	5	0	0	0	14	93.8
$n =$	33	33	33	33	33	33	33	33
$\bar{x} =$	18.4	10.5	9.2	1.24	0.61	1.97	41.9	93.9
$s =$	13.9	7.6	6.3	2.40	1.03	2.97	28.8	0.4

For the watches which are spent on maintenance the average value of the measured L_{eq} is 95.1 dB(A) (Table 4), which is only 0.5 dB(A) higher than the L_{eq_m} of the inspection watches. The measured L_{eq_m} appears to be one dB higher than $L_{\bar{A}}$ of the three lower decks, which is 94 dB(A). This is mainly caused by the high L_{eq_m} occuring during maintenance work with respect to the auxiliary diesel engines when the averaged value of L_{eq_m} appears to be 99 dB(A) (Table 9).

From Table 1 it appears that the $L_{\bar{A}}$ obtained from the sound levels measured near the auxiliary engines is about 97.5 dB(A), which is only one dB lower than L_{eq_m} (unrounded 98.5 dB(A)).

During the majority of the maintenance work the average value of L_{eq_m} is 94 dB(A) (Table 9) which equals $L_{\bar{A}}$ of the three lower decks.

For the harbour condition (Table 5) the L_{eq_m} of 91.6 dB(A) is 0.5 dB higher than the average value of the sound levels at the three lower decks.

So it may be concluded that aboard the ship concerned the measured L_{eq_m} agree with the averages of the levels $L_{\bar{A}}$ measured at the three lower decks in the engine room except with respect to the maintenance work concerning the auxiliary diesel engines where the sound levels in the vicinity of these engines are responsible for the L_{eq}.

Table 7. The measured and calculated L_{eqm} for the inspection watches

round no.	L_{eq_m} measured (see table 3)	L_{eq_m} calculated using routes and $L_{\bar{A}}$ per area of 1.5×1.5 m	L_{eq_m} calculated using exposure time per deck and $L_{\bar{A}}$ per deck (see table 6)
1	94.8	92.3	94
2	92.3	91.8	92.9
3	95.6	93.7	94.1
4	96.8	93.1	93.9
5	–	94.0	93.3
6	–	93.4	93.5
7	96.3	92.7	93.9
8	94.8	93.2	93.6
9	95.0	94.1	93.4
10	96.0	92.4	94.3
11	98.4	93.9	94.3
12	94.4	92.9	94.0
13	94.7	94.3	94.3
14	94.4	96.7	94.4
15	95.1	93.2	93.8
16	94.9	93.8	93.9
17	94.6	93.7	94.1
18	–	92.1	93.9
19	92.6	93.0	93.6
20	–	94.1	94.1
21	95.3	93.7	93.5
22	95.2	95.7	94.6
23	93.4	92.3	93.7
24	96.7	94.2	94.1
25	95.4	93.4	93.7
26	94.5	94.5	94.4
27	94.8	93.7	93.5
28	95.9	94.8	94.3
29	92.8	94.1	93.8
30	93.9	94.1	94.1
31	92.4	92.4	92.9
32	90.5	94.0	94.3
33	90.7	93.8	93.8
n =	29	33	33
$\bar{x}$ =	94.6	93.6	93.9
s =	1.7	1.0	0.4

Table 8. The measured and calculated L_{eq_8} for the inspection watches

round no.	L_{eq_8} measured	L_{eq_8} calculated using $L_{\bar{A}}$ per area	L_{eq_8} calculated using $L_{\bar{A}}$ averaged per deck
1	82.7	80.6	82.0
2	83.3	82.9	83.8
3	88.5	86.7	87.1
4	84.1	81.3	81.9
7	83.1	79.8	81.2
8	82.5	81.4	81.5
9	82.5	81.8	81.3
10	88.3	84.6	86.7
11	85.8	82.6	82.4
12	86.6	84.2	85.2
13	82.3	82.0	82.0
14	81.5	83.3	81.5
15	87.7	85.9	86.5
16	83.0	82.1	82.2
17	86.7	85.8	86.2
19	83.9	84.3	84.8
21	85.5	84.1	83.9
22	83.1	83.9	83.0
23	84.6	83.7	84.9
24	83.1	81.2	81.1
25	88.1	86.2	86.5
26	82.3	82.3	82.2
27	86.6	85.6	85.4
28	83.0	82.1	81.8
29	84.5	85.8	85.5
30	81.0	81.1	81.1
31	83.5	83.5	84.0
32	79.6	82.0	82.2
33	78.5	80.3	80.3
n =	29		
$\bar{x}$ =	84.0	83.1	83.4
s =	2.5	1.9	2.1

Table 9. Summary of the averaged values of the results of the noise dose measurements. The L_{eq} and their standard deviation s levels (in dB(A)) are given using the measuring time (L_{eq_m}) or 8-hours (L_{eq_8}) as the integration time

measuring conditions	number of measurements	L_{eq_m}	s	L_{eq_8}	s
1. sailing, inspection watches	29	95	1.7	84	2.5
2. sailing, maintenance watches	62	95	3.6	91	4.1
2a. from 2, maintenance of auxiliary diesel engines only	16	99	1.0	95	1.2
2b. other maintenance watches than 2a	46	94	3.4	90	4.0
3. in harbour, watches and maintenance	22	92	2.6	87	3.6

Table 10. Comparison between the L_{eq} obtained by measurement using noise monitors and by calculation using measured sound levels and exposure times

measuring conditions	L_{eq_8} measured (dB(A))	L_{eq_8} calculated (dB(A))	calculation based on			
			L_{A_i}	during	t_i(min)	table no.
1. sailing, inspection watches	84	83/83		many data		8
		84	94	(decks 1–3)	42	1, 6
			80	(control room)	210−42 = 168	1, 3
2. sailing, maintenance watches	91	90	94	(decks 1–3)	211	1, 4
2a. from 2, maintenance of auxiliary diesel engines only	95	94	97	(deck 1, near aux. diesel eng.)	207	1, 4
3. in harbour, watches and maintenance	87	88	91	(decks 1–3)	228	2, 5

7.2

To evaluate the noise exposure of the engineers with respect to the hearing impairment noise limit, L_{eq} based on an integration time of 8 hours, L_{eq_8}, is used.

The values of L_{eq_8}, calculated by using the measured L_{eq_m} and the exposure times, are given in the Tables 3, 5 and 8. This incorporates that when calculating L_{eq_8} it is supposed that within the total time of 8 hours only exposure to sound in the engine room and control room exists. Moreover, L_{eq_8} is calculated using the exposure during a 4-hour watch which includes that the L_{eq_8} given in the tables do not directly give an impression about the total noise exposure per week-day, which will be discussed in the next paragraph. In the Figs. 1–3 the distribution of the levels is illustrated. Only the L_{eq_8} measured during inspection watches (Fig. 1) and during maintenance work at the auxiliary diesel engines tend to a normal distribution of the levels. However, the amount of data is too small in fact to arrive at conclusions in this respect.

The L_{eq_8} shows in general a higher standard deviation than the L_{eq_m} which is caused by the deviations of data of the exposure times.

The averaged value of L_{eq_8} of the inspection watches, 84 dB(A), appears to be 7 dB(A) lower than the L_{eq_8} of the maintenance watches which is due to the short exposure time during the rounds through the engine room. The L_{eq_8} calculated by using the sound levels and exposure times are given in the Tables 8 and 10. The calculated levels are in good agreement with the measured levels if for the calculation the right assumption about the levels to be used is made and the average exposure times, given in table 10 are used. The assumptions are

1. the mean-square space averaged A-weighted sound pressure level $L_{\bar{A}}$ may be used
2. the $L_{\bar{A}}$ of the three lower levels in the engine room determines L_{eq_8} during sailing and the $L_{\bar{A}}$ of the floor during harbour conditions
3. when maintenace work is executed the levels in the

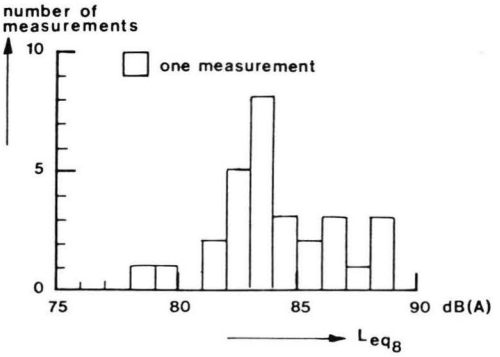


Fig. 1. Distribution of the equivalent sound levels (reference time: 8 hours) measured during the normal four-hour watches at service speed condition.

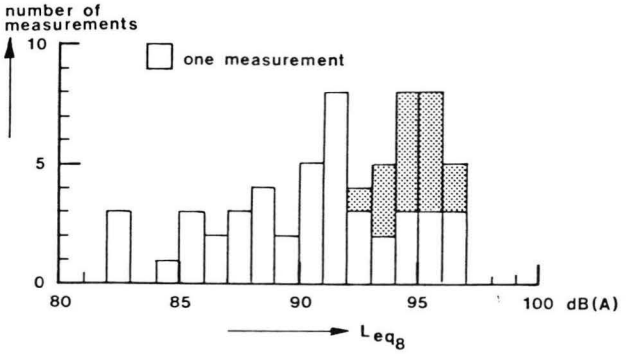


Fig. 2. Distribution of the equivalent sound levels (reference time: 8 hours) measured during the four-hour maintenance watches spent in the engine room. The shadowed area refers to measurements during watches during which auxiliary diesel engines were repaired.

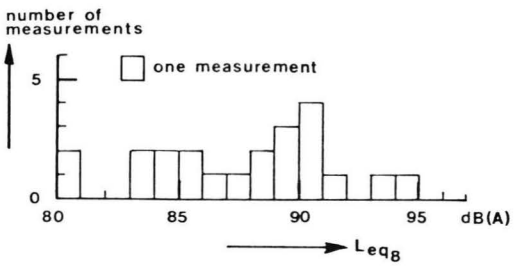


Fig. 3. Distribution of the equivalent sound levels (reference time: 8 hours) measured during the watches at harbour conditions.

vicinity of the engine(s) involved can be used to calculate $L_{\bar{A}}$.

Because the L_{eq8} based on the measured data may be considered as a sample of the total collection of occurring L_{eq8} it can be stated that the average value of these measured L_{eq8} is a good rating for the real L_{eq8} with inaccuracy of ± 1 dB (inspection and maintenace, Tabels 3 and 4) or of ± 1.5 dB (harbour, Tables 5) within a confidence range of 95%.

Calculation of L_{eq8} increases this inaccuracy only slightly.

7.3

To assess the noise exposure per week for an engineer aboard the m.v. "Trident Amsterdam" the distribution of the two types of watches during a week has to be considered. Aboard the ship an engineer keeps two four-hour watches a day and in a period of three days two inspection watches and four maintenance watches. This scheme is continued for long periods, seven days a week. So it is obvious to consider the L_{eq} for a period of six 4-hour watches, giving 24 hours exposure-time. To obtain L_{eq24} for one watch 5 dB has to be subtracted from the respective L_{eq8}:

$$L_{eq24} = L_{eq8} - 10\log 24/8 = L_{eq8} - 5 \text{ dB}$$

The resulting L_{eq24} of six 4-hour watches can now be derived by addition of the six L_{eq24} following the power law:

$$L_{tot} = 10\log(10^{0.1L_1} + 10^{0.1L_2} \ldots + 10^{0.1L_6})$$

For two inspection- and four maintenance watches, using the data of table 10 from which 5 dB are subtracted, the resulting L_{eq} becomes:

$$L_{eq24} = 10\log(10^{7.9} + 10^{7.9} + 10^{8.6} + 10^{8.6} + 10^{8.6} + 10^{8.6}) = 92.5 \text{ dB(A)}$$

When in all periods of 24 hours this L_{eq} occur the L_{eq56} in a working week of 56 hours is 92.5 dB(A). The contributions of the inspection and the maintenance watches to this level are 82 and 92 dB(A) respectively.

In [2] a working week of 40 hours is used. It is not known at the moment if the risk of hearing impairment increases when the number of working hours per week increases. Supposing the equal energy concept, on which [2] is based, is also valid for periods with more than 40 hours, the L_{eq40} for a 40-hour week would be 94 dB(A).

In the introduction it is mentioned that, to be sure that the limit of 90 dB(A) at the protected ear is not surpassed, the level in the engine room would not exceed 98 dB. The L_{eq40} is 4 dB lower which involves that it is unlikely that the sound level at the ears, when using earmuffs would exceed 86 dB(A). From some experiments carried out aboard it appeared that inside the earmuffs the sound level was lower than 80 dB(A). So, when using earmuffs, the engineers aboard the m.v. "Trident Amsterdam" have a low risk of hearing impairment.

8 Conclusions

1. The direct measured and calculated equivalent continuous sound levels L_{eq}, being the continuous levels which would result in the same amount of sound energy as it would be in the case for the varying levels, proved to be in good agreement.
2. For this particular ship the level of the mean-square space averaged sound pressure $\bar{p}^2$ measured at the three lowest levels in the engine room appears to offer a reliable base for the calculation of L_{eq}.
3. The method by which the data is gathered needs no further improvement. The necessity of having a person aboard whose task is to coach the engineers with respect to the use of the noise monitors and to administrate carefully the exposure times appeared clearly during the interpretation of the results.
4. The L_{eq} for a 56-hours week appears to be 92.5 dB(A). This level is composed of a contribution of 82 dB(A) caused by the exposure to noise during the inspection watches and by a contribution of 92 dB(A) caused by maintenace work.

9 Acknowledgement

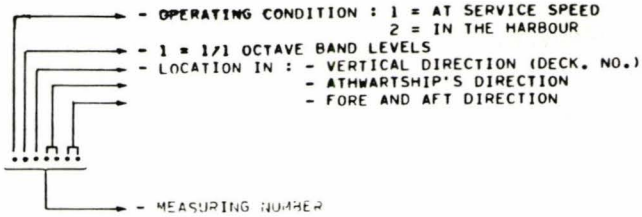
The Stichting Nederlands Maritiem Instituut and the authors express their gratitude to the ship owner, Koninklijke Stoomboot Maatschappij, for placing at their disposal the m.v. "Trident Amsterdam". They also appreciate very much the loyal cooperation of the engineers and thank in particular the chief engineer Mr. Van Wijngaarden whose forceful support contributed to the successful execution of the experiment. Furthermore we thank Mr. Zichtema of the Gemeenschappelijk Administratiekantoor in Amsterdam who guided the noise dose survey aboard and took care that the results were delivered conveniently arranged.

References

1. A. M. Mimpen and R. Plomp: De geluidverzwakking van 40 typen oorkappen, Instituut voor Zintuigfysiologie TNO, rapport IZF 197S-C10.
2. ISO-Recommendation R1999: Assessment of occupational noise exposure for hearing conservation purposes.

APPENDIX

Table 1. Survey of sound pressure level measurements



MEASURING NUMBER	SOUND-NR-LEVEL-NUM *A*	BER	CENTRE FREQUENCY OF OCTAVE BANDS IN HZ 31.5	63	125	250	500	1K	2K	4K	8K
1110125	88	84	99	98	90	89	87	82	78	71	73
1110130	85	80	95	98	89	86	82	80	76	70	72
1110135	85	80	101	96	89	85	83	80	77	71	68
1110140	85	80	101	93	88	85	83	80	77	72	68
1110145	92	89	91	87	88	89	91	87	85	76	72
1110146	91	87	92	95	87	89	89	86	85	77	73
1110247	93	89	90	92	90	91	91	88	86	79	75
1110249	94	91	93	95	90	92	93	89	87	80	77
1110250	94	91	95	93	90	93	93	89	87	80	77
1110251	95	92	95	93	91	93	94	90	87	80	77
1110252	96	94	93	92	90	95	96	91	88	81	78
1110253	96	93	92	92	91	94	95	91	89	82	78
1110254	95	92	93	95	90	94	94	91	88	81	78
1110255	96	92	93	97	88	95	94	91	88	81	78
1110256	96	92	92	94	89	94	94	92	88	82	79
1110258	94	91	91	93	87	93	93	90	87	81	77
1110345	93	89	91	90	88	89	91	87	84	77	73
1110447	94	91	92	95	90	91	93	89	87	81	78
1110449	98	94	91	94	91	93	96	92	92	86	84
1110450	99	96	93	94	91	92	98	94	93	87	84
1110451	100	98	94	93	92	93	100	95	93	87	84
1110453	97	94	91	94	91	93	96	93	90	83	81
1110455	98	94	90	91	89	94	96	93	91	83	81
1110456	97	94	92	91	91	93	96	93	91	83	81
1110457	97	94	91	92	91	93	96	93	90	83	82
1110458	96	93	92	89	88	93	95	91	89	83	81
1110548	94	91	91	95	89	93	93	90	87	81	78
1110550	98	96	95	93	91	95	98	94	90	84	80
1110552	99	96	93	93	90	94	97	96	91	85	83
1110554	97	93	94	93	91	93	94	93	90	84	81
1110555	97	93	94	94	90	94	95	93	91	84	81
1110556	99	96	95	93	90	94	97	94	94	87	83
1110557	99	96	95	94	90	94	98	93	93	87	84
1110558	97	94	94	93	88	94	94	92	92	86	87
1110660	94	91	95	94	91	94	93	90	86	79	77
1111158	94	90	89	89	89	94	92	89	87	79	75
1111245	90	85	92	88	87	88	88	85	83	75	71
1111248	93	89	92	92	90	88	89	86	87	77	73
1111249	92	88	94	95	91	91	89	87	86	77	72
1111250	95	94	96	93	90	90	89	87	92	77	72
1111251	94	92	96	94	90	91	89	87	90	78	72
1111252	93	91	95	93	89	91	90	87	89	78	72
1111253	94	93	94	91	91	90	91	87	91	78	72
1111254	94	92	93	92	89	91	91	88	90	78	71
1111255	93	90	93	92	90	90	91	87	88	78	71
1111256	93	90	92	92	89	90	90	88	88	78	72
1111258	94	90	89	90	89	92	92	89	88	79	75
1111347	91	88	91	89	89	88	89	86	86	77	72
1111355	92	88	90	90	87	91	90	87	86	79	74
1111446	89	85	95	89	86	87	88	84	83	74	69
1111447	91	87	93	89	89	88	89	86	85	77	72
1111450	91	88	92	90	86	90	88	86	86	76	70
1111452	93	92	91	91	86	88	89	86	90	77	70
1111454	92	88	93	86	86	89	89	87	86	78	72
1111457	93	90	88	91	88	91	90	88	88	80	75
1111458	93	89	92	87	87	90	91	88	86	80	75
1111549	91	88	94	90	87	89	88	86	86	76	72
1120148	93	91	93	89	88	90	90	88	89	79	75
1120157	93	89	88	94	88	92	91	89	86	79	74
1120158	93	89	88	92	88	91	91	89	87	79	74
1120249	93	90	90	90	89	91	91	87	88	81	81
1120250	93	89	90	90	90	92	91	88	87	82	80
1120251	95	90	92	89	90	92	92	89	88	84	84
1120252	95	90	92	92	91	92	92	90	88	82	81
1120253	95	91	92	89	91	92	93	90	88	81	79
1120254	95	90	91	91	90	93	92	90	88	82	80
1120255	92	89	90	87	89	92	91	87	84	77	74
1120256	94	90	91	87	89	93	92	89	87	80	78
1120257	94	90	89	89	89	92	92	89	87	80	76
1120258	93	90	89	90	88	91	90	89	88	79	75
1120348	83	79	89	84	83	82	82	78	74	65	61
1120357	93	89	89	92	88	91	91	89	87	79	77
1120451	81	77	88	83	82	80	79	77	73	63	61
1120453	80	75	84	82	79	80	78	75	72	61	58
1120455	79	75	85	84	78	79	77	75	71	60	56
1120457	79	74	82	83	77	80	77	74	72	61	58
1120547	84	80	87	88	85	83	83	79	75	65	60
1120549	86	82	91	88	87	87	85	81	77	68	63

Table 1. (continued)

MEASURING NUMBER	SOUND-NR-LEVEL-NUM *A*	BER	CENTRE FREQUENCY OF OCTAVE BANDS IN HZ 31.5	63	125	250	500	1K	2K	4K	8K
1120555	88	84	101	93	86	89	87	83	79	69	64
1120559	87	83	92	86	83	87	86	83	79	70	67
1120649	87	83	93	89	89	89	86	82	78	69	65
1120651	91	88	91	87	91	94	90	87	80	71	66
1121148	94	93	93	90	88	91	90	88	91	79	74
1121157	94	92	90	94	89	91	91	89	90	80	74
1121158	94	91	89	92	88	91	91	89	89	79	74
1121249	96	96	91	91	90	90	89	89	89	82	74
1121251	97	96	94	93	91	92	90	91	94	83	80
1121254	96	94	94	96	90	91	91	89	92	82	80
1121256	94	92	92	94	89	93	90	89	90	80	75
1121358	93	90	89	92	88	91	90	88	88	78	73
1121449	93	91	91	92	89	90	88	87	89	78	69
1121451	94	94	93	91	86	89	88	87	92	79	71
1121453	95	94	90	90	88	89	88	88	92	81	74
1121455	95	94	94	94	87	90	89	88	92	80	73
1121456	93	91	94	93	87	90	89	88	89	78	72
1121458	94	93	93	92	87	90	89	87	91	77	70
1121550	94	94	92	95	89	88	87	86	92	78	70
1121556	93	92	92	93	87	88	88	87	90	78	72
1121558	94	93	93	91	85	89	89	87	91	78	72
1121649	92	90	91	89	88	89	88	86	88	76	68
1130148	91	87	90	90	86	87	86	87	85	76	72
1130157	91	87	87	91	89	88	88	87	84	75	72
1130249	91	87	89	90	89	88	87	87	85	76	72
1130250	91	85	89	89	89	88	88	88	85	77	73
1130251	92	89	89	90	89	88	87	89	85	77	73
1130252	93	91	89	91	89	87	88	91	86	77	73
1130253	93	91	89	91	89	88	89	91	87	77	74
1130254	93	91	89	90	89	88	89	91	86	77	74
1130255	91	88	87	90	88	87	88	88	85	77	76
1130256	91	87	87	91	89	87	88	87	85	76	73
1130258	91	87	88	88	88	89	89	87	84	77	72
1130348	90	87	91	89	86	87	87	86	85	76	72
1130349	90	87	89	90	86	86	87	87	84	76	72
1130454	90	87	89	87	88	87	88	87	83	75	72
1130456	89	86	89	88	87	87	87	86	81	73	71
1130458	89	84	90	87	86	86	87	84	82	73	69
1130548	85	82	90	82	81	84	83	82	77	70	66
1130549	84	80	89	82	83	82	82	80	77	69	66
1130654	87	84	84	85	85	85	85	84	79	71	67
1130658	87	84	83	86	85	86	85	84	80	72	67
1130747	81	77	95	84	79	80	78	77	73	64	60
1130750	83	79	91	82	84	83	81	79	73	66	63
1130752	83	78	96	86	84	85	81	78	73	67	65
1130756	87	83	87	83	84	86	85	83	81	72	66
1131149	90	87	93	92	90	88	87	87	84	75	72
1131150	92	89	87	93	88	88	87	88	87	76	73
1131156	91	88	88	91	90	89	88	88	85	76	72
1131157	92	88	87	93	89	89	89	88	86	77	73
1131158	92	88	89	89	89	90	89	88	86	77	72
1131248	92	91	92	92	87	88	86	87	89	78	73
1131250	93	90	92	94	90	89	88	89	88	80	74
1131251	92	89	94	94	89	87	88	89	85	78	75
1131255	93	90	91	90	93	92	89	89	88	76	73
1131256	94	91	94	94	91	87	89	89	89	81	75
1131257	92	89	92	92	89	88	90	88	87	78	72
1131258	92	88	89	90	88	89	90	88	85	78	72
1131352	97	97	94	95	94	89	89	90	95	84	75
1131353	100	98	96	95	92	89	91	97	96	80	76
1131354	96	95	96	95	92	89	90	91	93	84	76
1131448	87	84	90	86	85	84	83	83	82	74	67
1131453	79	74	87	84	78	78	75	74	72	62	55
1131458	82	79	88	79	79	80	78	77	77	67	61
1131548	85	83	87	87	82	81	79	81	81	72	67
1131549	85	84	87	83	83	82	79	80	82	71	65
1131554	77	73	83	80	80	78	75	72	71	62	55
1131748	82	78	86	85	82	79	78	77	76	69	64
1131750	82	79	88	83	82	80	76	77	77	68	62
1131753	73	69	93	79	76	75	70	69	66	57	50
1131756	76	71	92	79	77	76	73	71	69	60	54
1131758	78	75	82	77	77	77	75	74	73	63	56
1140348	88	85	90	92	86	84	85	85	82	73	70
1150148	88	85	92	91	83	85	83	85	83	73	70
1150250	91	88	91	91	87	87	86	88	84	76	73
1150348	86	82	96	91	84	81	83	82	80	70	68
1150351	91	88	93	93	88	88	87	88	86	76	73
1151248	89	86	95	86	84	82	85	86	84	75	71
1160152	88	85	90	89	89	85	85	85	81	73	70
1160250	86	83	95	89	86	82	82	82	79	72	77
1160251	87	83	93	88	87	85	83	83	81	71	72
1160253	89	86	91	88	85	84	85	85	84	73	70
1160255	88	85	91	92	86	84	85	85	82	72	69
1161150	85	81	91	90	87	82	82	81	77	69	69
1161155	89	86	87	89	88	85	85	85	84	73	69
1161250	86	82	90	86	88	83	83	82	79	70	67
1161251	88	84	93	89	87	88	86	84	79	71	68
1170152	86	82	87	91	88	83	82	82	79	69	66
1170249	84	80	93	93	87	81	81	80	77	69	70
1170251	86	83	90	93	88	84	84	83	77	70	68
1170253	87	83	88	87	86	83	84	83	80	70	67
1171149	84	81	87	88	85	81	82	81	77	69	66
1171151	85	82	86	89	87	82	82	82	79	69	66
1171153	86	83	86	92	89	83	83	83	79	70	67
1171251	85	81	86	88	88	83	82	81	79	68	65
1171254	87	84	91	90	89	82	83	84	79	70	66
1180151	87	89	94	100	99	85	81	81	77	69	63
1180152	84	80	94	96	90	84	81	80	76	69	63
1180153	85	81	96	95	90	87	79	80	77	69	63
1180154	85	82	96	97	93	85	80	80	77	69	63
1181151	85	82	94	96	93	85	81	80	76	68	61

Table 1. (continued)

MEASURING NUMBER	SOUND-NR-LEVEL-NUM *A*	BER	CENTRE FREQUENCY OF OCTAVE BANDS IN HZ 31.5	63	125	250	500	1K	2K	4K	8K
1181154	84	80	96	90	90	84	79	80	77	70	63
1181155	84	80	97	96	92	82	79	79	77	69	63
1181251	86	86	95	101	97	85	80	80	76	68	61
2110125	77	74	85	94	75	78	75	71	65	57	50
2110130	79	78	82	97	79	76	79	74	69	61	56
2110140	83	80	82	79	80	82	83	78	73	67	63
2110146	92	90	89	88	87	88	92	86	84	79	76
2110247	94	91	91	87	88	90	93	89	86	81	78
2110249	97	93	90	91	89	93	95	91	90	85	84
2110250	98	94	92	93	86	92	96	93	91	86	83
2110251	98	95	93	95	90	93	97	94	91	85	83
2110252	98	94	92	96	89	92	96	93	91	85	81
2110254	95	92	90	99	86	92	94	90	87	80	76
2110256	92	89	92	94	85	89	91	88	83	77	72
2110345	92	91	85	83	86	89	93	87	83	77	74
2110449	96	93	87	94	91	93	95	91	90	85	82
2110450	99	96	89	100	92	94	98	94	93	87	84
2110451	99	97	88	97	91	93	99	94	93	85	83
2110453	95	92	85	92	89	90	94	91	87	80	78
2110455	90	87	83	86	85	87	90	86	82	75	70
2110457	89	86	83	91	84	87	89	85	81	74	69
2110458	88	85	84	87	82	84	88	84	79	72	67
2110548	94	91	86	89	86	92	93	89	86	80	76
2110550	97	94	94	92	94	95	96	93	90	82	80
2110552	98	96	92	92	89	95	98	94	90	83	81
2110555	89	85	87	93	83	87	88	84	81	74	69
2110557	89	85	87	93	83	87	88	84	81	74	69
2111158	88	85	89	92	85	86	88	83	79	73	67
2111245	90	86	92	85	85	89	89	85	82	76	73
2111249	88	84	90	87	85	89	87	83	79	74	71
2111251	87	83	94	85	88	86	86	82	78	73	67
2111253	86	82	90	91	87	86	85	81	77	72	66
2111255	86	82	88	89	85	85	85	82	77	72	65
2111258	87	83	85	90	84	87	86	82	78	72	65
2111347	89	85	83	87	89	91	87	85	80	75	72
2111355	86	82	84	83	84	86	85	82	78	73	67
2111446	89	85	86	87	85	87	88	84	80	74	70
2111450	87	83	87	85	85	85	86	82	78	72	67
2111452	87	83	84	89	82	85	86	83	80	75	69
2111454	87	83	90	88	82	86	86	81	79	74	67
2111457	86	82	84	88	83	86	85	81	77	73	67
2111458	85	81	87	87	83	85	84	81	77	72	65
2120157	87	84	82	89	82	85	87	83	79	72	66
2120249	91	89	89	84	85	89	91	85	81	75	70
2120251	91	89	89	88	87	89	91	86	83	77	72
2120253	92	89	88	88	87	89	91	88	84	77	72
2120256	90	86	84	89	84	86	89	85	82	75	68
2120258	88	85	81	88	83	86	88	84	80	73	67
2120453	78	75	76	77	77	78	78	74	69	57	52
2120455	78	74	81	81	77	77	77	74	68	56	50
2120457	78	74	79	76	78	78	77	73	68	56	49
2120547	89	86	87	91	86	89	89	83	79	72	67
2120549	89	87	83	88	87	89	90	83	79	72	68
2120555	86	83	93	95	89	89	86	80	75	63	57
2120559	83	80	90	87	81	84	83	78	70	60	54
2120649	88	85	89	87	88	89	88	84	78	70	65
2120651	91	88	90	87	92	94	90	87	80	71	65
2121158	87	83	82	87	81	85	86	82	78	71	65
2121256	84	80	85	86	83	84	83	80	75	70	64
2121358	85	81	83	92	80	83	84	81	76	70	65
2121451	86	83	86	89	86	84	86	81	76	71	64
2121453	85	81	83	82	83	84	84	80	76	71	64
2121455	84	80	82	83	80	83	83	80	76	70	66
2121649	86	83	82	86	87	85	86	81	78	73	65
2130249	86	82	87	88	85	85	85	81	76	70	64
2130251	85	81	87	86	85	86	84	81	77	69	64
2130254	83	79	83	90	83	83	82	78	74	67	61
2130256	83	79	82	90	82	83	82	78	75	67	61
2130258	85	82	85	88	81	82	85	81	76	69	62
2130348	84	81	86	86	82	83	84	80	75	69	64
2130349	86	82	89	87	84	85	84	82	77	70	64
2130454	84	80	84	89	84	82	83	80	76	69	62
2130654	81	78	80	80	80	81	81	76	71	63	56
2130658	82	78	80	79	80	81	81	78	72	64	56
2130747	78	74	95	83	80	79	77	74	68	60	56
2130750	82	78	86	83	81	83	81	77	72	65	60
2130752	83	80	94	80	85	86	82	77	72	67	68
2130756	81	78	84	89	81	80	81	77	72	64	56
2131157	83	80	83	88	82	82	83	79	74	67	61
2131158	85	81	81	87	82	83	83	81	76	69	61
2131248	86	81	88	91	85	87	84	81	77	70	66
2131250	84	80	91	95	87	85	82	80	75	69	64
2131251	85	81	82	85	86	86	83	81	75	67	60
2131255	82	78	83	85	82	80	80	78	73	66	59
2131257	84	81	88	85	82	81	84	79	75	68	60
2131353	88	85	96	95	88	85	87	85	79	71	65
2131354	81	77	89	92	82	82	80	77	72	65	59
2131448	82	78	89	81	82	81	81	77	73	67	63
2131549	79	75	84	80	82	79	77	75	71	65	62
2131750	77	73	85	79	78	79	75	73	68	62	59
2140348	84	80	92	94	84	84	83	79	74	67	62
2150148	82	78	87	93	80	84	80	78	73	67	61
2150348	79	75	92	89	83	78	78	75	70	62	57
2150351	84	80	89	89	88	84	83	79	75	67	63
2151248	82	78	93	92	80	82	80	78	73	66	61
2160152	81	77	86	92	84	81	80	77	72	66	60
2160250	81	77	88	94	85	80	80	76	73	67	64
2160251	85	82	87	87	88	86	85	79	74	70	68
2160253	82	78	86	85	84	82	81	78	74	67	62
2160255	81	77	84	91	81	79	79	77	72	66	60
2161155	82	78	83	93	81	80	80	78	73	66	60

Table 1. (continued)

MEASURING NUMBER	SOUND-NR-LEVEL-NUM *A*	BER	CENTRE FREQUENCY OF OCTAVE BANDS IN HZ 31.5	63	125	250	500	1K	2K	4K	8K
2161251	84	79	84	88	86	85	82	79	74	68	63
2170152	82	78	83	93	88	82	81	77	73	67	61
2170249	80	76	85	90	86	79	79	74	69	64	61
2170251	81	77	86	91	84	82	80	76	71	65	60
2170253	80	76	86	90	85	82	79	75	71	64	58
2171149	80	76	82	88	83	80	79	76	71	64	58
2171151	82	78	83	91	86	81	80	78	74	67	62
2171153	81	76	84	93	85	80	79	76	72	66	60
2171251	81	77	85	89	86	81	80	77	72	64	59
2171254	81	76	85	86	85	80	79	76	72	65	58

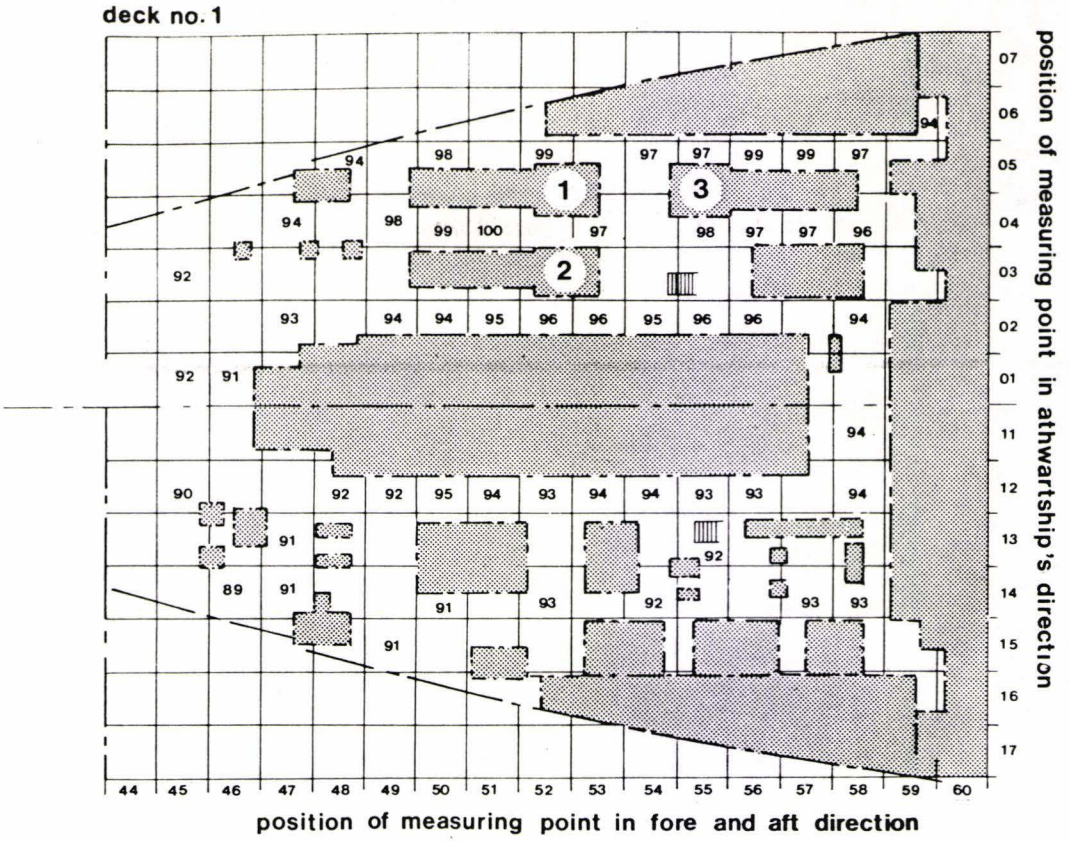


Fig. 1. View on deck no. 1 (floor). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: at service speed.

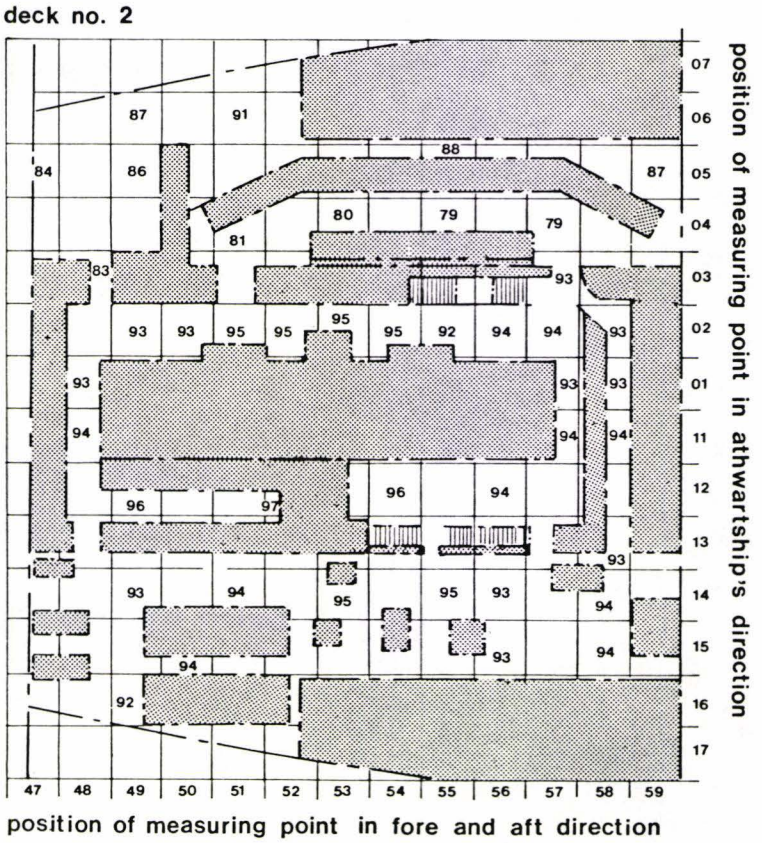


Fig. 2. View on deck no. 2 (2nd Tweendeck). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: at service speed.

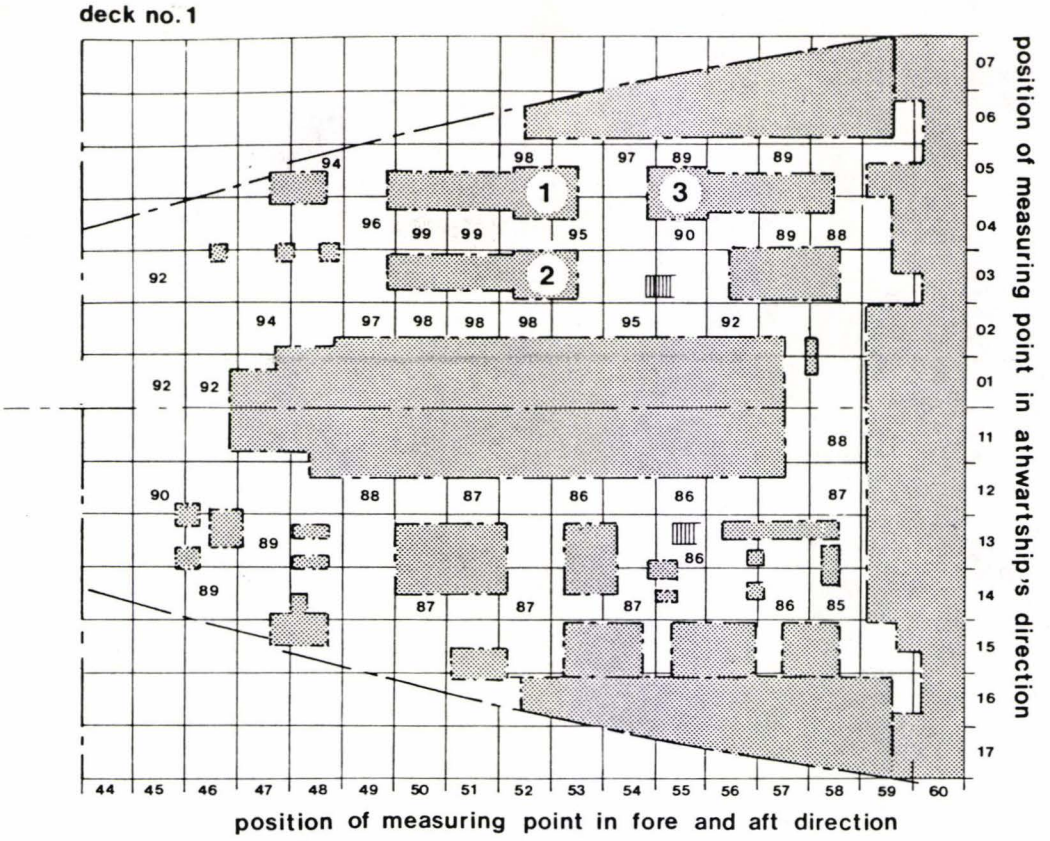


Fig. 5. View on deck no. 1 (floor). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: in the harbour.

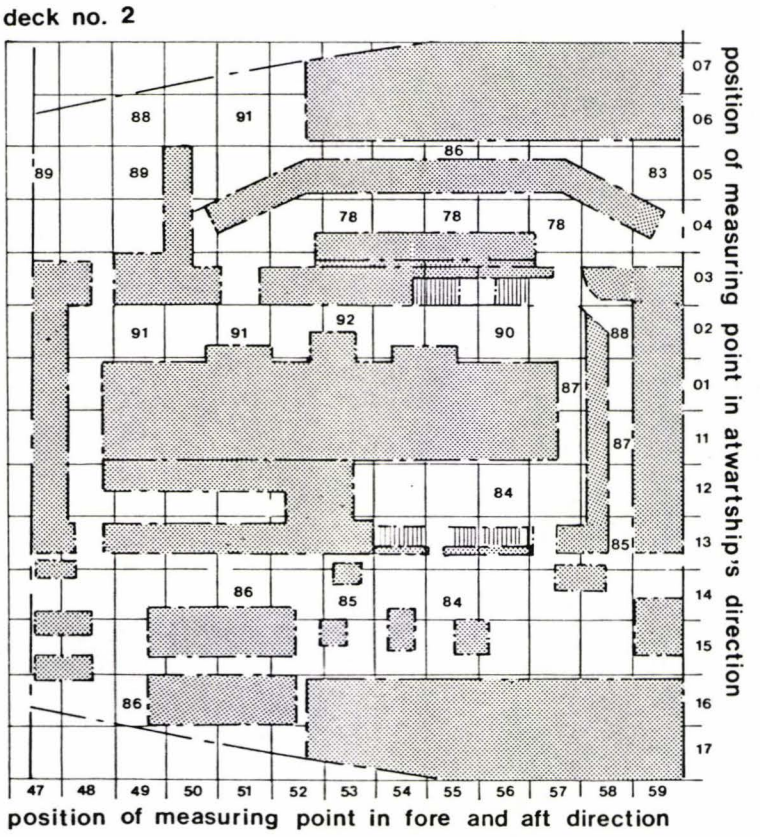


Fig. 6. View on deck no. 2 (2nd Tweendeck). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: in the harbour.

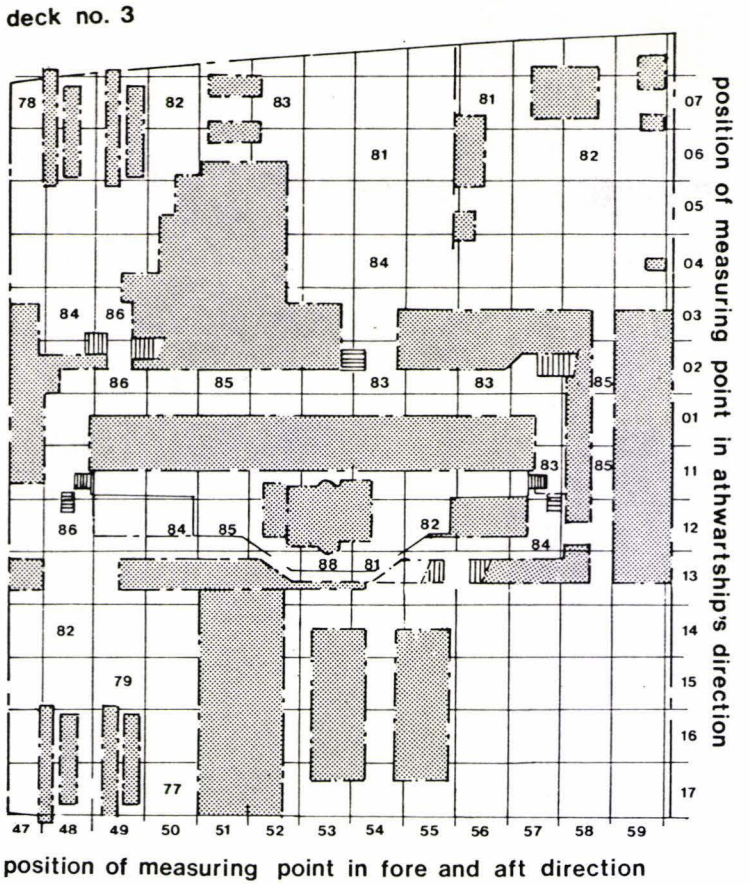


Fig. 7. View on deck no. 3 (1st Tweendeck). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: in the harbour.

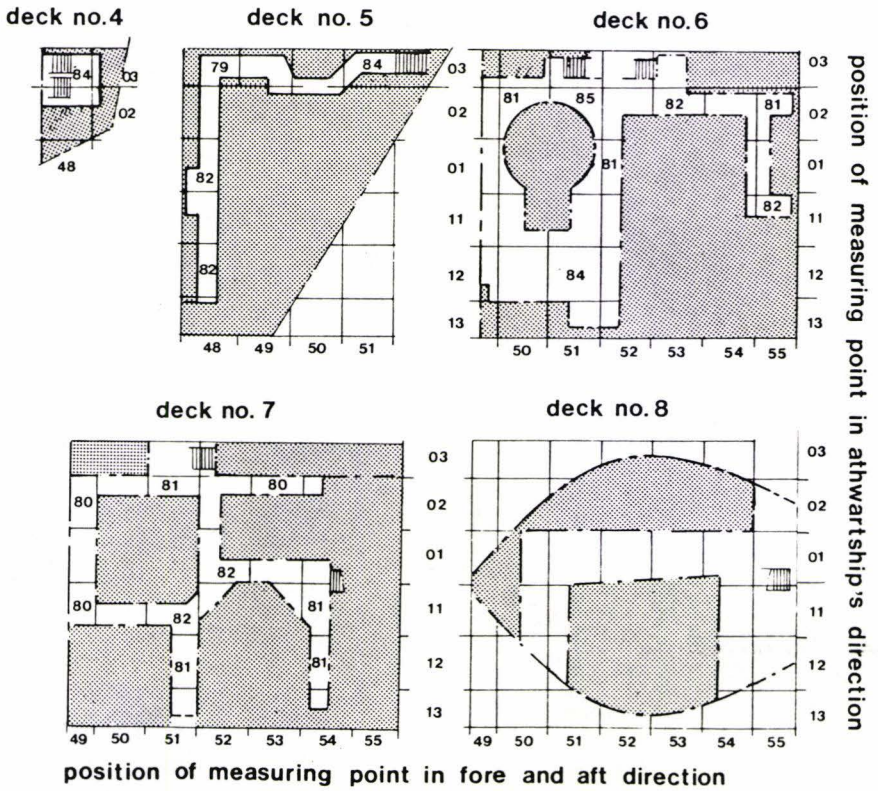


Fig. 8. View on decks no. 4–8 (A–E deck). The sound levels-A measured at the several locations are given in the concerned rectangular sections.
Operational condition: in the harbour.

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