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NOISE STUDY OF A NAVAL SHIP IN DIFFERENT OPERATING MODES ON THE DANUBE

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ABSTRACT

In this paper are described the experimental measurements of noise transmitted to the staff from a naval ship during different operating modes on the Danube. This paper is focused on the technical aspects of the Directive 2003/10/EC regulations. The measurements targeted the staff's comfort both in the engines room and on the decks. The living conditions inside the cabins and inside the common areas were also taken into account. The parallel between the limit values (Directive 2003/10/EC) and the mean value of the experimental results shows that:

Limit values (2003/10/EC) for noise level	*(dB)*
Values above which adverse comments are probable	*80*
Values above which adverse comments are not probable	*87*

KEYWORDS: noise, naval ship, Directive 2003/10/EC, Directive 2002/49/EC

1. INTRODUCTION

Noise effects have been analyzed for a long time, producing a scale of harmfulness (Fig. 1) of noise pollution (Fig. 2 and 3). Over the past few years, there is an increasing strain on the comfort of the military ship's crew members, on their work quality and mostly on their safety. In order to accomplish this challenge, it is very important to determine the noise transmitted by the ship to the crew members, in all the cases. Because of this the shipbuilders must take into account all the international regulations for all the cases: running, idling, etc.

Providing information, instruction and training on noise

Awareness of noise risks and controls is very important, as people will then take notice of the risks and use any risk-reduction measures properly. People in the industry have to be made aware of the potential for permanent hearing damage associated with working in a very noisy environment. This may require a considerable shift in personal attitude and collective culture [12].

Understanding the risks from high sound levels should form part of the basic education of performers and technicians, so people coming into the industry know how to protect themselves and become part of the solution rather than the problem. Information and instruction should also include posting warning notices around designated hearing protection zones and briefings to performers and other workers about the noise-reduction strategies adopted for the event [11].

Employers should try to ensure that employees understand the need to follow the employer's or venue operator's instructions on control measures including, for example, abiding by any agreed arrangements for job rotation or restriction of access to noisy areas or following any instructions relating to achieving agreed noise levels, as well as wearing hearing protection when required. Employees should be encouraged to report to their employer any new hazardous noise situations or hearing loss or tinnitus [6].

It is also worth educating employees on the general risks of noise from other non-work activities which still contribute to exposure. For example, the noise level within the in-ear headphones of music players can be 94 dB at around half volume (with peaks of 110-130 depending on headphones) and 105 dB at full volume (peaks 110-142).

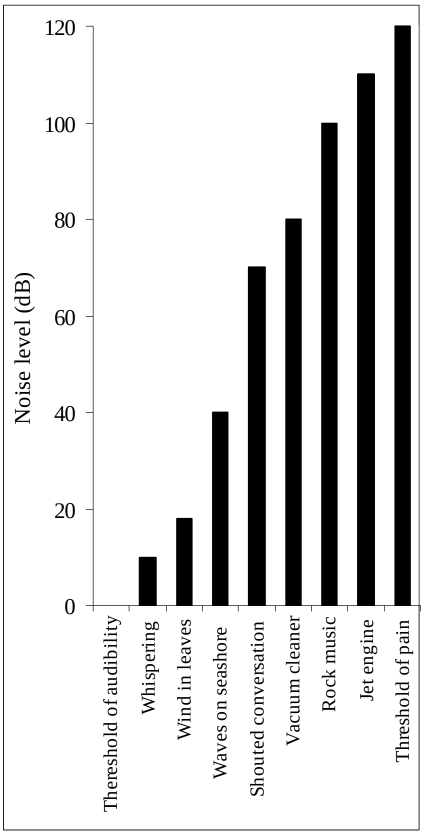

Fig. 1 Threshold of hearing

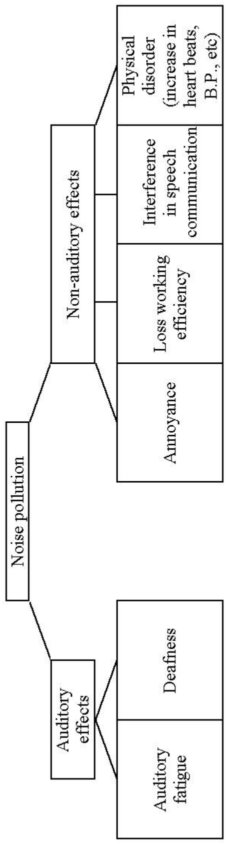

Fig. 2 Effects of noise pollution

There are many studies that relate to the harmful action of noise on ships; for example: the radiated noise data show high-level tonal frequencies from the ship's service diesel generator, main engine firing rate, and blade rate harmonics due to propeller cavitation [1]. Different theories and methods of calculation, experiment and noise reduction are summarized, evaluated, and some opinions for the future development are presented [5]. Biot and de Lorenzo [2] made a presentation to recent development in field of ship vibration, shock and noise research in China; also a prediction of the coupled vibration and acoustic radiation from a real ship is a problem in the naval engineering [3], [4].

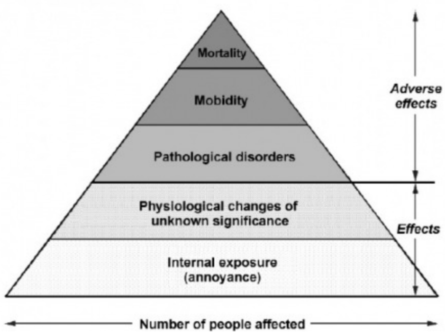

Fig. 3 Number of people affected by noise pollution

2. MEASUREMENTS

Noise levels provided by Romanian Government Decision no. 493/2006 implementing Directive 2003/10/EC:

- 80dB(A) lower exposure value, the employer must equip workers with hearing protection equipment and respectively p_{paek}=112Pa (135dB(C) ref 20μPa)
- 85dB(A) upper exposure value - worker must use ear protection equipment and respectively p_{paek}=140Pa (137dB(C) ref 20μPa)
- 87dB(A) limit exposure value for 8 h/day and respectively p_{paek}=200Pa 140dB(C) ref 20μPa).

European rules require:

- 88dB(A) 4 h exposure/day
- 91dB(A) 2 h exposure/day
- 94dB(A) 1 h exposure/day
- 97dB(A) 30 min exposure/day
- 100dB(A) 15 min exposure/day
- 103dB(A) 7.5 min exposure/day
- 106dB(A) 3.75 min exposure/day

It is noted that the result of the meeting of two identical noise levels noise is not a double, but the noise level increased by 3dB(A). For example, if a machine produces 80dB(A), two pieces of technical equipment of the same type will produce a noise level of 83dB(A).

Exposure and exposure level.
A quantity called A-weighted sound exposure (E_A, 8h) is used to assess the damaging effect of noise on a person (standard ISO 1999:1990).
- The damaging effect of noise on hearing depends on the quantity of sound energy absorbed by a person's ears and therefore depends on parameters such as the noise sound pressure level and the exposure duration.
- While performing his tasks, a worker may be subjected to noise at different sound pressure levels for varying periods of time. This is why assessment of the damaging effects of noise is conducted with reference to a nominal 8h working day or nominal five 8-hour working day week as specified in standard ISO 1999:1990.
- Exposure is a quantity corresponding to the amount of sound energy absorbed and is therefore sometimes called 'noise dose'.

Equivalent continuous A-weighted.
Sound Pressure Leve.
The equivalent continuous A-weighted Sound Pressure Level of non-steady noise is that A-weighted sound pressure level of steady noise, which would cause the same effect on a person as the noise, for which we calculate the equivalent continuous A-weighted sound pressure level.
- In the case of steady noise (i.e. noise whose SPL does not vary more than 5dB during its presence) affecting a person during a nominal 8h working day, the daily noise exposure level will equal its SPL expressed in dB(A).
- In the case of non-steady noise (i.e. noise whose SPL varies more than 5dB), an equivalent continuous A-weighted SPL (LAeq, T) is used to calculate the daily noise exposure level.

Peak Sound Pressure.
Peak sound pressure (ppeak) is the maximum value of 'C'-frequency weighted instantaneous noise pressure.
- Peak sound pressure (ppeak) is very often used to assess the damaging effect of noise in addition to the level of exposure to noise.
- Exposure limit values of peak sound pressure, quoted in the Directive, are values of sound pressure, at which there is a serious risk of instant hearing damage.
- We can say that:
a) Noise exposure level provides an assessment of the effects of prolonged exposure to noise.
b) Peak sound pressure provides an assessment of the effects of exposure to short, very loud sounds (impulse noise).

Formulae for calculation of noise exposure.
The daily noise exposure ($L_{EX,d}$) is found by summing all noise exposures in the day, like timeweighted average of the noise exposure levels for a nominal eight-hour working day as defined by international standards ISO 1999:1990, point 3.6. This is not a simple addition, because levels in dB are logarithmic and not linear values.
Where the Leq or SPL has been measured:

$$L_{EX,d} = 10\lg\left[\frac{1}{T_0}\sum_{i=1}^{n} T_i \cdot 10^{0.1(L_{Aeq})_i}\right] \quad (1)$$

where: the working day comprises n discrete periods of time; T_0=8h; T_i=the duration of period i; $(LA_{eq})_i$=the equivalent continuous A-weighted sound pressure level (or sound pressure level) to which the person is exposed during period i; and $\Sigma T_i = T_e$=the duration of the person's daily noise exposure to sound.
Where the Leq of discrete events has been measured:

$$L_{EX,d} = L_{eq} + 10\lg\left[\frac{n \cdot t}{m \cdot T_0}\right] \quad (2)$$

where: n=number of times the noise event occurs in the working day; m=number of times the event occurred in the measurement; T_0=8h, t=measurement duration.

Formulae for calculation of noise exposure
The weekly noise exposure level ($L_{EX,w}=L_{EX,8h}$) is found by summing all noise exposures in the week, like time-weighted average of the daily noise exposure levels for a nominal week of five eight-hour working days as defined by international standards ISO 1999:1990, point 3.6. This is not a simple addition, because levels in dB are logarithmic and not linear values.
Weekly noise exposure level can be expressed mathematically as shown below:

$$L_{EX,w} = 10\lg\left[\frac{1}{5}\sum_{i=1}^{m} T_i \cdot 10^{0.1(L_{EX,8h})_i}\right] \quad (3)$$

where: $(L_{EX,8h})_i$ = the values of L_{EX},d for each of the 'm' working days in the week being considered.

3. MATERIALS AND METHODS

To analyze noise were used BlueSolo sonometer and doseBadge Noise Dosimeter.

Sound Level Meter method (Fig. 4)

The guide requires an instrument that has the following minimum characteristics:

- ‘A’ frequency weighted L_{eq} (time-average noise level)
- ‘C’ frequency weighted Peak around 140dB (LCpk)
- At least IEC 61672 Class 2 accuracy

Each instrument within our assessor range has a special ‘ready reckoner exposure table’ which is displayed after each measurement to help you. It also provides a ‘settled’ indicator to help you decide when the average noise level has stabilised. Please note: the formal symbol for A-frequency-weighted L_{eq} as defined in IEC 61672 is LAT, but the use of L_{eq} has become accepted.

Dosemeter or PSEM Method (Fig. 5)

To use a PSEM or noise dosemeter, the setting-up is similar to that of a sound level meter. The batteries must be charged and the unit must be calibrated before the measurement. The PSEM is then fixed to the worker as near to the ear as convenient and is set running.

At the end of the working shift, the badge is stopped by pressing the ‘Stop’ button on the Reader unit. The doseBadge is then removed from the worker and the data in each badge is downloaded to the Reader, where it is now available to inspect. The data can also be transferred onto a PC, using the Pulsar software programme (dBlink3) provided, allowing you to analyze efficiently and report on the measurement.

A key benefit of the doseBadge system is that it gives the full time history of both ‘A’ weighted L_{eq} and ‘C’ weighted Peak. This allows you to get a much clearer picture about real work patterns, rather than each worker's subjective “opinion” as to the levels.

In this paper the measurements were made on a patrol ship on the Danube, over a distance of 50 km. The measuring conditions on human were different: the start from the shore, running, idling with generator engine, mooring manoeuvre. In order to determine the ship’s noise, measurements were made in different spots on the ship: on the navigating bridge, on the command cabin, on the main deck, in the engines room, in the rest area (Table 1).

Table 1 The measuring conditions of sound level

1. Measurements made on the navigation bridge	
	a. the ship starts from the shore
	b. the ship performs the mooring manoeuvre
2. Measurements made on the main deck	
	a. the ship is running
	b. the ship performs the mooring manoeuvre
3. Measurements made inside the engines room	
	idling with generator engine
4. Measurements made in the command cabin	
	idling with generator engine
5. Measurements made in the rest area	
	a. the ship is running
	b. the ship performs the mooring manoeuvre

4. RESULTS AND DISCUSSIONS

After these experimental measurements the following results were obtained:

4.1 Measurements made on the navigation bridge

4.1.1 Measurements made on the navigation bridge while the ship starts from the shore

During the measurements of the sound level on the navigating bridge while the ship is starting from the shore, the average of the obtained values was 74.6 dB(A). Figure 6 shows that all the measured values are under the limit value established by the Directive 2003/10/EC, which is 87 dB(A).

4.1.2 Measurements made on the navigation bridge while the ship performs the mooring manoeuvre

During the measurements of the sound level on the navigating bridge while the ship performs the mooring manoeuvre, the average of the obtained values was 73.73 dB(A). Figure 7 shows that all the measured values are under the limit value established by the Directive 2003/10/EC.

Fig. 4 Sonometer Blue Solo

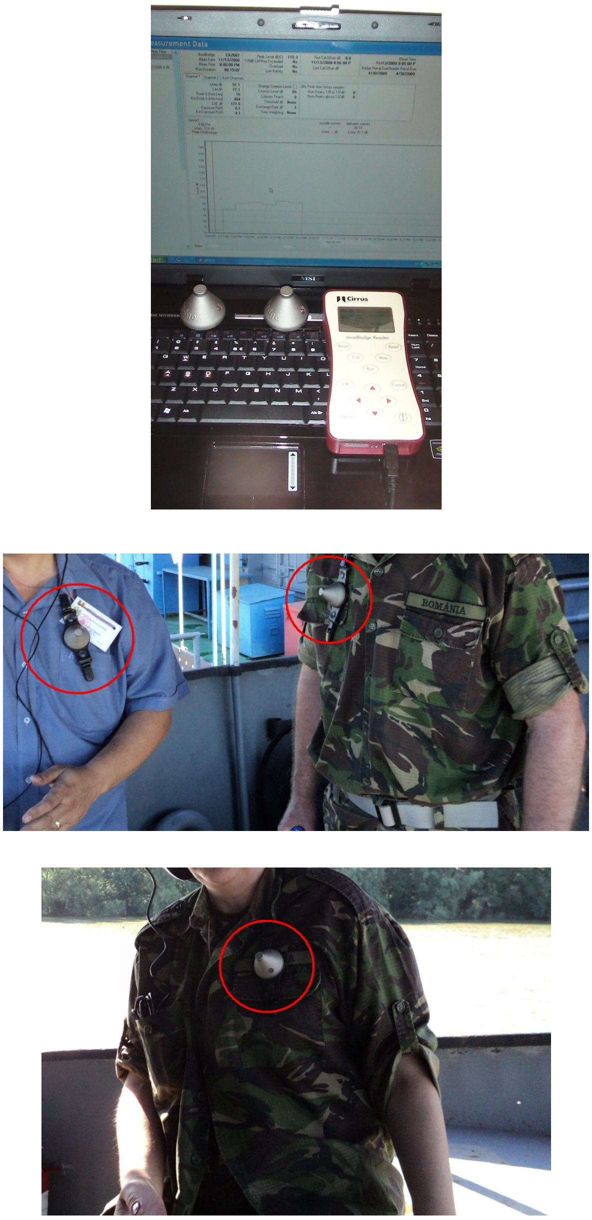

Fig. 5 DoseBadge Noise Dosimeter

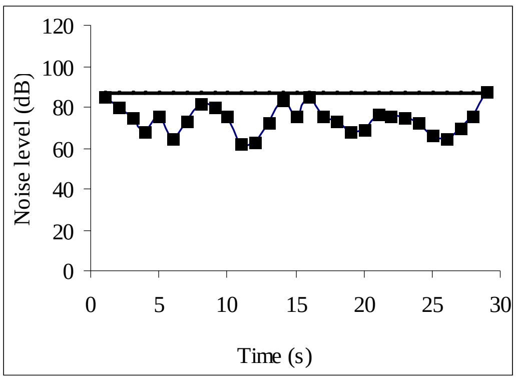

Fig. 6 The sound level on the navigation bridge while the ship starts from the shore
(—)-87dB, limit value [8]

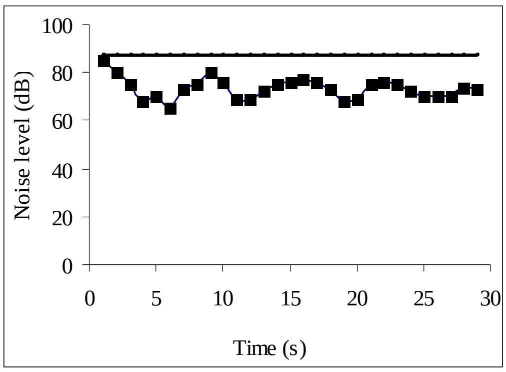

Fig. 7 The sound level on the navigation bridge while the ship performs the mooring manoeuvre
(—)-87dB, limit value [8]

4.2 Measurements made on the main deck

4.2.1 Measurements made on the main deck while the ship is running

During the measurements of the sound level on the main deck while the ship is running, the average of the obtained values was 91.9 dB(A). Figure 8 shows that all the measured values are beyond the limit value established by the Directive 2003/10/EC.

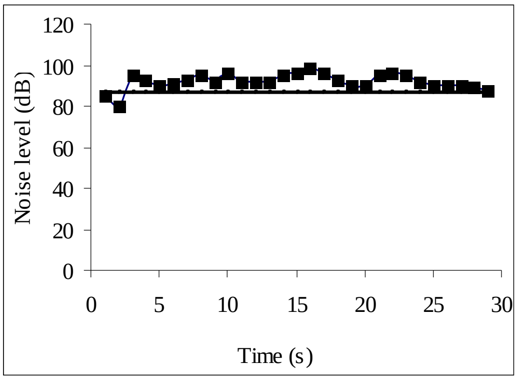

Fig. 8 The sound level on the main deck while the ship is running
(—)-87dB, limit value [8]

4.2.2 Measurements made on the main deck while the ship performs the mooring manoeuvre

During the measurements of the sound level on the main deck while the ship performs the mooring manoeuvre, the average of the obtained values was 85.33 dB(A). Figure 9 shows that all the measured values are right on the limit value established by the Directive 2003/10/EC.

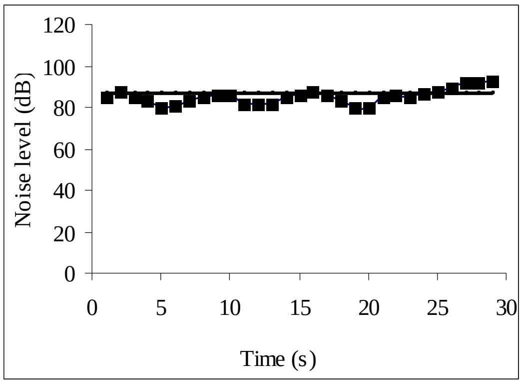

Fig. 9 The sound level on the main deck while the ship performs the mooring manoeuvre
(—)-87dB, limit value [8]

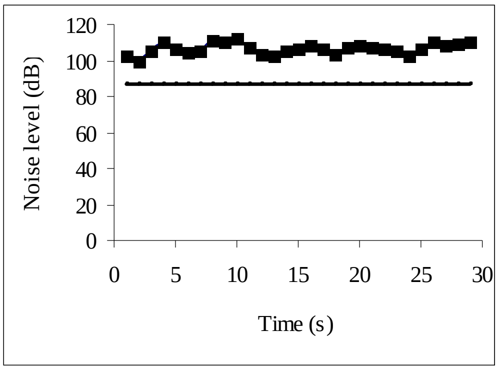

Fig. 10 Sound level inside the engines room (idling with generator engine);
(—)-87dB, limit value [8]

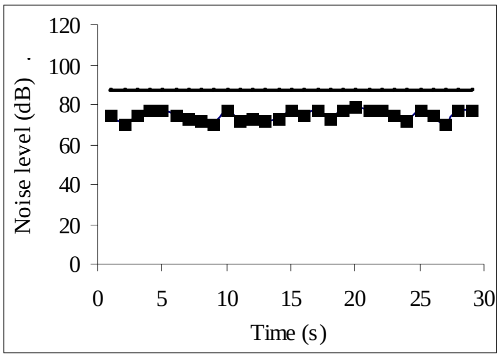

Fig. 11 Sound level in the command cabin while the ship is idling with generator engine generator; (—)-87dB, limit value [8]

4.3 Measurements made inside the engines room

4.3.1 Measurements made inside the engines room (idling with generator engine)

During the measurements of the sound level in the engines room (idling with generator engine), the average of the obtained values was 106.43dB(A). Figure 10 shows that all the measured values are above the limit value established by the Directive 2003/10/EC, which is 87 dB(A).

4.4 Measurements made in the command cabin (idling with generator engine)

During the measurements of the sound level in the command cabin (idling with generator engine), the average of the obtained values was 74.7666 dB(A). Figure 11 shows that all the measured values are under the limit value established by the Directive 2003/10/EC, which is 87 dB(A).

4.5 Measurements made in the rest area

4.5.1 Measurements made in the rest area while the ship is running

During the measurements of the sound level inside the rest area while the ship is running the average of the obtained values was 76.96dB(A). Figure 12 shows that all the measured values are under the limit value established by the Directive 2003/10/EC, which is 87 dB(A).

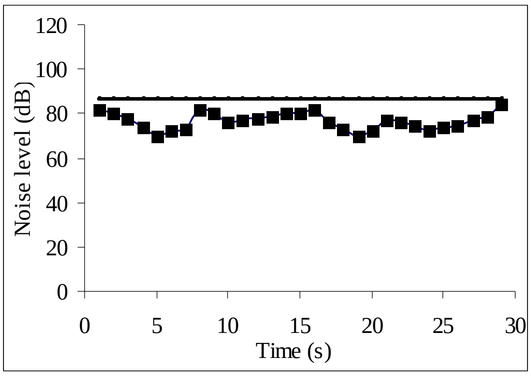

Fig. 12 Sound level inside the rest area while the ship is running;
(▬)-87dB, limit value [8]

4.5.2 Measurements made in the rest area while the ship performs the mooring manoeuvre

During the measurements of the sound level inside the rest area while the ship performs the mooring manoeuvre the average of the obtained values was 90.86dB(A). Figure 13 shows that all the measured values are under the limit value established by the Directive 2003/10/EC, which is 87 dB(A).

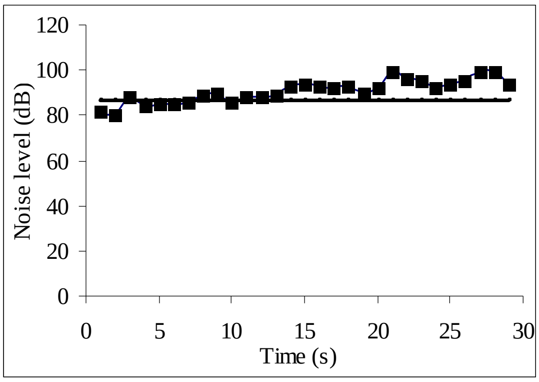

Fig. 13 Sound level inside the rest area while the ship performs the mooring manoeuvre;
(▬)-87dB, limit value [8]

5. CONCLUSIONS

Controlling noise risk and noise exposure [8]

1. Wherever there is noise exposure at work employers should be looking for ways of working that would reduce the noise. Employers should also be keeping up with what is good practice for noise control within their sector.
2. Where there are things that can be done to reduce risks from noise, which are reasonably practicable, they should be done. Where the risk assessment shows that employees or subcontractors are likely to be exposed at or above the upper exposure action values, the employer must put in place a planned programme of noise control. The risk assessment should have produced information on the risks and an action plan for controlling noise.
3. There are many ways of reducing noise and noise exposure. However, it is important to tackle the dominant or loudest noise sources first. Pick the most appropriate solutions to resolve the particular problems of the specific event.
4. Collective protective measures should always be used in preference to individual protective measures. The approach for the control of noise should done, in order of preference, to:
   - eliminate the hazard or risk altogether (if it is reasonably practicable to do this, it should be done);
   - control the risk at source (for example reduce the volume, substitute quieter sources);
   - reduce the noise as it travels to the people exposed (for example physical barriers, distance, absorptive materials);
   - reduce exposure (for example by organising the work to reduce the duration of exposure or the number of people exposed to noise).
5. If these measures are not adequate to reduce the exposure enough, then hearing protection must be provided.
6. Control measures should be accompanied by:
   • provision of information, instruction and training;
   • proper and regular maintenance of equipment.
7. Noise measurements may be necessary to establish the effectiveness of any control measures.

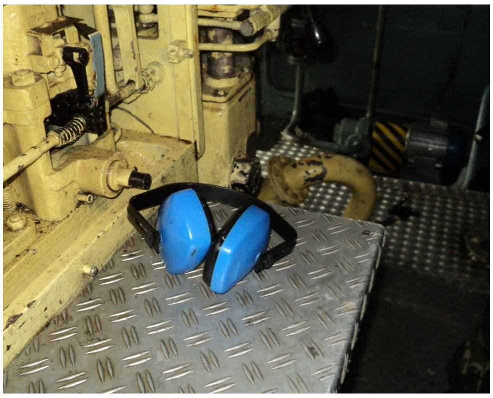

Fig. 14 Protection with headphones

Fig. 15 Protection with wax plugs

In the case of determinations made on the ship, it was found that the admissible sound level is exceeded in engines room (106.43dB(A). The best method of protection is the use of headphones (or wax plugs) (Fig. 14 and 15). Staff worker is equipped with headphones, but it is necessary to reassess the work program (is indicated intercalation breaks 0.5 – 1h) to enable people to rest in terms of noise pollution.

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