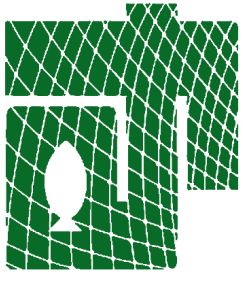
How to handle noise and vibrations in ships

The Danish Fishermen's Occupational Health Services



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How to handle noise and vibrations in ships

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Preface

In recent years more focus has been put on problems caused by noise and vibration. The requirements set by the authorities are stricter as regard to the noise level allowed on board a fishing vessel. Today noise is not just something to be accepted as part of the occupation. The requirements set by the Danish Maritime Authorities on noise level are as follows:

Unnecessary noise must be avoided. The noise level when working must be within reasonable limits taking the technological development into consideration. Stipulated threshold limit values(TLV) must be observed.

Therefore, noise and vibration problems must be avoided when ever possible. However, both knowledge, will and ability are required to solve the problems. Today we have extensive knowledge on the area and there are many ways to control noise and vibration problems.

This manual is made in an attempt to gather experience made and knowledge obtained on the area. The Danish Fishermen's Occupational Health Service hopes that in future the manual will be able to assist and advise shipyards, fishermen, Port Safety Committees and others in handling potential problems.

The purpose has been to create a both practical and useful tool. Therefore, a number of proposals on how to solve the most typical noise problems have been made. Furthermore, the manual contains basic knowledge necessary when discussing and controlling noise problems.

Noise problems can be controlled. However, it is important to know how it can be done in the most efficient and inexpensive way. Often solutions can be made if the means are unlimited. Unfortunately not many people have unlimited means. Therefore, it is crucial to consider your options thoroughly otherwise both time and money could be wasted. This manual is intended to serve as your tool in handling this process.

Enjoy your reading and good luck in the future with controlling noise and vibration.

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Chapter 1 Definitions of and useful knowledge on noise and vibration

1.1 What is noise?

Often it can be difficult to define noise as it is not something you can see - you can "only" hear it.

Usually noise is perceived in a negative way when it becomes annoying, disturbing or painful but even then it can be difficult to define exactly. Noise is everywhere but it is defined differently from person to person. Two people having been at the same Heavy Metal concert might have different opinions as to the quality of the music. One might say that the music was great the other wished that he brought ear protection. In other words noise is not always negative.

This manual will not go further into the more individual assessment of when noise becomes negative. Focus will be kept on determining whether or not the music played at the concert has damaging consequences for the hearing and if so what can be done to minimize the damage.

Many marine engineers having worked in an engine room for several years often define the noise from the engine as sweet music to their ears. Even though "the engine purrs like a cat" the risk of damage to the hearing might still be present if safety precautions are not taken. In short noise can be defined as follows:

Noise is sounds having a negative or even damaging effect on the physical and mental well-being of a person – their behaviour in general and their way of living.

In order to fully understand what noise is there are some fundamental concepts which must be defined. This will be done in the following. But before that a short introduction to vibration will be given as this book deals with both noise and vibration.

1.2 What is vibration?

When dealing with noise you also have to deal with vibration. On board a fishing vessel there is vibration everywhere. There are numerous vibration sources all of which can be felt onboard – some more distinct than others.

Vibration is movement caused by the impact made on for instance deck, bed-plate, frame, ceiling, etc. The impact is transformed energy which means that vibration is also transformed energy. Released energy is transformed into heat and therefore vibration is also transformed into heat.

Unnecessary vibration not only creates a lot of unnecessary noise it can also impact the occupational health on board in a negative way and in addition have a damaging effect on the construction of the vessel. Cracks in the structure are among the most typical damages caused by unnecessary vibration.

1.3 Noise spreads like ripples in a pond

Noise is air pressure vibrations usually caused by vibrating surfaces or objects transferring vibration into the air. The easiest way to illustrate pressure vibration is as follows:

When throwing a stone into a pond waves/ripples are created on the surface. These waves could be defined as vibration in the water rolling in the surface and spreading like ripples.

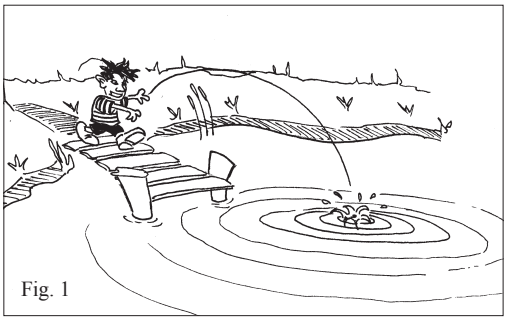


Fig. 1

In a similar way waves/ripples are create in a metal plate if you pound on it. The vibration transmits trough the air and when hitting the eardrum it is put into motion and you hear a bang or a crash. The vibration in the metal plate has through airborne sound waves transformed into vibration in the eardrum.

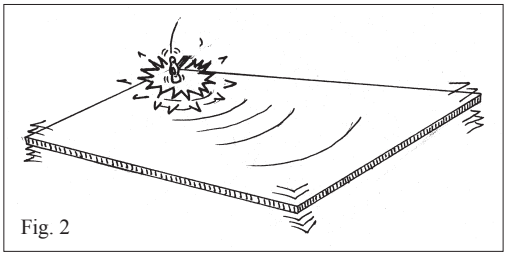


Fig. 2

1.4 Frequency

In other words sounds and noise is created when airborne vibration hits the eardrum. However, there is a difference in how noise sounds – the nature of the noise. The foghorn from a larger vessel is defined as deep whereas the noise created when you tap a glass with a spoon is defined as high. In addition noise can be for instance metallic, splashing, creaking or maybe even whistling.

The subjective description of noise is often used when telling about an experience we have had. Without the descriptions it will be very difficult to explain something as noise is often just as difficult to explain as it is to describe the colour red to a colour blind person.
Whether a sound is high or low is determined by frequency. Frequencies are measured by cycles per second. For instance when you strike a guitar string a tone is created and you can see the string vibrating. The tone – the frequency – will change when you change your grip at the fingerboard. The tone will either be higher or deeper depending on where you grip the fingerboard. High tones equal high frequency and deep tones equal low frequency.

Generally the human ear can perceive vibrations between 20-15000 Hertz(Hz). Hz = cycles per second.

Sounds and noise from your everyday life rarely consist of only one single tone. The sound/noise often consists of several more or less composed tones/frequencies. Sometimes the sound picture is constant without any variation and sometimes it often changes.

On board a fishing vessel the sound picture is often constant whereas the sound/noise from a road varies every time a car passes by. In acoustical terms a constant sound picture is called a harmonic oscillation. This means that the sound is characterised by being repeated after a certain period of time.

When put together the frequencies made by the different noise sources create the combined signal. The total sound picture can then be illustrated graphically in a frequency spectrogram. This spectrogram describes the amplitude (sound pressure) as a function of the frequency. Fig. 3 shows how various periodical signals and frequencies influence each other and how the combined sound picture looks.

A frequency response curve is used to illustrate the frequency in relation to the sound pressure level. The frequency response curve connects the sound pressure with frequency division. For practical reasons the frequency response curve is split up into frequency bands. The sound pressure is then determined within each

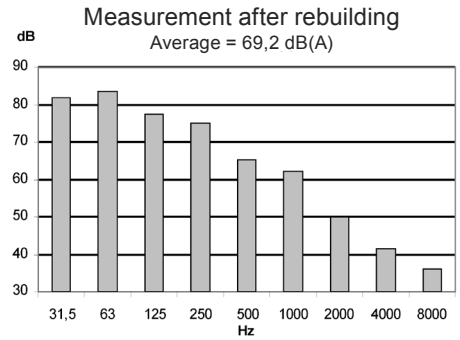


Fig. 3

band often called 1/1 or 1/3 octave. When dealing with frequency analysis on board a fishing vessel they must always be carried out in 1/1 octave.

1.5 Natural frequency

Natural frequency occurs in all constructions, elements, components, engines, etc. As already described in the above frequency means cycles per second. Natural frequency is the individual item's or construction's own cycles per second.

When for instance impact is put onto a deck or bulkhead the extent of the vibration will depend on the weight and rigidity of the construction. The number of cycles per second of the construction is its natural frequency.

In fishing vessels high construction rigidity quickly reduces the vibration intensity. The construction is simply better at absorbing the present impact.

1.6 Resonance

Resonance occurs when a construction or element is exposed to impact with a frequency equal to its own natural frequency. If the impact is strong enough the element vibration will intensify and create resonance noise. Often resonance occurs during port manoeuvring where for instance atypical propeller revolutions create a noise and vibration increase in the vessel.

1.7 Sound pressure level

The sound pressure level is indicated in decibel (dB). In technical terms decibel is a logarithmic scale. The use of the decibel scale is practical as it indicates the sound volume. The scale relates objectively to the noise and provides a clear picture of when the risk of hearing impairment is present.

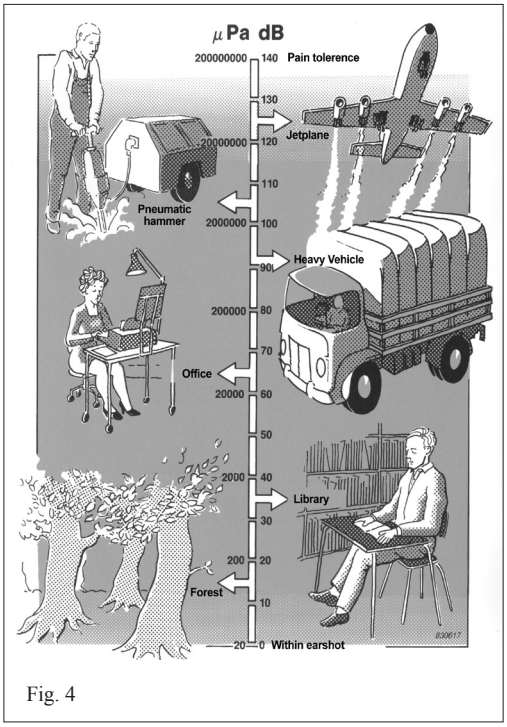


Fig. 4

Furthermore, the decibel threshold limiting values (TLV) define the allowed noise level in various areas of the vessel making them very useful.

Below sound pressure level variations indicates how a given change in decibel will be perceived by the human ear:

1 dB: The minimum change in sound pressure level to be perceived by the human ear.

3 dB: If the noise from two identical sources (for instance to auxiliary engines each having a sound pressure level of 100 dB) is added together a sound pressure level (noise level) increase of 3 dB will occur.

6 dB: An increase of this extend will be perceived by the human ear as a significant sound pressure level change.

10 dB: Will be perceived as a doubling of the noise.

The decibel scale is adjusted to the human ear which makes it a very useful tool in your everyday work.

1.8 Pure tone and broad band noise

As already mentioned sound contains frequencies. Noise predominated by one single frequency is called pure tone noise. The frequency from a generator when the vessel is in port where no other machinery is in use will create pure tone noise. The dialling tone from a telephone or the sound from the test card on the television is also pure tone noise.

On the other hand broad band noise contains more frequencies as is often seen in fishing vessels. There are several noise sources on board each with different frequencies. In other words the noise is composed by several components. The noise signal is composed by a combination of these noise sources overlaid with a number of more or less pure tones.

As noise usually consists of numerous frequencies and as the purpose is to get an overview of the frequency distribution the frequency scale is divided into sections. Each section is called a frequency band. Frequency bands of various widths are used for practical reasons. For an octave band the highest frequency limit is twice as much as the lowest frequency limit. The centre frequency is defined as the average value of the highest and lowest frequency limit of the band.

Measuring equipment can divide noise into frequency bands making it possible to identify which frequency areas create the most noise.

1.9 Frequency analysis

To obtain a sound picture a frequency analysis is made. Any machinery leaves an acoustic fingerprint depending on type.

Usually the frequencies are divided into octave bands. This division provides a quick and easy overview of the sound level at the various frequencies and also the possibility of identifying whether the noise is created by the general level or individual frequencies. This analysis enhances the possibility of finding the right solution to the problem in question. On page 5.4 a frequency analysis is shown.

1.10 Noise reduction

If you have ever tried talking to a colleague in a big empty auction hall you know how high the sound feels and surely recollect the echo created in these halls. Everyone has tried to move into a new house or apartment and recall the resonant noise coming from an empty and unfurnished room when entering it.

We all know that the resonant sound will be reduced as soon as fish and people are put into the auction hall and when furniture is put into the room. The echo or the resonant noise is reduced or has disappeared.

In acoustical terms you say that the echo is reduced when the sound waves are absorbed. Popular speaking it disappears into another material when absorbed. Just like when you wipe up water from a bath room floor with a sponge.

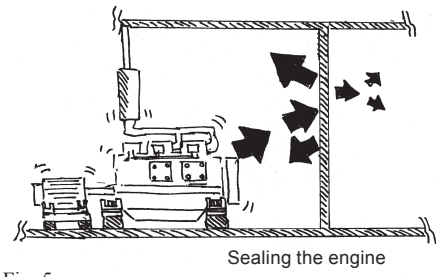


Fig. 5

All in all many noise reduction materials can be compared with an ordinary sponge. Some sponges can absorb a lot of water others less water. The structure of the sponge and the material of which the sponge is made determines whether or not the sponge is good at wiping up water. In other words the structure and the noise reduction material used determine how much the noise is reduced in any given room.

1.11 Reverberation time

The reverberation time of a room indicates how quickly the noise reflections disappear. The reverberation time indicates how long it takes for the sound pressure level to drop to 60 dB when a noise source has been interrupted.

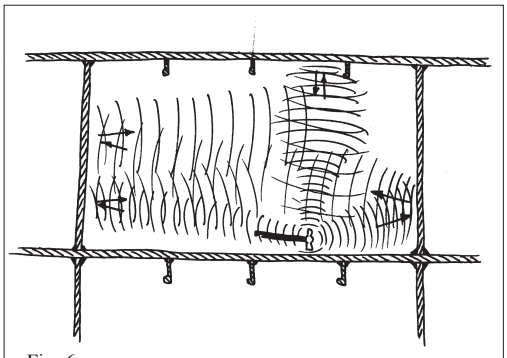


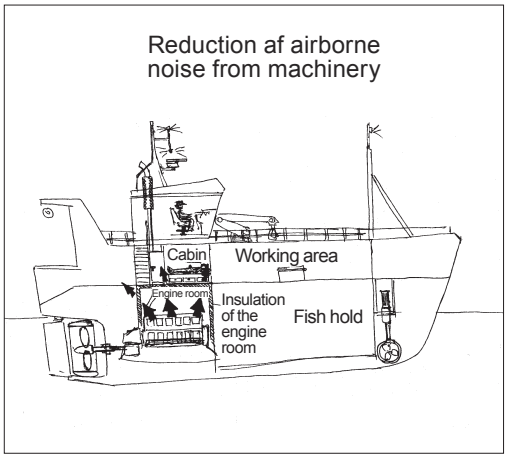
Fig. 6

The size of the room and the amount of absorbing materials in it has a crucial effect on the reverberation time

As indicated in the drawings the noise is reflected in the room when there is no noise absorbing materials. This means that it takes longer before the noise subsides or fades out. How the no is perceived varies. Whether you want a short or a long reverberation time depends on the purpose of the room. In a concert hall the reverberation time is often different than in an office in town.

1.12 Air and structure borne noise

The noise and vibration on board a fishing vessel are mainly caused by main and auxiliary machinery, pumps, propellers, hydraulics, etc. The noise consists of two parts which fundamentally are transmitted through two different transmission paths



It consists of radiated airborne noise in the room from which the noise sources is. This noise spreads through openings and is called airborne noise.

It also consists of noise sources transmitting and creating vibration in the construction of the vessel. This airborne sound causes the surrounding bulkheads, beams, deck, etc. to vibrate and transmit through the construction of the vessel and radiates as noise from floor, bulkhead, lining, ceilings and windows. This noise is called structure borne noise.

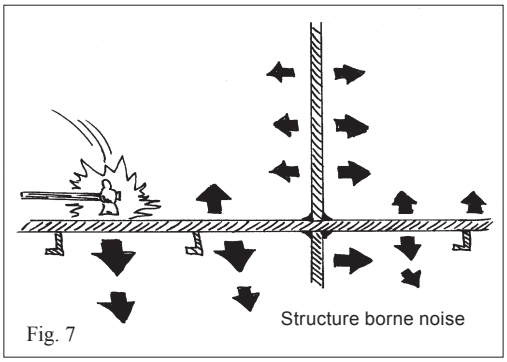


Fig. 7

Depending on how far from the noise and vibration source you are the structure borne noise on board a fishing vessel is usually the biggest problem. However, it is not important to establish whether it is airborne or structure borne noise until you choose how to reduce it. Airborne sound must be insulated whereas structure borne noise must be reduced by isolating it from the rest of the vessel construction.

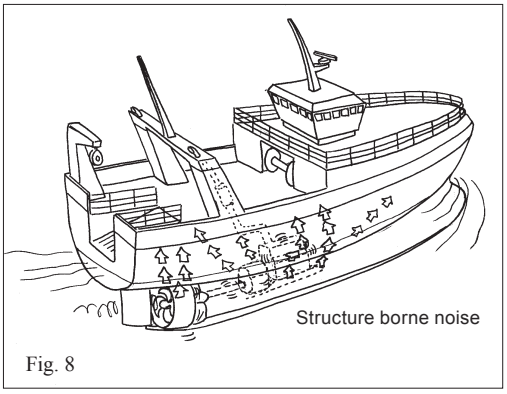


Fig. 8

Chapter 2 The impact of noise on the human ear and body

2.1 Noise and hearing

The human ear is a highly developed and sensitive sense organ capable of perceiving even slight differences in sound. Usually we do not pay much attention as to the function of the ear. The important thing to us is whether or not we can hear – whether the sound is too high or if it is annoying or calming.

When indicating the volume of the sound the decibel scale is used. The decibel scale implies that a human being with normal hearing can hear a sound pressure level above 0 decibel (dB). At the other end of the scale is the pain threshold which for most people is reached at 120 dB.

The decibel scale is a so-called logarithmic scale meaning that if the sound pressure level increases with 3 dB the sound energy reaching the ear is doubled. If the noise level is reduced by 3 dB you can be exposed to the noise twice as long without any change in the risk of hearing impairment.

Thus a high sound pressure level/noise level for a short period of time might have the same consequences as a lower noise level for a longer period of time. Fig. 2.1 shows how long it,

24	hours	-	85	dB
8	hours	-	90	dB
2	hours	-	96	dB
30	min.	-	102	dB
10	min.	-	107	dB
5	min.	-	110	dB
1	min.	-	117	dB

Illustration of sound pressure level/noise

Table 2-1

is possible to stay in a noisy room at various noise levels. The noise impact at 90 dB for 8 hours is the same as 107 dB for 10 minutes. Therefore, the sound energy level determines how long you can stay in a noisy room.

When it comes to the human being's own perception of noise level changes an increase of 10 dB will be perceived as a doubling of the noise level. In other words 90 dB is perceived twice as powerful as 80 dB. This means that even a slight noise reduction can have a huge impact.

In comparison ordinary conversation has a volume of approx. 60 dB. If noise from the surroundings exceeds 75 dB it is necessary to raise your voice. When background noise exceeds 90 dB you have to shout to be heard.

2.2 The construction of the ear

The ear is divided into three parts - the outer ear, the middle ear and the inner ear. The outer ear is what we can see including the auditory meatus into the eardrum. The purpose of the outer ear is to increase the sound before it hits the eardrum and also help us determine from where the noise comes

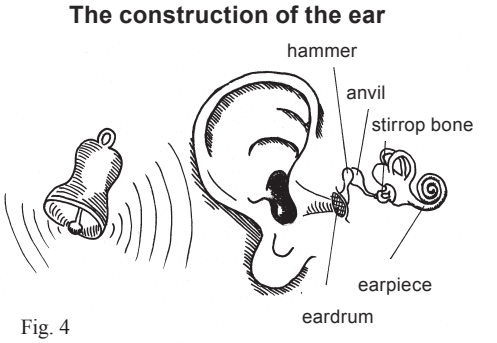


Fig. 4

The middle ear is a cavity filled with air in which the three ear bones are placed – the hammer, the anvil and the stirrup bone. The bones

transmit vibration from the eardrum into the inner ear. There are also two smaller muscles in the middle ear. One is used to tighten the eardrum and the other is used to prevent too much vibration in the stirrup bone. To some extent this enables the ear to reduce high volumes for a shorter period of time.

The inner ear is a cavity filled with fluid in which the organ of equilibrium and the earpiece are placed. There are numerous hair cells placed in the earpiece. They transform the vibration into nervous impulses transmitted via the nerve paths to the brain.

As the ear is so sensitive it will to some extent adjust the present sound picture. Therefore it is recommended that the measured sound pressure levels are adjusted in order to make them correspond to what is actually heard by the ear. This is done with a so-called "A-adjustment filter" mounted on the measuring equipment. The "A-adjustment" makes it possible to remove the high and low tones when measuring. When a measured volume has been adjusted by using the "A-adjustment filter" the sound level is indicated dB(A).

2.3 The impact of noise on human beings in everyday life

A high noise level not only impacts the hearing. The noise also impacts the body and the way it functions and often the psychological consequences are much worse than the physiological. When the body is exposed to noise it reacts by producing a series of hormones alerting the body's defence system. This is done because – contrary to the human brain – the body has not developed since the Stone Age.

How our nervous and hormone system react have not changed much since the Stone Age. Back then noise usually equalled danger making this specific reaction very useful. You had to fight for survival or possess enough strength to escape. Today noise provokes stress. When exposed to high noise levels it might:

- Impact the power of concentration
- Cause headache
- Cause stress
- Interfere in sleeping pattern
- Impact tolerance threshold
- Increase the risk of accidents
- Increase number of mistakes
- Reducing working capacity

Vibration might also have a negative effect on the working climate on board. Several of the above mentioned problems might also occur if the vibration level is too high.

2.4 How do damages to the hearing occur?

When a person is exposed to a continuous noise level above approx. 80 dB(A) for a longer period of time damages to the hearing might occur. The microscopic hair cells picking up movements in the fluids of the earpiece are worn down. At first they will deform and if still exposed to noise they will be destroyed. If this happens the damage to the hearing is permanent and the person must live with it for the rest of his life.

Damages to the hearing might also occur as a result of a single and very powerful noise impulse – for instance an explosion. Instantly an area with hair cells can be destroyed and the damage in this case is also permanent.

2.5 The risk of damages to the hearing

The possibility of hearing damages depends upon the person exposed to the noise. Some people have very "strong" ears and others have very "weak" ears. However, several elements are general:

1) The intensity and duration of the noise is significant to the risk of hearing damages.

2) The risk increases when exposed to noise for several years.

For many years the risk of damages to the hearing at various noise levels has been studied. On the basis of the knowledge gained The Danish Standards Association has prepared the below table (DS 797, "Assessment of occupational noise exposure for hearing conservation purposes") to be able to assess the risk.

Noise impact in the workplace for 10 years	Risk of hearing impairment
80 dB(A)	0 %
85 dB(A)	4 %
90 dB(A)	11 %
95 dB(A)	24 %

Table 2

2.6 The damaging effects

Hearing impairment results in social isolation. You loose the ability to communicate with other people. The first symptom is often that the injured person thinks that other people mumbles. Often damages to the hearing starts at the high tones – the person can no longer distinguish the consonants from each other (for instance t- and s-sounds). At this early stage permanent hearing impairment is already a reality and the person often experiences misunderstandings and other peoples' reluctance towards talking to him as he is very difficult to talk to. It is also difficult to be part of a discussion in which more than one person is talking. The sounds can not be separated from each other.

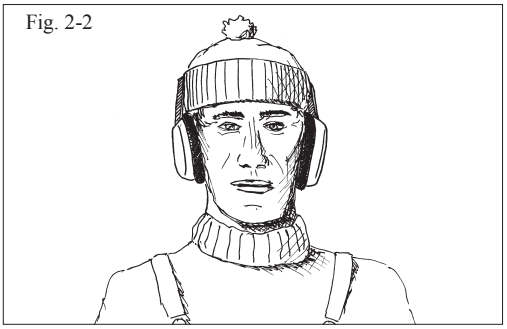
Tinnitus is a buzzing and burning sensation to the ears and is often a symptom of hearing impairment. Tinnitus varies significantly from person to person. Some describe the symptoms as putting the hose from a vacuum cleaner to the ears others experience a very loud tone – like the dial tone from a telephone. Tinnitus can be periodical but it can also become chronic. The side effects are often sleeping troubles, irritation and in extreme cases depression. In fact some musicians have given up playing music as the noise in the ear simply was too disturbing.

Noise impacts other areas than the hearing. Noise can cause stress which again causes a change in your breathing and a high blood pressure. Noise also reduces your ability to concentrate, lower level of productivity and is therefore suspected to cause more industrial accidents.

2.7 Personal protective equipment

The use of ear protection and earplugs is prohibited in areas with a high noise level. Today a series of personal protective equipment for hearing conservation is available and it is very likely that you will find something that suits your specific needs.

Fig. 2-2



When working in the engine room and other areas with an extremely high noise level the most effective personal protective equipment against noise is ear protection. Please note that the quality and thereby also the level of protection vary a lot. It is important to know in which frequency area the ear protection is most effective.

Please remember to check that your ear protection always provides you with the best protection.

Chapter 3 Measuring and calculating the noise impact

3.1 Noise measuring and calculation

To determine the noise impact on a person in his working environment thorough measurements and calculations must be carried out. This is done to get a clear picture of the overall noise impact during a workday. A slight change in the sound pressure level/noise level might have a significant impact on how damaging the noise is. To get at complete picture of the noise impact all noise changes must be taken into consideration. It is just as damaging to be exposed to 110 dB for 5 minutes as it is to be exposed to 90 dB for 8 hours.

In general the guidelines for assessing noise focuses on the noise impact on the human being. The assessment focuses among others on:

- Hearing loss
- Difficulty in processing speech
- The impact on the well-being

When analysing and assessing the noise impact on a given person a procedure taking into consideration the working environment of the person is applied. The noise impact is measured in the areas in which the person works an entire workday. It is recommended that the microphone is placed approx. 10 cm from the most exposed ear.

The measurements must be carried out at a time during which the noise impact is equivalent to a typical day. If convinced that the sound does not change it is often sufficient to measure the sound level for a minute – or even shorter. If on the other hand the sound changes the measurements should be prolonged in order to determine an average level for the entire day.

In case the noise level changes all day measurements must be carried out continuously during the day. By means of some simple formulas the average impact level can then easily be calculated. In acoustic terms it is called L_{Aeq}.

L_{Aeq} (the equivalent constant sound pressure level) is equivalent to a constant sound pressure level measured during the same period of time. The constant sound pressure level is the same as an equalization of the noise during a certain period of time. The equalization – the L_{Aeq}–value – makes it easier to establish how damaging the varying and total noise impact is on the individual human being.

Noise impact analysis is carried out only with approved, maintained and calibrated measuring equipment.

If bangs and sharp sounds occur more than once a minute and exceed 115 dB(A) they should also be included in the analysis. Therefore impulse sounds must be included in the L_{Aeq}-value. Typically the correction is 5 dB.

Such loud impulses can occur at:

- bangs – metal against metal
- hydraulic noise when using gear
- resonance areas

3.2 Noise impact analysis

As mentioned above the noise impact is calculated as L_{Aeq} and is equivalent to an 8 hour working day. However, an 8 hour working day on board a fishing vessel is not realistic. Therefore, the noise impact on board a fishing vessel is most often more intense. The ear simply does not get the chance to rest.

The extent of the impact is shown in the below analysis. In the following average noise impact on board an existing fishing vessel is reviewed. Systematic and continuous measurements have been carried out.

3.3 Noise impact analysis in a fishing vessel

When analysing the total noise impact on board a noise point system is used. The advantage of the noise point system is that it is very simple and easy to use and it is just as useful as any other mathematic formula.

The following example is fictitious.

During a workday a fisherman carries out many different tasks on board his ship. In the course of 24 hours he is exposed to the following noise impact (L_{Aeq}):

Hydraulic noise	94 dB(A) for 2 h.
Working on deck	77 dB(A) for 6 h.
Working with gear	87 dB(A) for 3 h.
Working in engine room	100 dB(A) for 2 h.
Staying in mess	75 dB(A) for 4 h.
Staying in cabin (rest)	70 dB(A) for 7 h.

Calculation method

When calculating the above mentioned noise impact table 3.1 and 3.2 are used. In the tables the figures used in the example are highlighted.

In table 3.1 the following shows:

Hydraulic noise, 94 dB(A) for 2 hours = 250 noise points

As 94 dB(A) does not exist in the table the closest value is used: 95 dB(A)

Working on deck 77 dB(A)	for 6 h. =	10 noise points
Working with gear 87 dB(A)	for 3 h. =	40 noise points
Working in engine room 100 dB(A)	for 2 h. =	790 noise points
Staying in mess 75 dB(A)	for 4 h. =	5 noise points
Staying in cabin 70 dB(A)	for 7 h. =	0 noise points
Total:		1095 noise points

In table 3.2 it is shown that:

1000 noise points is equivalent to 95 dB(A)
1250 noise points is equivalent to 96 dB(A)

The total and average noise impact which the fisherman has been exposed to can then be found in table 3.2. As the number of noise points (1095 noise points) is closer to 1000 than 1250 the impact is set to be 95 dB(A) over a period of 24 hours. When looking at the noise points for the individual tasks the noise from the engine room has the biggest impact. Despite the fact that the fisherman only stays there for 2 hours the noise from the engine room is the worst noise source.

According to Notice A from The Danish Maritime Authorities – Technical regulation on occupational health in ships it is stipulated that the daily noise impact for a person must not exceed 83 dB(A). In the above mentioned example this threshold limit has been exceeded. As a minimum the fisherman should wear ear protection when working in the engine room.

Table 3.1

Noise points for a noise level from 75-115 dB(A) and a duration from 2 minutes up to 8 hours a day

Duration a day	Noise level, dB(A)								
	75	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**
2 min.					5	15	40	130	415
3 min.					5	20	65	200	625
4 min.					10	25	85	265	835
5 min.				5	10	35	105	330	1040
6 min.				5	10	40	125	395	1250
8 min.				5	15	55	165	515	1670
10 min.				5	20	70	210	660	2080
12 min.			5	10	25	80	250	790	2500
14 min.			5	10	30	90	290	920	2920
16 min.			5	10	35	105	330	1050	3330
18 min.			5	10	40	120	375	1190	3750
20 min.			5	15	40	130	415	1320	4170
24 min.			5	15	50	160	500	1580	5000
30 min.			5	20	65	200	625	1980	6250
36 min.			10	25	75	235	750	2370	7300
42 min.		5	10	30	90	275	875	2770	8750
48 min.		5	10	30	100	315	1000	3160	10000
1 hour		5	15	40	125	395	1250	3950	12500
1 hour 12 min.		5	15	45	150	475	1500	4740	15000
1 hour 24 min.		5	20	55	175	555	1750	5530	17500
1 hour 36 min.		5	20	65	200	630	2000	6320	20000
1 hour 48 min.		5	25	70	225	710	2250	7110	22500
2 hours	5	10	25	80	**250**	**790**	2500	7910	25000
2 hours 24 min.	5	10	30	95	300	950	3000	9490	30000
2 hours 48 min.	5	10	35	110	350	1110	3500	11100	
3 hours 12 min.	5	15	**40**	125	400	1260	4000	12600	
3 hours 36 min.	5	15	45	140	40	1420	4500	14200	
4 hours	**5**	15	50	160	500	1580	5000	15800	
5 hours	5	20	65	200	625	1980	6250	19800	
6 hours	**10**	25	75	235	750	2370	7500	23700	
7 hours	10	30	90	275	875	2770	8750	27700	
8 hours	10	30	100	315	1000	3160	10000	31600	

Table 3.2

Conversion of noise points L_{Aeq} for a period of 24 hours

Total noise points	Noise Level Energy Equivalent dB(A)
10	75
15	77
20	78
25	79
30	80
40	81
50	82
60	83
80	84
100	85
125	86
160	87
200	88
250	89
315	90
400	91
500	92
630	93
800	94
1000	**95**
1250	96
1600	97
2000	98
2500	99
3150	100
4000	101
5000	102
6300	203
8000	104
10000	105
12500	106
16000	107
20000	108
25000	109
31500	110

Chapter 4 An analytical approach to problem solving

4.1 In general

When something has not been solved we often perceive it as a problem. Some would call it a challenge. Problem or challenge: both are solved but the procedure is different.

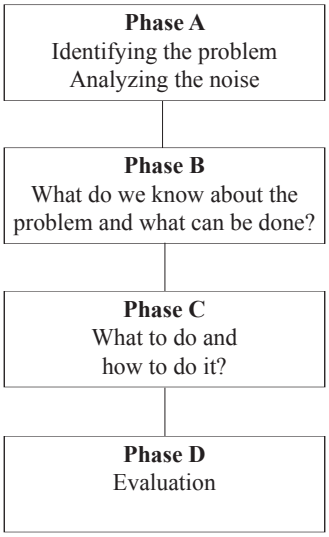
Studies show that 80% of all problems are solved intuitively. This means that they are solved based on our experience and education. This type of problem is often solved quickly and is not perceived as difficult and requiring extensive consideration.

The remaining 20% of all problems are solved either by the method of trial and error or by being analytical. Not all people have tried to solve problems analytically. On the other hand most people have tried solving problems by the method of trial and error.

Approaching problem solving analytically is effective when bigger and more difficult problems must be solved. The method is effective as it lies out specific guidelines for the problem solver. Throughout the process you are forced to take into consideration a series of questions which are usually easy to miss.

The method shown here is identical to the one used on the occupational health and safety training courses carried out for the members of the Port Safety Committees. The only difference is that adjustments have been made to specifically comply with the handling of noise problems in order to make the most effective tool for solving problems.

The problem solving method is divided into the following main points – 4 phases:



4.2 Unnecessary noise in fishing vessels

On board a fishing vessel you have a problem when crew members are exposed to unnecessary noise. In the Technical Regulation on Occupational Health in Ships §13 the Danish Maritime Authorities set out the following requirements on noise:

"Unnecessary noise must be avoided. The noise level when working must be within reasonable limits taking the technological development into consideration. Stipulated threshold limit values(TLV) must be observed."

However, controlling noise is not just at matter of complying with the rules and regulations from the authorities. **The most important thing is to take care of your hearing!** Too many fishermen suffer from hearing impairment due to many years of unnecessary exposure to noise. Therefore, it is not only the aim to provide you with a tool to fulfil the requirements from the Danish Maritime Authorities.

4.3 The analytical approach to problem solving used on noise in vessels

Before solving the problem it is very important to clearly identify the specific problem – this forms a solid basis for the whole procedure. If a clear identification of the problem has not been made your efforts are wasted from the beginning.

Treating symptoms must be avoided. For instance it is better to shot the window if there is a draught than to put on more clothes. You being cold is just a symptom – the open window is the real problem.

You have to identify the cause of the symptoms otherwise the problem cannot be solved. By some it is called identifying the causes and the effects.

Problems may easily be caused by several things. Please be careful not only to focus on one single cause. It might hamper the rest of the procedure.

Phase A
Identifying the problem – analyzing the noise

It is rarely a problem identifying noise problems on board a fishing vessel. However, it is often difficult to identify the source of the noise problem as it is often composed of more than one noise source. Identification of noise sources it not easily done. The conditions must be checked and an analysis of the noise picture must be carried out.

When identifying noise source problems the following procedure can be followed:

1) During which working conditions do the noise problems occur?
   - Identifying noise in the room
   - Noise level – measured in dB(A)?
   - In which frequency areas does the problem occur?
   - Is it permanent or sudden noise?

(The Danish Fishermen's Occupational Health Service has the necessary measuring equipment and is happy to assist you in analysing the noise conditions on board your vessel)

   Which machinery or rotating parts are in operation?
   - Main engine
   - Auxiliary engine
   - PTO - Coupling
   - Ventilation
   - Propellers
   - Pumps
   - Hydraulics

   Analyse the working conditions:
   - Speed
   - Sea and weather conditions
   - Water depth
   - Revolutions per minute for engines and pumps
   - Propeller pitch
   - Oil consumption
   - Draught
   - Are windows and doors open?
   - Are sealing in doors and windows damaged?

2) Identifying noise sources
   - Which noise sources are present?
   - The working conditions and variation of the noise source
   - Do the noise source/surroundings vibrate?
   - How is the noise perceived in the different rooms?
   - How does the noise sound?

3) Analysing the information gathered:
   - Do we have enough information to identify the problem or do we need more analysis or information?
   - Is it structure and/or air borne noise?

Phase B
1. What do we know about the problem?

In preparing and choosing the right solution correct information is essential. In Phase B you gather all information available and come up with a lot of different solutions. The key word in this phase is not to restrict yourself.

Before determining which solution to use it is important to gather the correct information by for instance:

- Analysing daily routines and procedures
- Analyse a typical situation
- Find out if others have experienced the same or similar situation
- Talking to the people on location (feelings, opinions and facts are all relevant information)
- Hold meetings with the involved parties
- Sharing information
- Use manuals, instruction material, rules and regulations, etc.
- If necessary involve specialists, leaders or other personnel groups in the project

During this phase it is important to write down as much information as possible. Information not relevant to begin with could later turn out to be essential for the solution of the problem. Anything with even the slightest connection to the problem must be written down. Too much information is better than too little.

1) The noise source in relation to the rest of the vessel:

   - Is the noise source properly insulated?
   - Is the insulation in the room of the noise source sufficient?
   - During which operation conditions do the problems occur?
   - Are there any vibrations in and around the noise source?
   - At what number of revolutions per minute do the problems occur?
   - In which way is the noise source mounted and connected to pipes, bed and bulkhead?
   - Is the noise source imbalanced?

2) The affected rooms:
   - Has the room been properly insulated?
   - Are there any noise threshold limit values that must be kept?
   - In which way has the insulation been mounted?
   - What kind of insulation material has been used?
   - How old are the insulation materials?
   - Has the insulation been damaged?
   - From where is the noise most intensive – deck, bulkheads or ceiling?
   - How is the room furnished?
   - Where is the source of noise placed in proportion to the cabin?

3) General conditions:
   - In which part of the vessel do you stay the most and during which circumstances?
   - How does the noise affect you in your daily work?
   - Which noise problems can be solved at the source?
   - In which areas are noise reduction most important?
   - Make yourself familiar with the rules and regulations on noise threshold limit values.
   - For how long do you stay in the affected room?

Phase B
2. What can be done to solve the problem?

1) Potential solutions

Chapter 8 provides you with at series of solutions for noise reduction.

When a solution must be chosen it is important to answer the following questions:

- What are the costs of the various solutions?
- Which solution is the best at the lowest costs?
- How much are we willing to invest?
- Which materials have been approved by the Danish Maritime Authorities?
- Who can advise and guide us?
- Have others experienced the same and can we learn from them?

Phase C
1. What to do?

Answering this question can only be done when many of the above questions have been answered. Pros and cons must be discussed and a financial analysis must be made, alternative technical solutions must be considered and the expected effect compared with the financial investment must be evaluated.

Contrary to Phase B you have to seriously and thoroughly consider each solution in Phase C. You have to establish which solution to choose and how exactly to carry it out. Now you know whether or not your previous analysis and information gathering have been thorough enough to provide you with at solid basis for choosing the right decision and subsequently realising it.

When choosing how to solve your noise problems please keep the following basic principles in mind:

1) Always try to reduce the noise problem at the source. It always provides the best results.
2) Learn from others – there is no point in inventing solutions that already exists. Always talk to somebody who knows about noise.
3) Please make sure that the solution chosen is in compliance with the craftsmanlike procedures within the area. Make sure that the suppliers used know what they are dealing with.
4) Please make sure that the solutions carried out are in compliance with the requirements set by the authorities.
5) Make sure that the solutions are practical and easy to use.
6) Could changes in working and operational procedures solve some of the problems?
7) Make sure that the correct and most important noise sources have been identified.

Phase C
2. How to do it?

An action plan must be made. Please answer the following questions:

- How do we do it?
- What do we do?
- Who does what?
- When do we do it?
- Why do we do it?
- Which material do we need?
- Which suppliers do we use?

It is important to make a clear and specific action plan. The tasks must be planned and carried out in the best way possible. If necessary make an activity plan on how to solve the problem from A-Z.

Phase D
Evaluation

An evaluation of the solutions chosen must always be made. New noise measurements can show how much the noise has been reduced. The reduction obtained must of course be seen in relation to the price.

Chapter 5 Principles for reduction of noise and vibration

5.1 In general

There are a lot of possibilities when it comes to noise reduction in fishing vessels. However, it is important to consider it thoroughly before choosing a final solution. Make sure that the construction engineer is familiar with all the basic principles within noise reduction and the trade as such to avoid many of the pitfalls there are. If you take all of the above into consideration the best possible solution will be obtained.

5.2 How to reduce noise and vibration most efficiently

Today we possess extensive knowledge within noise and vibration reduction. Furthermore, many suppliers and consultants are able to guide and deliver suitable materials and components for the purpose.

Please always remember to **reduce the noise and vibration at the source.**

When reducing noise and vibration at the source you more or less have to either "wrap in" the noise source or isolate it from the rest of the ship.

When reducing noise three different factors are important to keep in mind:

1. How the noise is created
2. When spreading in or at the noise source
3. Where the noise radiates

In some cases it is not possible to identify all three principles and you have to use other methods i.e. solving symptoms. In principle symptom solving is all solutions that are not solved at the noise source. In existing vessels symptom solving is often used as they are often easier to handle.

A typical example of symptom solving is:

- Preventing noise from transmitting by insulating the engine room
- Mounting absorption panels
- Mounting sealings in doors
- Floating deck

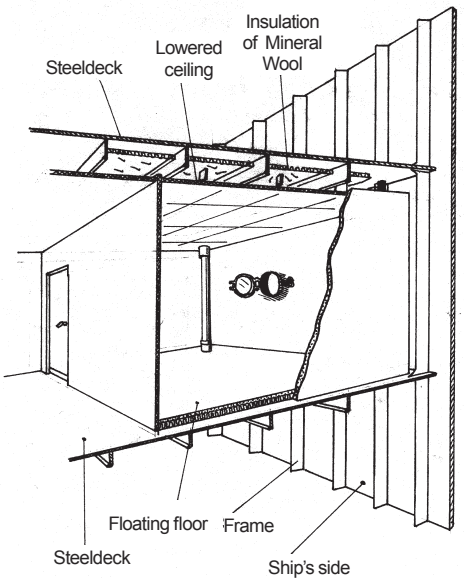
5.3 Insulating and absorbing

When **insulating** you insulate the noisy component from the rest of the vessel. However, you rarely have that possibility in existing vessels. The place is limited and the varying operational conditions are also a significant factor. For instance the use of flexible supporters under the main engine has created problems which make it difficult to insulate it from the rest of the vessel. In addition it is difficult to insulate engine components due to the lack of space.

Instead you often insulate a cabin or galley from the rest of the vessel. In other words you wrap the room. This solution is often expensive and you only solve the problem in the specific room.

When choosing noise reduction by means of **absorption** you primarily change the noise conditions in the room in which the absorbing material is mounted. If absorbing plates are mounted in the engine room the transmission of noise from the main engine will remain the same but the reverberation has changed as the reflection back into the room is lowered. This creates a different sound picture.

Most people recognise this from empty houses or halls. If there are no furniture in the room or the floor is hard the sound resonate. This resonation only disappears when you put furniture, people or carpets into the room to absorb the sound. This creates a different sound picture.



Example of a cabin structure

Fig. 10

Absorbents in the room prevent the sound from being thrown back. Close to machines the direct sound will still be dominating and the reduction is limited. However, the improvement is significant in the room as a whole. When the reflections are reduced the directions of the individual noise sources can be defined while being in a room without any noise reduction it feels like you are drowning in noise.

When using absorption primarily the airborne noise is reduced. As indicated in figure 11 the structure borne noise from the main engine will still transmit from the hull into the vessel. It is important to remember that structure borne noise only can be reduced by insulating the component from the rest of the vessel. Absorption is therefore most efficient when used locally.

Absorbing materials are often non-compressed or fibrous materials. The inner structure is put into vibration and the incoming sound energy is absorbed due to friction in the material. This friction is transformed into heat energy.

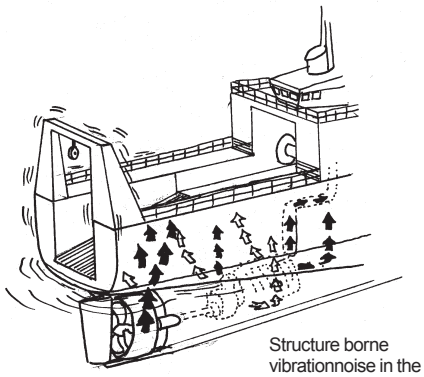


Fig. 11

Materials as glass wool and rock wool are highly applicable absorbing materials

5.4 Mass and rigidity

When reducing noise in a steel structure both mass and rigidity can be increased. As vibration in constructions is transformed into heat a larger mass will absorb the energy/noise/vibration better than a smaller mass. A rigidity increase will improve the construction's ability to reduce the vibration.

A rigidity increase is more or less also a weight increase. Therefore it can often be difficult to determine which one provides the biggest effect. However, an increase in mass is not equal to an increase in rigidity. For instance a viscoelastic solution is not likely to increase the rigidity of the structure significantly.

5.5 Principles for reducing noise created by vibration

Noise is created by annoying vibration in the steel structure of the vessel transmitting into the elements of the vessel. The elements are put into vibration which is transmitted into the surrounding air. The individual elements radiate noise into the rooms in which their limitation zone is a part of.

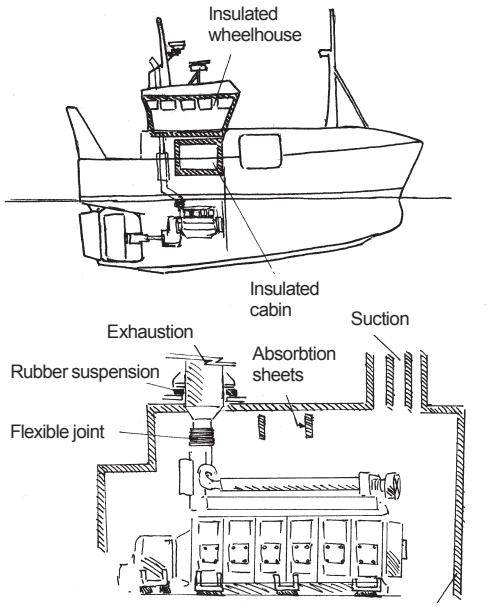


Fig. 12

Vibration creates noise. If the vibration in the steel structure can be reduced a reduction of the noise will be obtained. Therefore, the noise can be reduced by increasing the natural frequency of the steel which will make the structure more rigid.

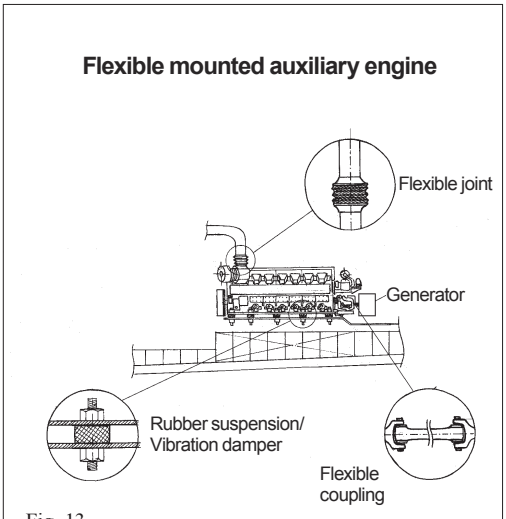


Fig. 13

For instance vibration and noise from the propellers can be reduced abaft by welding reinforcements on the steel structure right above the propellers. The rigidity increase makes the structure more capable of absorbing the vibration and thereby also the noise.

Figure 13 shows a couple of examples on how the vibration from the auxiliary machinery can be reduced and thereby also the noise which otherwise would transmit into the rest of the vessel.

5.6 Absorption coefficients and reduction figures

The ability to absorb noise varies from each absorbing material. They each possess an absorbing coefficient – a number indicating how good they are at absorbing. The coefficient indicates how much energy (noise) is absorbed into the material compared with the energy reflected. Which absorbing material is the best depends upon the frequency of the noise.

The Absorption coefficient α, indicates the noise absorbed in a surface and thereby reduces the noise in the room. The absorption coefficient is between 0 and 1 and depends upon the frequency.

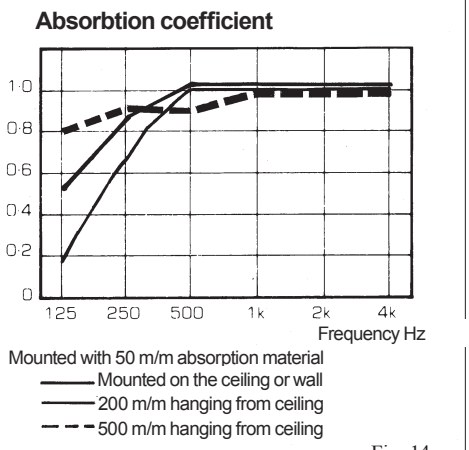


Fig. 14

A material with an absorption coefficient of 0 is 100% reflecting (a concrete wall has a value of 0.02).
A material with an absorption coefficient of 1 is 100% absorbing (mineral wool has a value of 0.9-1.0 at frequencies higher than 500 Hz).

The **sound reduction** number indicates the noise penetrating a surface and is measured in dB. It also depends on the frequency. Most materials have low values at low frequencies and higher values at higher frequencies.

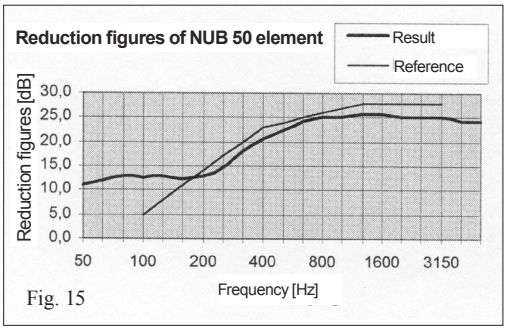


Fig. 15

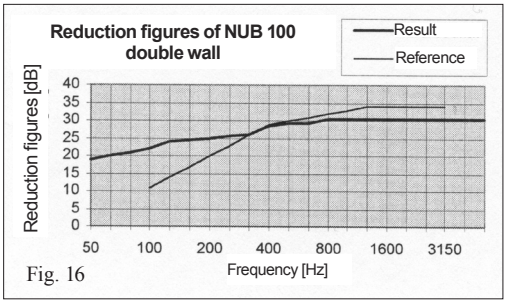


Fig. 16

Figure 15 and 16 show a 50mm and a 100mm wall element. You can see that the reduction number at low frequencies increases when the wall is thicker.

A sound reduction number of 0 dB is equal to no reduction (an open window). A sound reduction number of 10 dB reduces the sound by 1/10 on the other side of the surface which equals a 50% noise reduction.

5.7 How to use absorption numbers and frequency analysis

The below example shows noise measurements in a mess before and after noise reduction measurements have been carried out. The actual noise differences are also indicated.

Figure 17 shows the frequency distribution of the noise prior to the adjustments. The noise level is 73.6 dB(A).

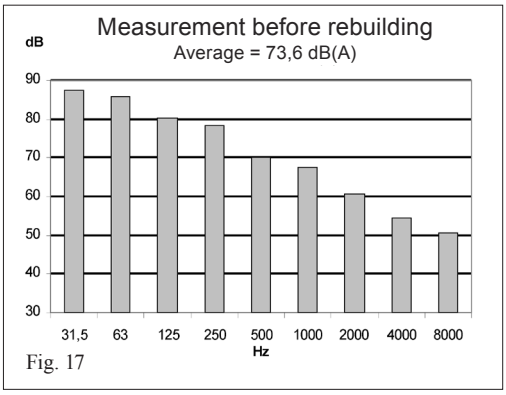


Fig. 17

The measurement is quite typical and shows high levels at low frequencies. In this case an absorbing ceiling consisting of 40 mm absorption sheets will be mounted. It replaces the original veneer ceiling in order to lower the reverberant sound and thereby also the noise in the mess.

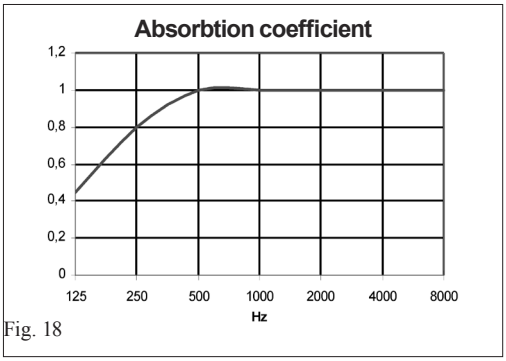


Fig. 18

The absorption coefficient curve for the ceiling shows that a considerable reduction in the

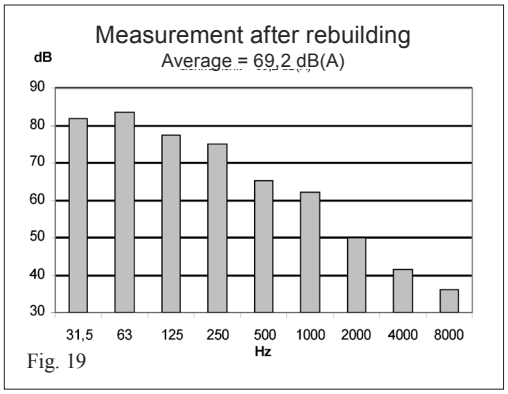


Fig. 19

noise above 500 Hz can be expected. At lower frequencies thicker absorption sheets and considerable space to the deck is needed.

Figure 19 shows the frequency distribution of the noise after the new ceiling has been mounted. The noise level is now 69.2 dB(A). This means an improvement of 4.4 dB(A).

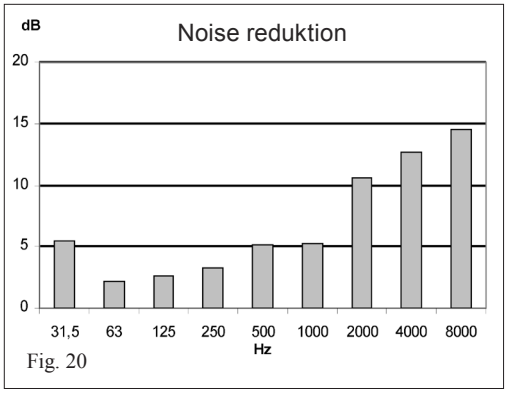


Fig. 20

Figure 20 shows the difference in the noise level before and after at the various frequencies. Please note that a considerable reduction at the high frequencies is obtained. You can also compare the diagram with the absorption curve of the ceiling (fig. 18) and see that there is cohesion between the two curves.

At 63-250 Hz the lowest reduction is seen due to the absorption coefficient being lower in this area.

Chapter 6 Noise and vibration sources on board a fishing vessel

6.1 Propellers

What causes the problems?

The propellers often cause a lot of noise and vibration problems on board fishing vessels. The problems are among others caused by the pressure momentum from the propeller blades each time they pass by the bottom of the hull. Varying forces and momentums from the propellers will also transmit through the steel structure.

How does cavitation occur?

Another problem is cavitation. Cavitation occurs when the pressure on the propeller blade front edge drops causing the water to boil. At low pressure water boils at a lower temperature. This creates bobbles again creating pressure load transmitting into vibration in the hull. Cavitation always starts at the front edge of the propeller blade.

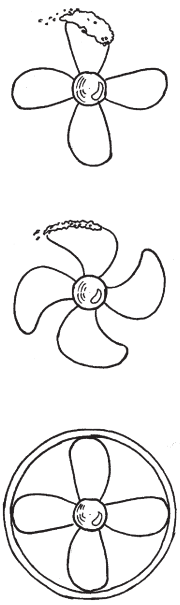


Fig. 21

In order to fully understand cavitation it is important to take a closer look at the propellers – their features and mode of operation.

When propellers turn low pressure is created on the front edge and overpressure is created on the back. The low pressure on the front edge causes the vessel to move forward and the overpressure on the back pushes. The low pressure is the one providing the biggest propelling force. This means that the low pressure is the most important force in getting the vessel to move.

The propeller blade can more or less be compared with the wing from an aeroplane. On top op the wing low pressure is created and underneath the wing overpressure. But the impact on the top is the one creating the most efficient propelling force.

Another factor essential for the risk of caviation is the propeller wake area. The wake area indicates the water flow to the propellers and depends upon the shape of the hull and the stern of the vessel in particular. The water flow

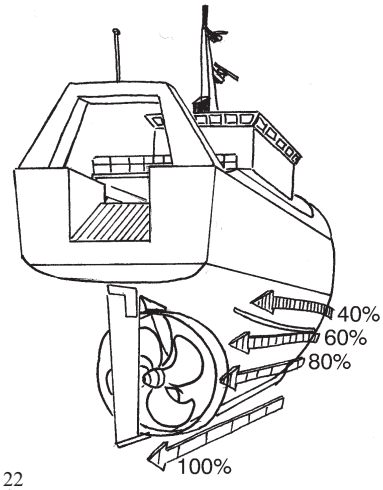


Fig. 22

to the propellers is rarely completely homogeneous. In vessels with poor water flow the risk of cavitation is more likely. When in motion the water flow in the area which the propellers pass varies constantly.

In fig. 23 a wake distribution is shown. The curves in the figure have been drawn through certain points in the wake area of the propellers and are indicated by a number from 0-1. At the top of the figure a wake factor of 1.0 is shown. This means that the water either does not move or moves opposite the direction of the vessel.

0,7 = 30% of the vessel speed
0,5 = 50% of the vessel speed
0,1 = 90% of the vessel speed

The most optimal wake area would be 0 throughout the diameter of the propellers. However, this is not possible to achieve.

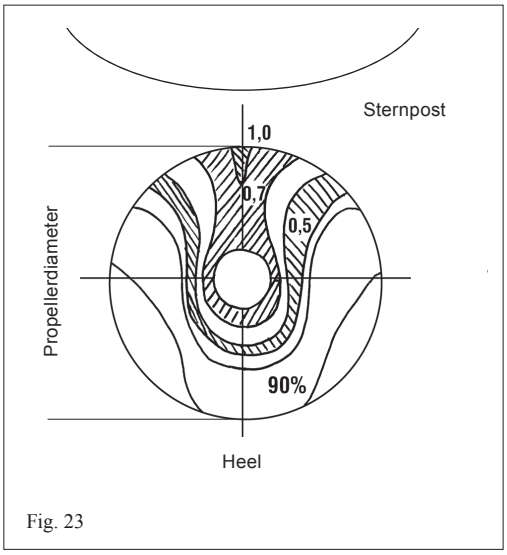


Fig. 23

The wake area varies from vessel to vessel depending on the vessel speed. This means that vibration may intensify when for instance trawling as the water flow to the propellers is too low. Typically noise and vibration problems caused by the propellers are structure borne. In serious cases propeller-made vibration can cause fatigue cracks. The propellers can also cause noise either directly or by vibration causing resonance in the structure.

How to reduce the problems in general?

How to reduce noise and vibration problems from the propellers must be evaluated individually. If it works in one vessel it does not necessarily work in another. The solutions must be tailor-made to each vessel and often it is difficult to reduce any problems in existing vessels.

It is most optimal to solve noise and vibration problems during the designing phase. The best hull shapes and propeller designs are easier to achieve before the vessel is build.

There are also several ways of improvement for existing vessels. However, the possibilities are limited if you are not prepared to reconstruct the entire stern frame as it is not easily modified. In chapter 8 various solutions are described.

6.2 Machinery on board

What causes the problems?

Obviously the engine creates both vibration and noise problems. The engine is mounted to a bed-plate which is part of the entire steel structure of the vessel and vibration and noise created here is transmitted to the rest of the vessel.

It varies how much noise and vibration the individual engine creates and how the noise and vibration is transmitted to the rest of the vessel. Revolutions per minute and how auxiliary equipment has been mounted to the main machinery are important. Turbo-charger, pumps, gear, etc. all contributes negatively to the over all noise level when the machinery is in operation. In other words there are a lot of different noise

and vibration sources in the engine room and often it is difficult to identify the exact problem. Often the individual noise sources reinforce each other. However, if you only look at the engine the noise and vibration is either aerodynamic or mechanical noise.

Aerodynamic noise occurs during the combustion process. Gas generation creates sound waves in the cylinder transmitting through the inlet air and the combustion gas into the cylinder walls as structure borne noise. Initially the sound pressure level will depend on the combustion process. Cylinder lining and the shape of the cylinder-head also impacts the noise transmission.

Mechanical vibration is transmitted from the piston through the piston rod, shafts, tooth gear, chains and journal bearings to the engine structure and will transmit further into deckhouse, covers, hatches, etc. Mechanical vibration also creates vibration sideways transmitted from the sideway motions from the piston rod against the cylinder lining. Valves and other equipment also add to the structure borne noise.

How to reduce the problems?

Noise and vibration from the engine is (contrary to the propeller problems) much more difficult to solve by reconstructing the engine. These problems must often be solved by changes in the surrounding equipment. In chapter 8 ways of handling noise from engine parts are described.

6.3 Hydraulics

What causes the problems?

On board fishing vessels hydraulic systems are used as a source of energy for among others winches, pumps, cranes, fishing tackles, steering gear, etc. Hydraulic systems are very dependable and therefore indispensable. Unfortunately they often create high and annoying noise caused by the impact motion created by the pumps of the hydraulic unit. In other words the higher pressure the more noise.

How to reduce the problems?

Sometimes an increase in pipe size might reduce the problems. It is also important to make sure that there are not any unnecessary fittings in the systems and that there are no mechanical contact to the structure. The oil velocity must not exceed 4.5 m/sec.

6.4 Ventilation

What causes the problems?

Noise from ventilation systems are often caused by the air velocity and resistance being too high.

How to reduce the problems?

It can sometimes be reduced by changing air intake and outlet, increase passage or changing the ventilator.

Chapter 7 Proposals for problem-solving containing partial solutions

Chapter 8 has been made to solve noise and vibration problems.

Within each main field a series of **solutions** have been listed. These proposals form the basis when attempting to solve noise problems. Furthermore, the procedure described in chapter 4 ensures that the problems are handled in a constructive way.

Enclosed examples (appendix 3) indicate how the problem-solving models and forms in chapter 8 are used.

Before using the tables it is crucial to identify the specific problem – or more precise: Where does the noise come from? It is very important to clearly identify the noise source. Furthermore, it is important to carry out the necessary frequency analysis. The result of the frequency analysis is important when selecting solution method.

In chapter 4 the **problem solving model** is described. The description contains a series of questions which will help the problem solver identifying the noise problem/source. Please do not try to ignore this first step. In doing so you risk that the problems are not solved in a correct manner and a lot of time and effort will be wasted.

Finally it is important to remember that no vessel – not even sister ships – are identical. When choosing a solution to noise problems it must always be evaluated individually. It is important to get on board and listen, measure, evaluate, feel and analyse the noise in order to find **the most optimal and cost efficient solution.** If the means where unlimited it would be very easy to reduce the noise. However this is rarely the case and it is important to consider every option thoroughly. Therefore, chapter 4 and 8 serve as a tangible and effective tool in finding the best solution to the problems.

If you have any questions or comments to the problem-solving model and the tables in chapter 8 please do not hesitate to contact the Danish Fishermen's Occupational Health Service.

The Danish Fishermen's Occupational Health Service is also happy to carry out noise measurements free of charge.

Description of Silje Martine E 147

Vessel data:

Construction year	1973
Extended	1981
Shelter deck	1984
Length	37,38 m
Breadth	6,72 m
Draught	3,55 m
Engine power	690 Bhk Callesen 6-427-FOT
Auxiliary machinery	105 Bhk Iveco

The crew cabin is placed above the propellers and abaft the engine room with stowage room under the berths against the shell plating. The mess is placed on the tween-deck with an isolated storesroom to the starboard side and auxiliary machinery on the port side passageway.

Silje Martine is an industrial trawler and is build like many other fishing vessels were built in the seventies. Back then not many requirements as to noise control were made which meant that noise insulation on board was very limited.

A - Identifying the noise problem

Measurements both during normal steam velocity and maximum velocity were carried out.

In the table below the noise levels measured during both velocities are indicated.

Location	400 RPM	500 RPM
Cabin below deck	75-78 dB(A)	80-82 dB(A)
Mess	73,5 dB(A)	78 dB(A)
Storesroom	87-88 dB(A)	88-89 dB(A)
Storesroom	83-87 dB(A)	86-90 dB(A)
Wheelhouse	68 dB(A)	
Master cabin	64 dB(A)	
Engine room	102-103 dB(A)	105 dB(A)

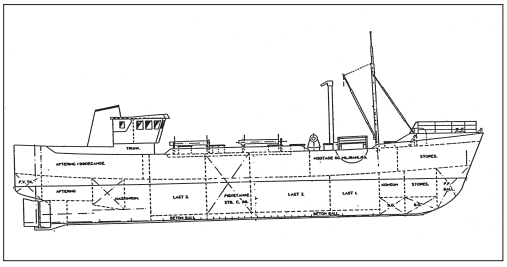
The noise problems on board Silje Martine was within the "typical" problem area between 125-1000 Hz. The main noise source was the propellers and main engine. In the crew cabin specifically low frequency noise from the propellers was the main noise source.

B1 - What do we know about the problem?

As indicated in the table in section A the noise problems were present at both 400 and 500 R.P.M.

The noise from the propellers was transmitted into the vessel through the abaft bulkhead and shell plating. Neither the abaft bulkhead or the shell plating were insulated. The main engine was directly mounted to the bed-plate and there was no insulation in the engine room.

Apparently neither the propellers nor the main engine seemed to be imbalanced. The existing insulation was old and in several places it was missing. Especially the flooring was very run down in several areas.



B2 - How to solve the problem?

Inspiration as to how to solve the problems can be found in table 8.8 and 8.10. As already stated both expensive and less expensive solutions are available. It is therefore important to compare the effect of the measures taken against the costs.

The most effective way to reduce the noise is to reduce it at the source. This is often very expensive in older vessels. For Silje Martine the

most effective measures would be to replace the propellers and noise insulate the engine room. However, this solution is often much too expensive.

C1 - What to do?

Cabin:
A solid rubber mat is put in the floor. Above the head of the berths absorption panels are mounted. In the passage way between the front cabins the ceiling is replaced with absorption panels. Absorption panels are also mounted on the break bulkhead in the front cabins.

Mess:
Bulkheads and ceiling are dismounted. Solid rubber mats are mounted also in lockers. Steel bulkheads are insulated with Rock wool, frames are insulated off the steel and the ceiling is mounted with a flexible joint in top and bottom. The ceiling is insulated with Rock wool and frames are insulated off the steel. Absorption panel cassettes are mounted as ceiling. Sealings are replaced in engine room doors and abaft storesroom doors.

Storesroom:
A solid rubber mat is placed in port side and abaft. There is a wooden deck in starboard side.

Master cabin:
Absorption panel is mounted above berth.

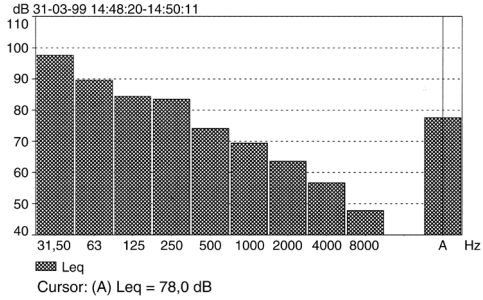
Stairwell:
Absorption panel is mounted under shelf for survival suits.

C2 - How to do it?

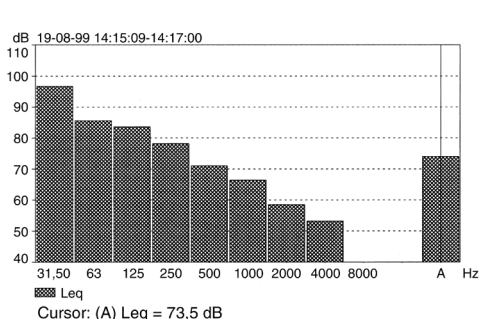
Rebuilding was carried out while the vessel was in shipyard due to engine renovation.

D - Evaluation

After the rebuilding new noise measurements were carried out. In the crew cabins the overall noise level was reduced by 1-2 dB(A) and the high frequency noise level was also reduced. The low frequency noise from the propellers was not reduced. In the mess the overall noise level was reduced by 4-5 dB(A) and the high frequency noise level was also reduced.



Measurement in the Mess before rebuilding



Measurement in the Mess after rebuilding

Chapter 8 Solution proposals

Please find below tables showing various solutions for reduction of noise and vibration. The tables have been divided into areas and within each area different potential noise sources are listed. For each of the described noise sources a series of potential solutions have been prepared.

The tables are divided into three main areas:

1. Noise from engine room
2. Noise in accommodation and wheel house
3. Noise in working areas above and below deck

How to use the tables

In order to use the tables as an effective tool when reducing noise problems two questions must be answered:

4. In which areas of the vessel do the noise problems occur?
5. What causes the noise?

If for instance the propellers cause noise problems in the mess table 8.10 must be used. Table 8.10 shows that noise from the propellers may be caused by cavitation or a nozzle. In order to solve these problems various proposals have been prepared. Some of the proposals are quite inexpensive and others are expensive. Furthermore, some solutions work in one vessel but not in another.

At some point you discover that some of the proposals are similar. In repeating the solutions you avoid having to look for them in other places of the book.

8.1 Engine room: main engine

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(S) General	(SO) Adjusting main engine	Ensures a minimum of imbalance in order to avoid any further transmission of noise.
	(SO) Correct operation mode for main engine	To the extent possible revolutions and propeller pitch must be adjusted to reduce noise and vibration.
	(SO) Correct alignment of main engine	Please make sure that alignment of main engine, gear and shaft is correct.
(S) Mounting of main engine	(SO) Flexible mounting of main engine with fixed mounted separate gear (with integrated single direction thrust bearing)	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine with bolted gear and separated fixed single direction thrust bearing.	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Fixed single direction thrust bearing is installed. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing.	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. The absorbers below the gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing.	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling is placed after gear. The absorbers below the main engine/gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(A) Noise radiation	(SO) Sealing the engine	When the main engine is the main noise source it can be necessary to seal the engine. This must be combined with flexible mounting of the engine. When sealing it is important to ensure that the necessary cooling and air is present. The air supply is carried out with absorbing labyrinth openings. All lead-ins must be tightly and flexibly sealed. This solution requires a lot of space around the engine.
	(S) Sealing engine room from noise penetration	When sealing the engine room all surfaces are insulated (rock wool and galvanized sheet) and lead-ins and component mountings are insulated.
	(S) Absorption panels, noise reduction in rooms	For noise reduction in engine room freely hanging absorption systems for reduction of the reverberation is used. The system must not absorb oil fumes.
	(S) Packings in doors, openings, etc.	Close-fitting rubber profile packings are mounted in doors, hatches, etc.

8.2 Engine room: noise from exhaust system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Mounting of exhaust system	(SO) General	All fixed spots between structure and exhaust must be removed. Expansion joints must never be fully compressed or extracted. The exhaust with absorber must not hang in or be supported by the expansion joints.
	(SO) Mounting sound absorber	Sound absorbers can be mounted on absorbing elements of rubber or full-metal. At the top high absorbers can be supported by a ring of wire pads (compressed steel wool).
	(SO) Mounting pipes	Support of the exhaust pipe can be done in the same way as with the sound absorber.
	(SO) Rain cap on exhaust pipe	Is carried out with fixed rain cap with overflow and coaming on top of funnel. The exhaust pipe must not touch the funnel top (use wire pads or profiled wire).
(A) Radiation of sound from exhaust system	SO) Insulating sound absorber with pipes	Thorough insulation and sealing of exhaust pipe and sound absorber also at suspension, flanges and expansion joints.
	(SO) New sound absorber	High efficient sound absorber with extra absorbing features designed specifically to the individual vessel. This normally requires extra space.
	(SO) Tuning the exhaust system	Tuning the entire exhaust system to avoid any resonance.
(A) Radiation of sound from exhaust system	(S) Insulating casing	Insulating surfaces towards accommodation.
(A) Standing sound waves in casing	(S) Baffles in casing	Sound baffles (absorptive panels) or insulation of side sections reduce standing sound waves and noise from the exhaust. Ensure free air flow in casing.

8.3 Engine room: noise from propellers

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Cavitation	(SO) New/modified propellers	New propellers adapted to the wake field. Possibly nozzle propellers. Old propeller systems can often be improved when replaced as new and improved calculation methods for optimizing drawing power and noise are available.
	(SO) Changing blade tilt	Low-noise shape of blade tilt (this might have an impact on drawing power).
	(S) Changing increase	If any problems are experienced at a certain increase or number of revolutions try to avoid this.
	(S) Area above propellers	Hull plate reinforcement above the propellers by means of bracing and/or thicker plates.
		Mounting bitumen/vibration reduction system material or viscoelastic sandwich system on hull plate above propellers and on deck.
		Absorptive material in rooms with reverberation will reduce the reverberation time and subsequently the noise in the room.
		Place cement in hull plate area above propellers.
	(S) Insulating engine room towards propellers	Insulating abaft bulkhead and hull plate.
(ST) Noise from nozzle	(SO) Reinforcement of nozzle shaft	Please ensure that nozzle shaft in hull is fixed and efficiently mounted. Soft plate areas must be strengthened.
(ST) Cavitation	(S) Other trimming	Trimming the vessel to obtain best working conditions and the lowest possible noise level.
(ST) Cavitation	(SO) Placing of Zink	Zink must be placed in current paths to avoid unnecessary eddy currents around propellers.

8.4 Engine room: engines, pumps, etc.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Balancing	(SO) Repairs	The pump must be balanced, bearings without backlash, etc.
(ST) Wrong size/capacity	(SO) New component	Make sure the size is right. If the pump is too small there is a risk of cavitation and damage and subsequently noise and vibration.
(ST) Mounting of machinery	(SO) Solid foundation	Foundation for pumps and engines must be rigid and thoroughly mounted to the construction.
	(SO) Absorbers	Must be placed on rubber absorbers/mats.
(ST) Connections	(SO) Flexible connections	When mounting a component flexibly all connections must, whenever possible, be flexible.
(A) Radiation from component	(SO) Sealing	Many electric motors come with noise absorbing casings.
		The component can be mounted in a sound absorbing case. Take into consideration heat release, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.
	(SO) Shielding	If sealing is not possible absorptive panels for shielding can be mounted.

8.5 Engine room: noise from pipe systems

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Speed/ pipe diameter	(SO) Changing the pipe dimensioning	At high speeds/pressure this can be solved by enlarging the pipe diameter.
(ST) Pipe suspension	(SO) General	Pipe brackets must be placed on stay or similar fixed point – not in the middle of a soft plate.
	(SO) Flexible mounting	Pipes must be suspended in either flexible brackets or brackets with rubber lining.
(ST) Pipe rigidity	(SO) U-bend	Long rigid pipes can be mounted with U-bend. Make sure that pipes are not attached to two fixed points without the ability to move.
(ST) Pipe penetration	(SO) Waterproof lead-ins	If possible use flexible lead-ins – if not it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	When using open lead-ins please make sure that the pipe is free from the opening and does not clank.
(ST) Valves	(SO) Changing valve type	Replace valves with butterfly valves if possible as they generate less noise.
(ST) Resonance/natural frequency in pipe system	(SO) Changing suspension	Pipe brackets are moved or added to reduce vibration.
	(SO) Noise reduction of pipes	Sound absorbing material either a mat or by spray coating can be placed on thin-walled pipes.
	SO) U-bend	U-bend can be greased to break the pattern.
(A) Penetrations	(SO) Waterproof lead-ins	If possible use flexible lead-ins otherwise it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	At non waterproof lead-ins the hole can be closed with a rock wool plate on each side.
(A) Noise radiation from pipes	(SO) Pipe insulation	Rock wool pipe insulation or similar for sealing can be mounted where pipes radiate noise directly.
	(SO) Insulation	Armaflex is primarily used for heat protection but it also provides a smaller noise reduction.

8.6 Engine room: noise from hydraulic system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Piping/ suspension	(SO) General	Avoid any sharp elbows and transitions. Avoid straight pipes between two structure fixing points. Suspension must be flexible whenever possible. Flexible connections at bulkhead lead-in, engine and pump.
(ST) Pressure deviation/ speed	(SO) Sound absorber	Sound absorbers can be mounted in the high pressure system.
	(SO) Pressure accumulator	In systems with substantial pressure deviations an accumulator can be installed.
	(SO) Pipe size increase	At high speeds and with many pipe bendings an increase in pipe diameter is recommended.
(ST) Hydraulic engine / power pack	(SO) Suspension	Mounted/suspended with absorbers with flexible connections (hose connections)
(A) Hydraulic engine / power pack	(SO) Sealing	The component can be installed in an airproof box. Remember to take into consideration heat emission, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.

8.7 Engine room: noise from ventilation

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
ST) Air duct rumble	(SO) Reinforcement	Cross bracing of plate areas or bending the plates (pyramidal shape).
	(SO) Silencing mass	Silencing mass on plate area as bitumen plates or coating.
	(SO) Lower speed	Larger duct to reduce air speed.
	(SO) Sleek Transitions	Avoid sharp elbows and large changes in cross cut.
(ST + A) Ventilator	(SO) Modification	Flexible suspension of ventilator, change number of revolutions, replace rotor.
	(SO) New ventilator	Decrease number of revolutions, blades with low noise level.
(A) Air noise in duct	(S) Absorptive material	Absorptive material with thin plastic coating to avoid tearing.
	(S) Sound absorbers	Mount sound absorbers in the air ducts.
	(S) Lower speed	Enlarge the duct cross cut or increase number of air ducts to reduce air speed.
(A) Air noise in blow-off	(S) Silenced blow-off valve	Special valves or valves with larger openings to reduce opening speed.
(A) Air noise in air diffusion	(S) Baffles	Baffles inside air intake grill. Requires extra space.
	(S) Larger opening	Larger air intake grill with smooth transition to air duct cause an intake speed reduction.

8.8 Accommodation: noise from main engine

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
ST) General	(SO) Adjusting main engine	Ensures a minimum of imbalance in order to avoid any further transmission of noise.
	(SO) Correct operation mode for main engine	To the extent possible revolutions and propeller pitch must be adjusted to reduce noise and vibration.
	(SO) Correct alignment of main engine	Please make sure that alignment of main engine, gear and shaft is correct.
	(SO) Flexible mounting of main engine with fixed mounted separate gear (with integrated single direction thrust bearing)	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine with bolted gear and separated fixed single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Fixed single direction thrust bearing is installed. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. The absorbers below the gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling is placed after gear. The absorbers below the main engine/gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Mounting of main engine	(SO) Sealing the engine	When the main engine is the main noise source it can be necessary to seal the engine. This must be combined with flexible mounting of the engine. When sealing it is important to ensure that the necessary cooling and air is present. The air supply is carried out with absorbing labyrinth openings. All lead-ins must be tightly and flexibly sealed. This solution requires a lot of space around the engine.
	(S) Sealing engine room from noise penetration	When sealing the engine room all surfaces are insulated (rock wool and galvanized sheet) and lead-ins and component mountings are insulated.
	(S) Absorption panels, noise reduction in rooms.	For noise reduction in engine room freely hanging absorption systems for reduction of the reverberation is used. The system must not absorb oil fumes.
	(S) Packings in doors, openings, etc.	Close-fitting rubber profile packings are mounted in doors, hatches, etc.

8.9 Accommodation: noise from exhaust system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Mounting of exhaust system	(SO) General	All fixed spots between structure and exhaust must be removed. Expansion joints must never be fully compressed or extracted. The exhaust with absorber must not hang in or be supported by the expansion joints.
	(SO) Mounting sound absorber	Sound absorbers can be mounted on absorbing elements of rubber or full-metal. At the top high absorbers can be supported by a ring of wire pads (compressed steel wool).
	(SO) Mounting pipes	Support of the exhaust pipe can be done in the same way as with the sound absorber.
	(SO) Rain cap on exhaust pipe	Is carried out with fixed rain cap with overflow and coaming on top of funnel. The exhaust pipe must not touch the funnel top (use wire pads or profiled wire).
(A) Radiation of sound from exhaust system	(SO) Insulating sound absorber with pipes.	Thorough insulation and sealing of exhaust pipe and sound absorber also at suspension, flanges and expansion joints.
	(SO) New sound absorber	High efficient sound absorber with extra absorbing features designed specifically to the individual vessel. This normally requires extra space.
	(SO) Tuning the exhaust system	Tuning the entire exhaust system to avoid any resonance.
(A) Radiation of sound from exhaust system	(S) Insulating casing	Insulating surfaces towards accommodation.
(A) Standing sound waves in casing	(S) Baffles in casing	Sound baffles (absorptive panels) or insulation of side sections reduce standing sound waves and noise from the exhaust. Ensure free air flow in casing.

8.10 Accommodation: noise from propellers

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Cavitation	(SO) New/modified propellers	New propellers adapted to the wake field. Possibly nozzle propellers. Old propeller systems can often be improved when replaced as new and improved calculation methods for optimizing drawing power and noise are available.
	(SO) Changing blade tilt	Low-noise shape of blade tilt (this might have an impact on drawing power).
	(S) Changing increase	If any problems are experienced at a certain increase or number of revolutions try to avoid this.
	(S) Area above propellers	Hull plate reinforcement above the propellers by means of bracing and/or thicker plates.
		Mounting bitumen/vibration reduction system material or viscoelastic sandwich system on hull plate above propellers and on deck.
		Absorptive material in rooms with reverberation will reduce the reverberation time and subsequently the noise in the room.
		Place cement in hull plate area above propellers.
	(S) Insulating engine room towards propellers	Insulating abaft bulkhead and hull plate.
	(S) Changing trim	Trimming the vessel to obtain best working conditions and the lowest possible noise level.
	(SO) Placing of Zink	Zink must be placed in current paths to avoid unnecessary eddy currents around propellers.
(ST) Noise from nozzle	(SO) Reinforcement of nozzle shaft	Please ensure that nozzle shaft in hull is fixed and efficiently mounted. Soft plate areas must be strengthened.

8.11 Accommodation: noise from engines, pumps, etc.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Balancing	(SO) Repairs	The pump must be balanced, bearings without backlash, etc.
(ST) Wrong size/capacity	(SO) New component	Make sure the size is right. If the pump is too small there is a risk of cavitation and damage and subsequently noise and vibration.
(ST) Mounting of machinery	(SO) Solid foundation	Foundation for pumps and engines must be rigid and thoroughly mounted to the construction.
	(SO) Absorbers	Must be placed on rubber absorbers/mats.
(ST) Connections	(SO) Flexible connections	When mounting a component flexibly all connections must, whenever possible, be flexible.
A) Radiation from component	(SO) Sealing	Many electric motors come with noise absorbing casings.
		The component can be mounted in a sound absorbing case. Take into consideration heat release, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.
	(SO) Shielding	If sealing is not possible absorptive panels for shielding can be mounted.

8.12 Accommodation: noise from piping system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Speed/ pipe diameter	(SO) Changing the pipe dimensioning	At high speeds/pressure this can be solved by enlarging the pipe diameter.
(ST) Pipe suspension	(SO) General	Pipe brackets must be placed on stay or similar fixed point – not in the middle of a soft plate.
	(SO) Flexible mounting	Pipes must be suspended in either flexible brackets or brackets with rubber lining.
(ST) Pipe rigidity	(SO) U-bend	Long rigid pipes can be mounted with U-bend. Make sure that pipes are not attached to two fixed points without the ability to move.
(ST) Pipe penetration	(SO) Waterproof lead-ins	If possible use flexible lead-ins – if not it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	When using open lead-ins please make sure that the pipe is free from the opening and does not clank.
(ST) Valves	(SO) Changing valve type	Replace valves with butterfly valves if possible as they generate less noise.
(ST) Resonance/natural frequency in pipe system	(SO) Changing suspension	Pipe brackets are moved or added to reduce vibration.
	(SO) Noise reduction of pipes	Sound absorbing material – either a mat or by spray coating can be placed on thin-walled pipes.
	(SO) U-bend	U-bend can be greased to break the pattern.
(A) Penetrations	(SO) Waterproof lead-ins	If possible use flexible lead-ins otherwise it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	At non waterproof lead-ins the hole can be closed with a rock wool plate on each side.
(A) Noise radiation from pipes	(SO) Pipe insulation	Rock wool pipe insulation or similar for sealing can be mounted where pipes radiate noise directly.
	(SO) Insulation	Armaflex is primarily used for heat protection but it also provides a smaller noise reduction.

8.13 Accommodation: noise from ventilation

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Air duct rumble	(SO) Reinforcement	Cross bracing of plate areas or bending the plates (pyramidal shape).
	(SO) Silencing mass	Silencing mass on plate area as bitumen plates or coating.
	(SO) Lower speed	Larger duct to reduce air speed.
	(SO) Sleek Transitions	Avoid sharp elbows and large changes in cross cut.
(ST+A) Ventilator	(SO) Modification	Flexible suspension of ventilator, change number of revolutions, replace rotor.
	(SO) New ventilator	Decrease number of revolutions, blades with low noise level.
(A) Air noise in duct	(S) Absorptive material	Absorptive material with thin plastic coating to avoid tearing.
	(S) Sound absorbers	Mount sound absorbers in the air ducts.
	(S) Lower speed	Enlarge the duct cross cut or increase number of air ducts to reduce air speed.
(A) Air noise in blow-off	(S) Silenced blow-off valve	Special valves or valves with larger opening to reduce opening speed.
(A) Air noise in air diffusion	(S) Baffles	Baffles inside air intake grill. Requires extra space.
	(S) Larger openings	Larger air intake grill with smooth transition to air duct cause an intake speed reduction.

8.14 Accommodation: noise from hydraulic systems

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Piping/ suspension	(SO) General	Avoid any sharp elbows and transitions. Avoid straight pipes between two structure fixing points. Suspension must be flexible whenever possible. Flexible connections at bulkhead lead-in, engine and pump.
(ST) Pressure deviation/ speed	(SO) Sound absorber	Sound absorbers can be mounted in the high pressure system.
	(SO) Pressure accumulator	In systems with substantial pressure deviations an accumulator can be installed.
	(SO) Pipe size increase	At high speeds and with many pipe bendings an increase in pipe diameter is recommended.
(ST) Hydraulic engine / power pack	(SO) Suspension	Mounted/suspended with absorbers with flexible connections (hose connections)´.
(ST) Hydraulic engine / power pack	(SO) Sealing	The component can be installed in an airproof box. Remember to take into consideration heat emission, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.

8.15 Accommodation: in general

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) In general	(S) Joint filling	Wherever there is a risk of plates or similar rubbing or banging against each other a flexible and compact joint is made.
Structure	(S) Insulating off	The structure is insulated off the floor/bulkhead with rubber band and rubber bushing
Sealing	(S) Sealing openings	Soft sealing is put in doors, hatches, etc.

8.16 Accommodation: floor

Floor type	Solution type (SO-source, S-symptom)	Description
Wooden floor	(S) Insulating off	Floor on joists with rubber interlayer and flexible joint along edges and bulkhead.
	(S) Mat	Solid rubber mat on floor and heavy carpet.
	(S) Absorption material	Fluent absorption material sprayed on the bottom or absorption plate glued on upper or lower side.
	(S) Sandwich	Sandwich consisting of: existing floor an on top core material and a top coating of either fibre glass or veneer with joint along edges and lead-ins.
	(S) Floating floor	30-60 mm Rock wool marine slabs 140 kg/m3 + wooden plate.
Steel floor	(S) Strengthening	Reinforcement can be mounted in case of vibration.
	(S) Mat	Rubber mat and solid carpet.
	(S) Absorption material	Fluent absorption material sprayed on the bottom or absorption plate glued on upper or lower side.
	(S) Existing concrete floor	Rubber mat and solid carpet.
	(S) New concrete floor	Latex concrete floor. A flexible joint is put around lead ins and along edges.
	(S) Floating floor	When using floating floor it is important to ensure that the entire floor plate does not connect with the surrounding structure and that lead ins are relieved by joint filler.
	(S) Standard floating floor	30-60mm Rock wool marine slabs 140 kg/m3 30-50mm concrete or similar + floor coating.
	(S) Low height floating floor	30-60mm Rock wool marine slabs 140 kg/m3 2-4mm steel plate + floor coating.
	(S) Efficient floating floor	Even deck, 2-3mm visco-elastic coating with 1.5-2mm steel plates 400*500mm laid as tiles, 30-60mm Rock wool marine slabs 140 kg/m3 30-50mm, special absorbing concrete + floor coating.
	(S) Efficient low floating floor	Even deck, 2-3mm visco-elastic coating with 1.5-2mm steel plates 400*500mm laid as tiles, 30-60mm Rock wool marine slabs 140 kg/m3 30-50mm, special steel sandwich plate on top + floor coating.

8.17 Accommodation: bulkhead

Bulkhead type	Solution type (SO-source, S-symptom)	Løsning
Wooden bulkhead	(S) Strengthening	The bulkhead can be strengthened by solid battens
	(S) Reduction	Reduction using sprayed on absorption mass.
		Reduction using a clued on heavy bitumen plate.
Steel bulkhead	(K) Strengthening	Steel bulkhead can be further strengthened with reinforcement if still vibrating considerably.
	(S) Reduction	Mounting of visco-elastic mass and steal plate.
	(S) Lead ins	To avoid fixing the lead ins in the bulkhead are made flexible, if possible.
Floating bulkhead ceiling	(S) In general	At structure borne noise the bulkhead is noise reduced by absorption material, bitumen plate, 100 mm Rock wool 32 kg/m3 batts and plastic film (vapour barrier).
	(S) Finished bulkhead panel elements	At floating floor the bullhead is placed on the floating floor. The top connection is made flexible. At ordinary floor a rubber band is placed in the base frame.
	(S) Wooden panels	The frame is insulated off the steel using rubber rubber bushing, if necessary a heavy MDF plate is put on a rubber joint/band in order to insulate off. Openings and similar is insulated of the steel.
	(S) Reduction of reverberation time	Mounting of absorption panels on bulkheads and other critical places reduce the reverberation time. If possible move them 20-50mm. away from the bulkhead.
	(S) Bulkhead connections	Cables and similar must have soft bendings at switches, etc.

8.18 Accommodation: ceiling

Ceiling type	Solution type (SO-source, S-symptom)	Description
In general	(S)	Lower side of deck is insulated also around stay.
Ceiling plates (wood)	(S) Flexible framing	The frame is insulated of the steel with rubber rubber bushing, the plates are mounted with flexible joints along the edges.
Finished ceiling panel elements	(S) Finished ceiling panel elements	Panels with framing are flexibly mounted to avoid direct contact with bulkhead or deck.
Absorption panels	(S) Reverberation time reduction	Absorption plate cassettes can be directly mounted to the ceiling panels or below the ceiling

8.19 Working below deck: noise from main engine

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) General	(SO) Adjusting main engine	Ensures a minimum of imbalance in order to avoid any further transmission of noise.
	(SO) Correct operation mode for main engine	To the extent possible revolutions and propeller pitch must be adjusted to reduce noise and vibration.
	(SO) Correct alignment of main engine	Please make sure that alignment of main engine, gear and shaft is correct.
(ST) Mounting of main engine	(SO) Flexible mounting of main engine with fixed mounted separate gear (with integrated single direction thrust bearing)	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine with bolted gear and separated fixed single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Fixed single direction thrust bearing is installed. Flex-coupling between main engine and gear. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling between main engine and gear. The absorbers below the gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.
	(SO) Flexible mounting of main engine and bolted gear with integrated single direction thrust bearing	Engine is placed on vibration absorbers. The absorbers must be designed against increased dynamic and axial load compared with other cargo vessels. Flex-coupling is placed after gear. The absorbers below the main engine/gear must be designed for axial load. This can be done with hard flexible limit stops. It is recommended that the actual design is carried out by a qualified and competent supplier. It must be ensured that the bed-plate is rigid as the engine is not a part of the rigidity.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(A) Noise radiation	(SO) Sealing the engine	When the main engine is the main noise source it can be necessary to seal the engine. This must be combined with flexible mounting of the engine. When sealing it is important to ensure that the necessary cooling and air is present. The air supply is carried out with absorbing labyrinth openings. All lead-ins must be tightly and flexibly sealed. This solution requires a lot of space around the engine.
	(S) Sealing engine room from noise penetration	When sealing the engine room all surfaces are insulated (rock wool and galvanized sheet) and lead-ins and component mountings are insulated.
	(S) Absorption panels, noise reduction in rooms	For noise reduction in engine room freely hanging absorption systems for reduction of the reverberation is used. The system must not absorb oil fumes.
	(S) Packings in doors, openings, etc.	Close-fitting rubber profile packings are mounted in doors, hatches, etc.

8.20 Working below deck: noise from exhaust system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Mounting of exhaust system	(SO) General	All fixed spots between structure and exhaust must be removed. Expansion joints must never be fully compressed or extracted. The exhaust with absorber must not hang in or be supported by the expansion joints.
	(SO) Mounting sound absorber	Sound absorbers can be mounted on absorbing elements of rubber or full-metal. At the top high absorbers can be supported by a ring of wire pads (compressed steel wool).
	(SO) Mounting pipes	Support of the exhaust pipe can be done in the same way as with the sound absorber.
	(SO) Rain cap on exhaust pipe	Is carried out with fixed rain cap with overflow and coaming on top of funnel. The exhaust pipe must not touch the funnel top (use wire pads or profiled wire).
(A) Radiation of sound from exhaust system	(SO) Insulating sound absorber with pipes	Thorough insulation and sealing of exhaust pipe and sound absorber also at suspension, flanges and expansion joints.
	(SO) New sound absorber	High efficient sound absorber with extra absorbing features designed specifically to the individual vessel. This normally requires extra space.
	(SO) Tuning the exhaust system	Tuning the entire exhaust system to avoid any resonance.
(A) Radiation of sound from exhaust system	(S) Insulating casing	Insulating surfaces towards accommodation.
(A) Standing sound waves in casing	(S) Baffles in casing	Sound baffles (absorptive panels) or insulation of side sections reduce standing sound waves and noise from the exhaust. Ensure free air flow in casing. Ensure free air flow in casing.

8.21 Working below deck: noise from engines, pumps, etc.

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Balancing	(SO) Repairs	The pump must be balanced, bearings without backlash, etc.
(ST) Wrong size/capacity	(SO) New component	Make sure the size is right. If the pump is too small there is a risk of cavitation and damage and subsequently noise and vibration.
(ST) Mounting of machinery	(SO) Solid foundation	Foundation for pumps and engines must be rigid and thoroughly mounted to the construction.
(ST) Connections	(SO) Flexible connections	When mounting a component flexibly all connections must, whenever possible, be flexible.
(A) Radiation from component	(SO) Sealing	Many electric motors come with noise absorbing casings.
		The component can be mounted in a sound absorbing case. Take into consideration heat release, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.
	(SO) Shielding	If sealing is not possible absorptive panels for shielding can be mounted.

8.22 Working below deck: noise from piping systems

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Speed/ pipe diameter	(SO) Changing the pipe dimensioning	At high speeds/pressure this can be solved by enlarging the pipe diameter.
(ST) Pipe suspension	(SO) General	Pipe brackets must be placed on stay or similar fixed point – not in the middle of a soft plate.
	(SO) Flexible mounting	Pipes must be suspended in either flexible brackets or brackets with rubber lining.
(ST) Pipe rigidity	(SO) U-bend	Long rigid pipes can be mounted with U-bend. Make sure that pipes are not attached to two fixed points without the ability to move.
(ST) Pipe penetration	(SO) Waterproof lead-ins	If possible use flexible lead-ins – if not it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	When using open lead-ins please make sure that the pipe is free from the opening and does not clank.
(ST) Valves	(SO) Changing valve type	Replace valves with butterfly valves if possible as they generate less noise.
(ST) Resonance/natural frequency in pipe system	(SO) Changing suspension	Pipe brackets are moved or added to reduce vibration.
	(SO) Noise reduction of pipes	Sound absorbing material – either a mat or spray coating can be placed on thin-walled pipes.
	(SO) U-bend	U-bend can be greased to break the pattern.
(A) Penetrations	(SO) Waterproof lead-ins	If possible use flexible lead-ins otherwise it must be ensured that the pipe is not fixed at both sides.
	(SO) Open lead-ins	At non waterproof lead-ins the hole can be closed with a rock wool plate on each side.
(A) Noise radiation from pipes	(SO) Pipe insulation	Rock wool pipe insulation or similar for sealing can be mounted where the pipes radiate noise directly.
	(SO) Insulation	Armaflex is primarily used for heat protection but it also provides a smaller noise reduction.

8.23 Working below deck: noise from hydraulic systems

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Piping/ suspension	(SO) General	Avoid any sharp elbows and transitions. Avoid straight pipes between two structure fixing points. Suspension must be flexible whenever possible. Flexible connections at bulkhead lead-in, engine and pump.
(ST) Pressure deviation/ speed	(SO) Sound absorber	Sound absorbers can be mounted in the high pressure system.
	(SO) Pressure accumulator	In systems with substantial pressure deviations an accumulator can be installed.
	(SO) Pipe size increase	At high speeds and with many pipe bendings an increase in pipe diameter is recommended.
(ST) Hydraulic engine / power pack	(SO) Suspension	Mounted/suspended with absorbers with flexible connections (hose connections).
(ST) Hydraulic engine / power pack	(SO) Sealing	The component can be installed in an airproof box. Remember to take into consideration heat emission, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.

8.24 Working below deck: noise from ventilation

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Air duct rumble	(SO) Reinforcement	Cross bracing of plate areas or bending the plates (pyramidal shape).
	(SO) Silencing mass	Silencing mass on plate area as bitumen plates or coating.
	(SO) Lower speed	Larger duct to reduce air speed.
	(SO) Sleek Transitions	Avoid sharp elbows and large changes in cross cut.
(ST + A) Ventilator	(SO) Modification	Flexible suspension of ventilator, change number of revolutions, replace rotor.
	(SO) New ventilator	Decrease number of revolutions, blades with low noise level.
(A) Air noise in duct	(S) Absorptive material	Absorptive material with thin plastic coating to avoid tearing.
	(S) Sound absorbers	Mount sound absorbers in the air ducts.
	(S) Lower speed	Enlarge the duct cross cut or increase number of air ducts to reduce air speed.
(A) Air noise in air diffusion	(S) Baffles	Baffles inside air intake grill. Requires extra space.
	(S) Larger openings	Larger air intake grill with smooth transition to air duct cause an intake speed reduction.

8.25 Working below deck

Cause (ST-structure, A-air borne)	Solution type (SO-source, S-symptom)	Description
(A) Noise from deck	(S) Rubber mats	Solid rubber mat can be put on floor.
(A) Noise in the room	(S) Absorbing panels	Absorbing panel cassettes can be mounted between ribs below deck. No contact with deck.
(A) Noisy equipment	(S) Curtain	Noise equipment can be sealed with a plastic curtain.
(A) Clanking from loose equipment	(S) Fixing loose equipment	Chains, shovels, shackles, etc. are placed on wooden lining, rubber mats or similar.

8.26 Working on open deck

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Mounting of exhaust system	(SO) General	All fixed spots between structure and exhaust must be removed. Expansion joints must never be fully compressed or extracted. The exhaust with absorber must not hang in or be carried by the expansion joints.
	(SO) Mounting sound absorber	Sound absorbers can be mounted on absorbing elements of rubber or full-metal. At the top high absorbers can be supported by a ring of wire pads (compressed steel wool).
	(SO) Mounting pipes	Support of the exhaust pipe can be done in the same way as with the sound absorber.
	(SO) Rain cap on exhaust pipe	Is carried out with fixed rain cap with overflow and coaming on top of funnel. The exhaust pipe must not touch the funnel top (use wire pads or profiled wire).
(A) Air noise in duct	(S) Absorptive material	Absorptive material with thin plastic coating to avoid tearing.
	(S) Sound absorbers	Mount sound absorbers in the air ducts.
	(S) Lower speed	Enlarge the duct cross cut or increase number of air ducts to reduce air speed.
(A) Air noise in blow-off	(S) Silenced blow-off valve	Special valves or valves with larger openings to reduce opening speed.
(A) Air noise in air diffusion	(S) Baffles	Baffles inside air intake grill. Requires extra space.
	(S) Larger opening	Larger air intake grill with smooth transition to air duct causes an intake speed reduction.

8.27 Working on open deck: noise from hydraulic system

Cause (ST-structure A-air borne)	Solution type (SO-source, S-symptom)	Description
(ST) Piping/ suspension	(SO) General	Avoid any sharp elbows and transitions. Avoid straight pipes between two structure fixing points. Suspension must be flexible whenever possible. Flexible connections at bulkhead lead-in, engine and pump.
(ST) Pressure deviation/ speed	(SO) Sound absorber	Sound absorbers can be mounted in the high pressure system.
	(SO) Pressure accumulator	In systems with substantial pressure deviations an accumulator can be installed.
	(SO) Pipe size increase	At high speeds and with many pipe bendings an increase in pipe diameter is recommended.
(ST) Hydraulic engine / power pack	(SO) Suspension	Mounted/suspended with absorbers with flexible connections (hose connections).
(ST) Hydraulic engine / power pack	(SO) Sealing	The component can be installed in an airproof box. Remember to take into consideration heat emission, cooling air, etc. Air intake and outlet must be made as an airlock. All connections must be insulated.

Chapter 9 Flexible mounting of machinery

9.1 Introduction

The main machinery is one of the most powerful noise sources on board vessels. Together with the individual units connected to the main machinery (turbo-charger, gear, etc.) various noise types are created. Especially in fishing vessels the main machinery provides a lot of noise in the accommodation area as it is often placed relatively close to each other.

Flexible mounting of machinery is one way to reduce the noise – especially when the accommodation area is close to the main machinery.

Flexible mounting of machinery primarily provides a reduction in the structure borne noise. When main machinery is fixed the noise is transmitted through the bed-plate to the rest of the hull. Flexible mounted machinery isolates the engine from the bed-plate which means that the noise transmission can be reduced with up to 15 dB(A).

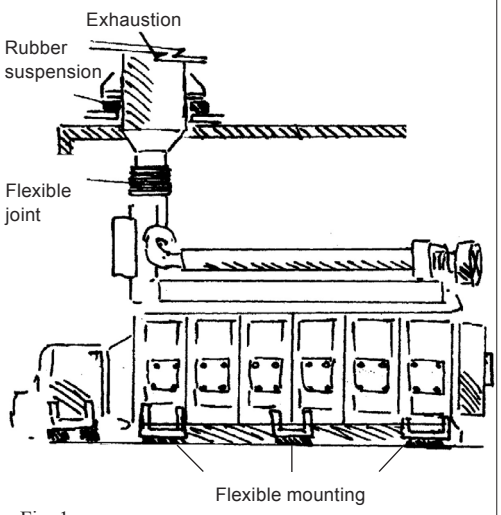


Fig. 1

In new vessels – and in vessels where main machinery is a significant noise source – the noise threshold limit values set by the Danish Maritime Authorities (DMA) more or less indicate that flexible mounting of machinery is necessary.

In Appendix 1 in "How to Handle Noise and Vibrations in Ships" the maximum and recommended noise threshold limit values set by the DMA are shown. How to handle and interpret them in practice is stated in the current circular from the DMA. It indicates that it can be difficult to observe the recommended threshold limit values – and also the maximum values (see app. 2, Technical regulation on noise and vibrations in ships)

The DMA emphasises that the best known solutions must be used to reduce the noise in the best possible way. In order to ensure that the most effective noise reduction steps are taken as early in the process as possible the circular provides guidelines for the following vessels and situations:

1. New fishing vessels L ≥ 15metres
2. New fishing vessels L < 15metres
3. Purchased fishing vessels regardless the size.
4. Rebuilding existing fishing vessels
5. Rebuilding after damage
6. Deceleration of main engine

Please contact The Danish Fishermen's Occupational Health Service for further information.

9.2 Flexible mounting – how effective is it?

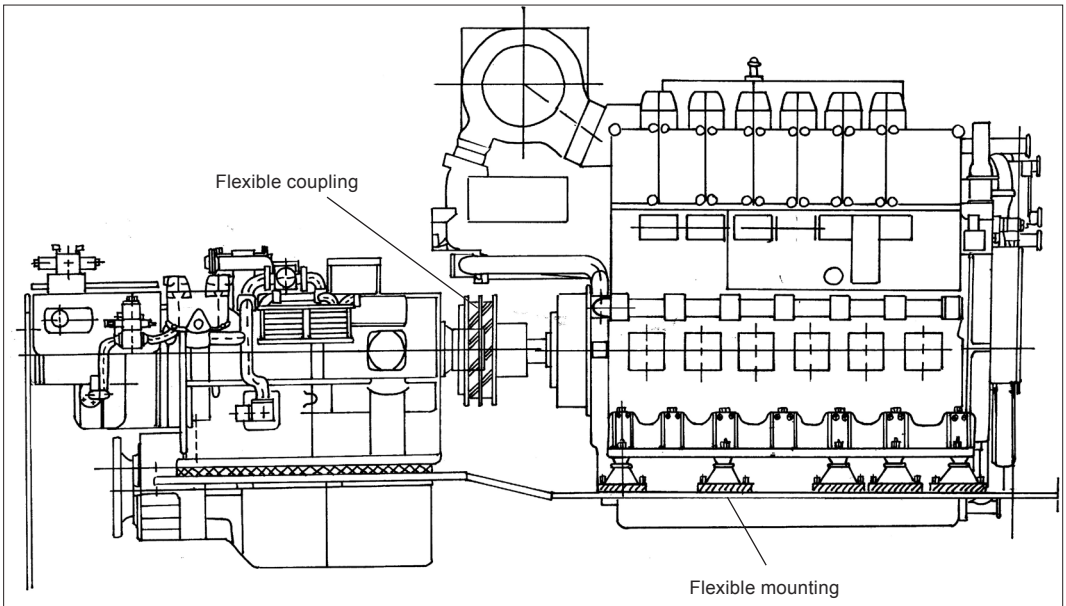


Fig. 2

How efficient a sound insulating step is must of course be seen in relation to the costs against the noise reduction obtained. When it comes to flexible mounting numerous examples indicate that this kind of noise reduction is very efficient. Unfortunately it can also be a very expensive solution.

Engine suppliers as for instance MAN B&W Alpha Diesel, Wärtsilä, Mitsubishi and Caterpillar have in many years delivered flexible mounted machinery for fishing vessels. Experience gained shows that a vibration reduction of up to 90% can be obtained. This equals a noise reduction of up to 15 dB(A).

It has not been possible to get hold of any documentation on the extent of the noise reduction obtained when mounting flexibly. Usually flexible mounting is used in new buildings. Old machinery is very rarely replaced by flexible mounted machinery. It is however still very important to keep in mind that efficient noise reduction is only possible if all noise sources are included in the assessment. In other words it is not recommended to use a lot of money on flexibly mounting the main engine if the main noise source is the propellers.

If the main engine is in perfect running conditions and does not contribute significantly to the noise level, the noise from propellers will still maintain the noise on the same level. It is important to reduce the most significant noise sources but the general noise reduction in the rest of the vessel must not be ignored.

9.3 Flexible mounting requires thought

Flexible mounting requires thought. You have to be both careful and cautious. The risk of choosing the wrong solution is high. Subsequently it can result in considerable maintenance costs, earning loss and a lot of frustration due to engine problems.

It is therefore important always to choose a supplier with the necessary knowledge and skills to solve the problem. If not it will go wrong. Flexible mounting is not only a matter of getting some "rubber-blocks" (vibration absorbers) and mount them under the main engine. When mounting flexibly all connections must be taken into consideration: the gear, the durability of the rubber blocks, centre of gravity, thrust load from the propeller shaft, the coupling between the gear and the main engine, etc. Altogether it is significant to ensure that the entire machinery has been adjusted to the flexible mounting. All connections must be flexible and no components must be fixed between hull and engine.

The following section describes the elements which must be mounted in order to make the machinery function properly. The necessary parts required for flexible mounted machinery consists of the following:

- Vibration absorbers (rubber supports)
- Flexible coupling (high-flexible coupling) between gear and main machinery
- Flue gas compensator
- Flexible cables
- Hydraulic compensator

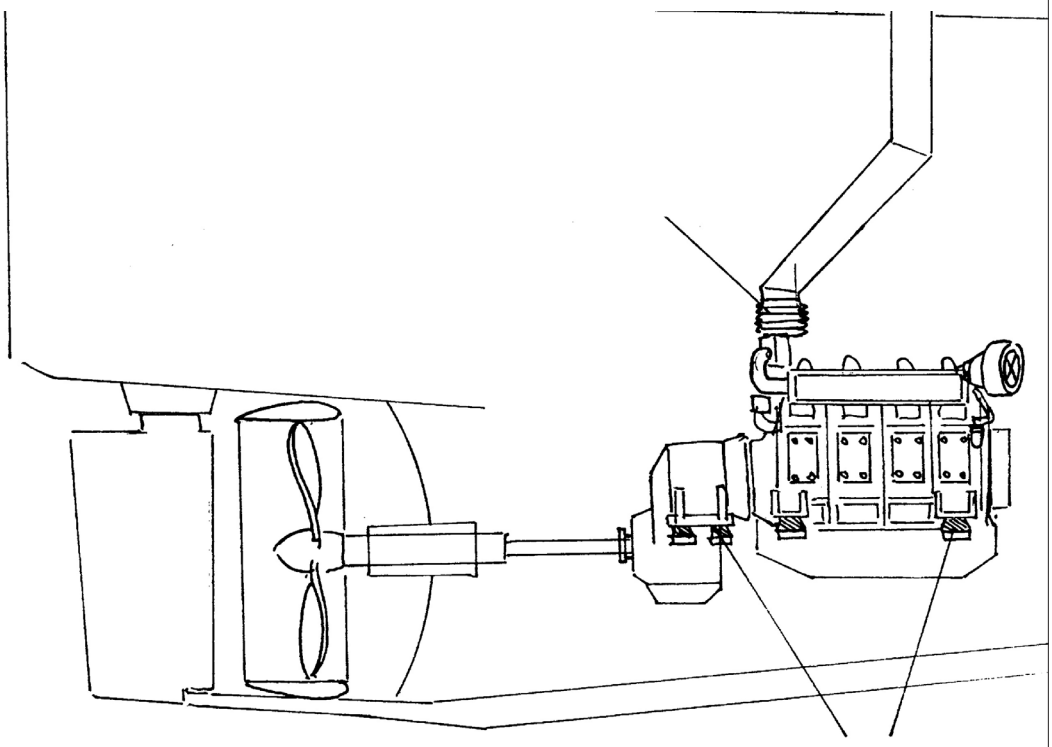


Fig. 4

9.4 Vibration absorbers – rubber blocks

Vibration is often caused by unadjusted rotating or forward and backward moving parts. The extent of the vibration depends upon the inadjustment and the speed.

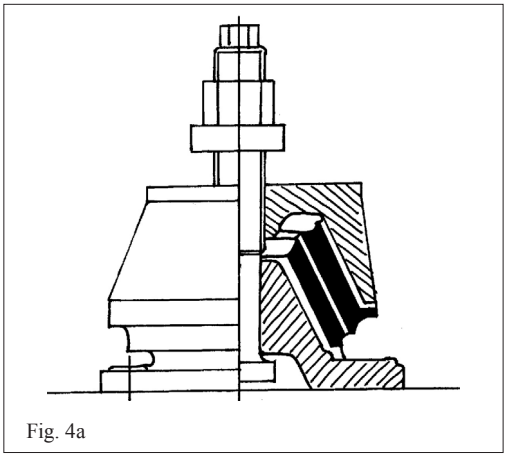


Fig. 4a

If the engine is fixed on the bed-plate the vibration will transmit further into the vessel. At worst it can cause damage to various components and increase the general wear and tear. At the same time unnecessary high vibration and noise levels are created annoying the people staying close to the engine.

As all machines to a certain extent are unadjusted transmission of vibration to the rest of the vessel will always take place. But if the fixed connection between engine and bed-plate is replaced by vibration absorbers the inadjustment of the engine does not impact the bed-plate to the same extent.

Vibration absorbers consist of a rubber block (natural rubber) onto which two steel flanges is glued. The design varies depending on where the vibration absorbers are placed and to which purpose they are intended. The hardness of the rubber also varies.

Natural rubber is used as opposed to synthetic rubber types as the natural product possesses a series of physical features specifically suitable for this purpose. Natural rubber possesses high dynamic strength, low permanent deformation and is relatively resistant towards temperature fluctuation.

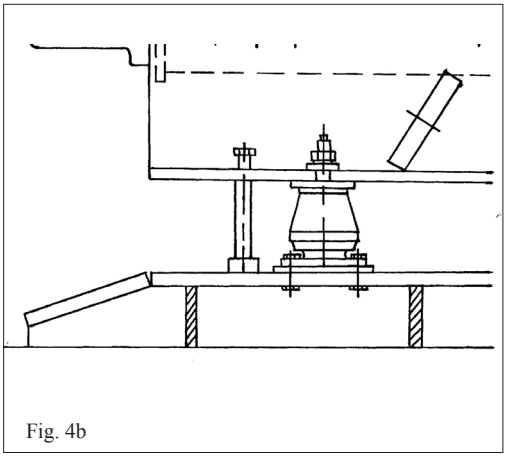


Fig. 4b

Figure 4a – 4b illustrate the typical design of a vibration absorber for maritime use.

9.4.2 The limitations of vibration absorbers

When using vibration absorbers of natural rubber please note the following:

1. Only expose natural rubber to compressive and shearing forces or a combination of both. Please avoid drawing forces.
2. Please make sure that the rubber (in case of high deflection) is free to move without rubbing or touching any other construction components.
3. The temperature must not exceed +70 degrees Celsius. High temperatures shorten the life of the rubber. At temperatures below -30 degrees Celsius the elasticity of the rubber is reduced. However, such temperatures are very rarely experienced in fishing vessels.
4. Natural rubber is resistant towards inorganic acids, salt and leaching solution ex-

cept from concentrated hydrochloric acid and nitric acid.

5. Ozone and mineral oils do affect rubber. However, the damages are often only superficial and the elasticity is only affected to a minimum. Refined oil products as: diesel oil, hydraulic oil, fuel and paraffin do penetrate the rubber making it bubbly and soft. Therefore, vibration absorbers must be protected against any contact with these substances.
6. If possible always use vibration absorbers with an natural frequency different to that of the engine.
7. When the rubber is exposed to a deformation created by a constant load pressure marks in the rubber will occur.

The life of the vibration absorbers depends upon the operation mode. If maintained properly the typical life span is between 10 to 15 years.

9.4.3 Fixed gear with flexible coupling

Between gear and main engine a flexible mounted machinery will create more vibration than and ordinary fixed machinery. In order to absorb the transmission of power a highly flexible coupling between the fixed gear and the flexible mounted main engine must be mounted. This can also be done by means of a combined coupling or clutch mounted onto the flywheel.

The flexible couplings are specifically designed to absorb torsions and possess excellent absorbing features. It is important that the natural frequency of the coupling is not the same as that of the adjuster in order to prevent the machinery from self-oscillating.

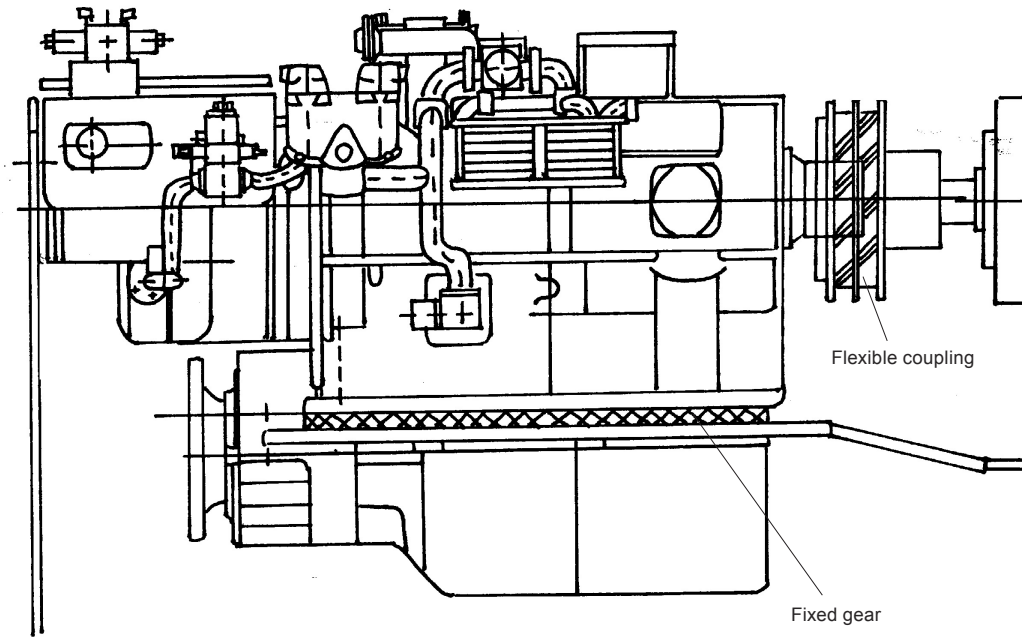


Fig. 5

9.4.4 Compensators and mounting of flue gas system

From all machinery both noise and vibration is transmitted through the flue gas system. If the exhaust system is fixed, noise and vibration will be transmitted into the structure of the vessel and will be heard in other places of the vessel. However, if the flue gas system is mounted flexibly a significant reduction in both noise and vibration can be obtained.

Companies as Rubber Design claim that a properly designed system with flexible mounting are able to reduce the noise with up to 10 dBA within the frequency area of 45 – 4000 Hz. On the basis of weight, transmission forces, temperature and frequency area the most optimal solution is chosen.

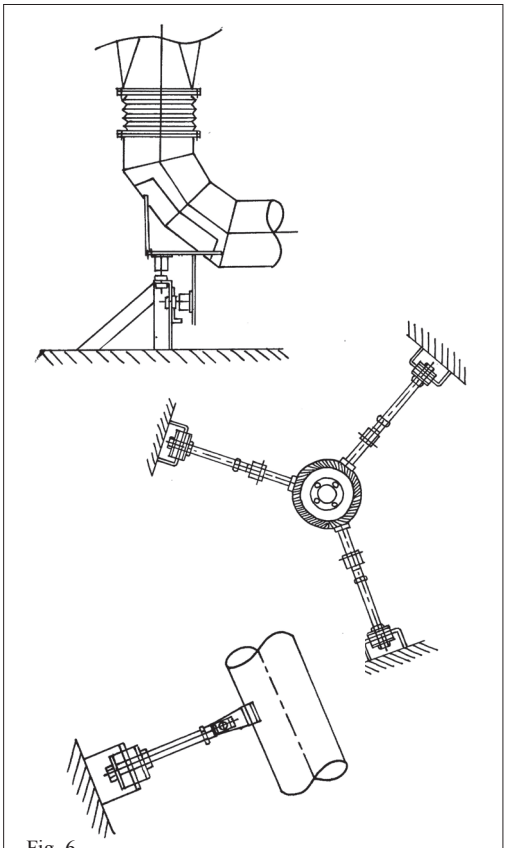


Fig. 6

Flexible flue gas compensators must also be mounted to the flue gas system. The flue gas compensator must be specifically designed to the main engine in order to absorb the vibration properly. These compensators are among other delivered by PipeCon and Discom.

9.5. Pipe connections

The design of and how to mount the piping system must be taken into consideration when dealing with flexible mounted engines. The purpose is to achieve the best possible insulation of engine against bed-plate but also to avoid unnecessary loads on the fixed pipe connections.

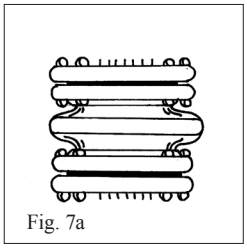


Fig. 7a

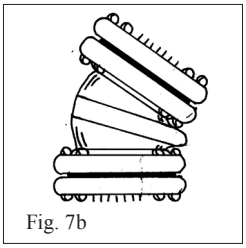


Fig. 7b

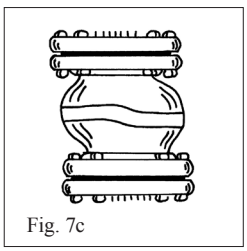


Fig. 7c

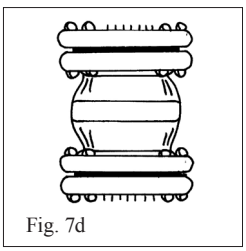


Fig. 7d

There are various options:

- Tubes (comes in both steel and rubber)
- Rubber compensators
- Fabric conpensators
- Steel compensators

Flexible tubes are primarily used for pipes with a small diameter and with a high pressure and at high temperatures. Countless tubes are available for all kinds of liquids, pressure and temperatures. If the tubes are properly mounted they are very flexible. Either by shifting

connections between engine and piping system or with a tube with “sack”. The solution with the tube provides more flexibility when mounting as inaccuracies between the fixed piping system and the engine can be absorbed by them.

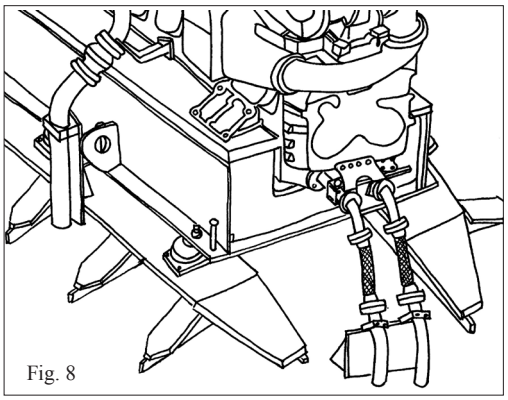


Fig. 8

Rubber compensators are among others used for cooling water connections. They have excellent features as they are very flexible and have a low spring constant both axially and laterally. However, the limitations of the rubber compensators must be investigated thoroughly prior to mounting. Please pay specific attention to their resistibility towards liquids and surroundings and also to flow, pressure and temperatures in the system.

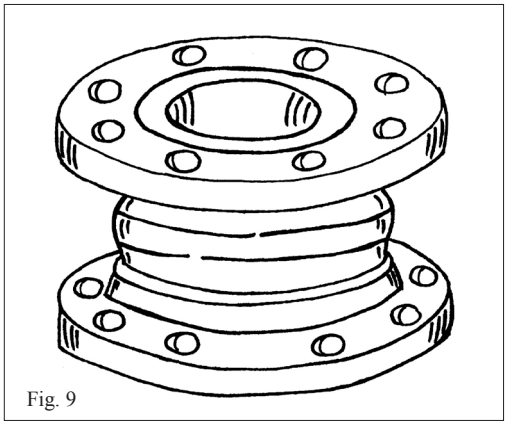


Fig. 9

Fabric compensators are only used for turbo air intake. Steel compensators can also be used.

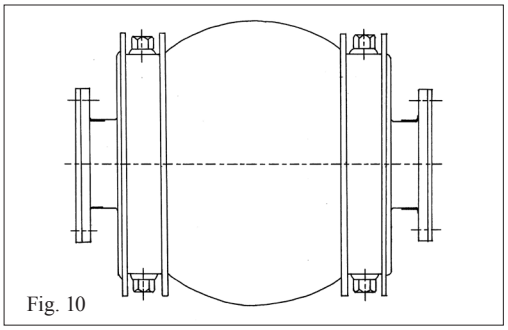


Fig. 10

Steel compensators are used where flexible tubes and rubber compensators cannot be used (both price and ability to function are taken into consideration. A tube-solution can become very expensive when using a bigger diameter). Steel compensators are primarily used for the connections between the engine turbo charger and the fixed exhaust system but can also be used in other connections – for instance water and oil systems.

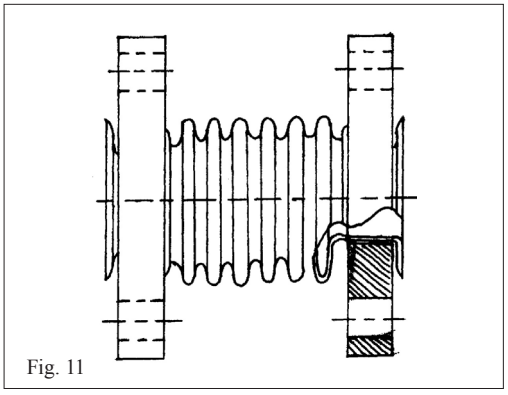


Fig. 11

The steel compensator must be chosen from the following main criteria for for instance the exhaust system:

- Low spring constant in the axial direction (the longitudinal direction of the piping) and a low spring constant in the lateral direction (the transverse direction of the piping). The spring constant determines the extent of back pressure on the flanges when load is put on the compensators (action=reaction).

To obtain the above mentioned the steel compensators must have double joints. This is important to avoid damages on the turbo-charger at:

- Engine vibration against fixed piping system.
- Thermal movements of the engine (from cold to hot engine)
- Thermal movements of the fixed piping system (from cold to hot flue gas).
- The weight of the fixed piping system.

The low spring constant prevents the joints from being damaged when turning on/off the engine as substantial vibration due to temporary resonance may occur.

- **Multi-layer joints** ensure longer life.
- **Double joints with a steel middle piece (normal pipe width)** to prevent induction of the middle piece due to vacuum.

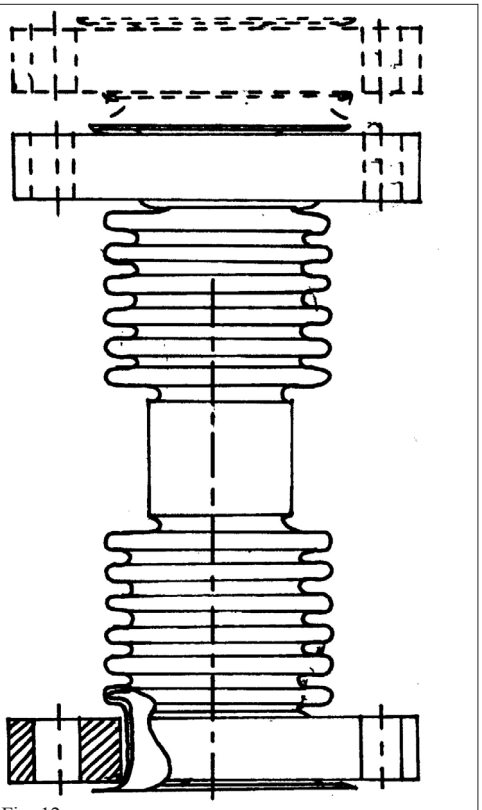


Fig. 12

9.5.2 How to install the piping system

It is important in all types of pipe connections to put at pipe clamp just after the compensator or tube. This reduces the load put on the engine connections which are specifically important at the turbo charger flange (see figure 12).

In addition it is important that the fixing of the flue gas pipes (and the entire flue gas system) is made with special absorbing elements preventing flue gas noise or pulsations from transmitting into the vessel structure creating structure borne noise or vibration.

Among other H. C. Puck delivers compensators for cooling water, fuel and air-intakes. Typically the compensators consist of two flanges and a rubber coated steel lattice reinforcement. The compensators are suitable for flexible mounted main engines as they within the standards set both can be bend, pressured, stretched and parallel displaced (see figure 13).

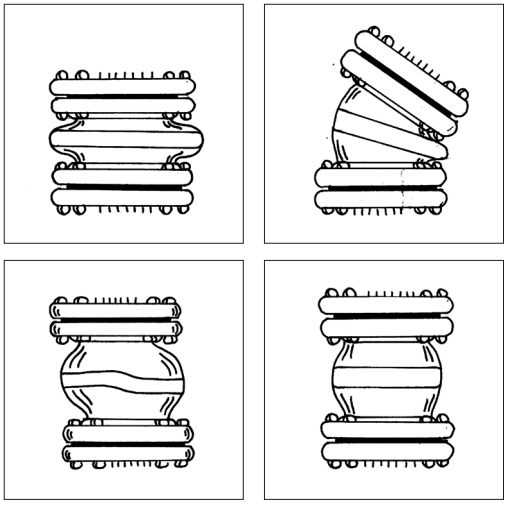


Fig. 13

9.6 Maintenance and repair

In general a flexible mounted main engine requires frequent alignment. Without frequent alignment especially the coupling – between gear and main engine - is unnecessarily worn. How complicated the alignment procedures are depends upon the rubber blocks chosen. Some rubber blocks are more suitable than others.

When choosing which flexible mounting to use please make yourself familiar with the alignment procedure of the machinery. Alignment should be easy and simple to prevent the vessel from staying in yard for too long.

In addition please make sure that crew members are aware that the vibration absorbers are not exposed to too much oil. Compensators are not damaged by occasional oil spills removed relatively quickly. However, compensators constantly exposed to mineral oils are quickly damaged.

9.7 Experience gained from existing machinery

Experience gained from existing machinery varies. In some cases the solutions chosen have caused expensive and unnecessary repairs and operational stop. Often the optimal solution has not been chosen as the shipyard, the supplier or the smith were not aware of all the things to take into consideration when mounting main machinery flexibly.

As already mentioned it requires thought to mount the main machinery on rubber blocks. A lot of factors must be taken into consideration. It is important to go through all connections and make the theoretical calculations necessary to ensure a long life of the machinery.

We recommend the following suppliers: Wärtsilä, Mitsubishi, Caterpillar and Man B&W Alpha Diesel. The experience gained from these suppliers has been positive. For instance Annalise, L56 has had a flexible mounted Wärtsilä Cummins for two year without any problems.

The Danish Fishermen's Occupational Health Service is on a regular basis in contact with fishing vessels with flexible mounted machinery and in that way we gather a lot of useful information. Please do not hesitate to contact us if you are interested in further information or if you have any questions.

Appendix 1 Suppliers of sound-absorbing materials

To read the supplierlist we refer to the Danish edition.

Appendix 2 Technical regulation on noise and vibrations in ships

Notice A Chapter III. Technical regulation on occupational health in ships

Translation: Only the Danish document has legal validity.
Danish document: "Meddelelser A Kapitel III af 1. januar 2006, Fysiske arbejdsmiljøpåvirkninger"

Part B 1 Notice A Chapter III of 1 January 2006

Part B - 1 Noise

Regulation 1 Application

1) The provisions in this part shall apply to all ships on which workers are employed.

2) The provisions shall also apply to one-man operated commercial vessels with a scantling number of or above 20.

3) The provisions have been formulated on the basis of the provisions hitherto in force in technical regulation no. 4 of 3 May 2002 on noise in ships as well as Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)

Regulation 2 Definitions

1) In this part the following definitions shall apply:
   .1 "New ship" means a ship the keel of which is laid or which is at an equivalent stage of construction on or after 1 July 2002.
   .2 "Existing ship" means a ship that is not a new ship.
   .3 "Length (L)" means the ship's length L, as defined in the relevant regulations on ship's construction and equipment etc.
   .4 "Scantling number" means the vessel's length multiplied by the vessel's breadth as defined in the relevant regulations on ship's construction and equipment etc.
   .5 "Propulsive power" means the total maximum output (MCR) in kilowatts at continuous operation of all machinery that can simultaneously propel the ship. The output is determined by the Danish Maritime Authority on the basis of the engine manufacturer's test plan forms and shall be recorded in the ship's minimum safe manning document.
   .6 "Maximum noise pressure, (P_{max})" means the greatest value of the C-weighted instantaneous noise pressure (impulse noise).
   .7 "Energy equivalent noise level, $L_{Aeq,T}$" means the constant noise pressure level, measured in dB(A), which in time period T has the same energy content as the measured, possibly varying noise level.
   .8 "Daily noise exposure level, $L_{EX,8h}$" means the time-weighted average of the noise exposure levels for a nominal eight-hour working day measured in dB(A), as defined by international standard ISO 1999: 1990, point 3.6. This shall cover all noise in connection with work, including impulse noise. For a daily working period of T_d hours $L_{EX,8h} = L_{Aeq,T} + 10 \log(T_d/8)$. *1
   .9 "Air sound insulation, R_w" means the weighted reduction figure as defined in

*1 For a working period T_d of 12 hours, the daily noise exposure is therefore increased by 1.8 dB(A) and for 16 hours by 3.0 dB(A), when the noise level is unchanged.

DS/EN ISO Standard 140-4 and 717-1.

.10 "Impact sound insulation, $L_{n,w}$" means the weighted impact sound level in the room as defined in DS/EN ISO Standard 140-7 and 717-2.

.11 "Infrasound" means sound with a frequency of less than 20 Hz.

.12 "Ultrasound" means sound with a frequency of more than 18,000 Hz.

.13 "Unnecessary noise" means noise which can be reduced significantly in level and which it seems reasonable to protect against.

Regulation 3 Personal noise limits

1) The limit values for daily noise exposure and maximum sound pressure are fixed at:
$L_{EX,8h}$ = 85 dB(A) *2
P_{max} = 130 dB(C)
When applying the exposure limit values, the determination of the worker's effective exposure shall take account of the attenuation provided by the individual ear protectors worn by the worker. The limit values shall not be exceeded, cf. regulation 7.

2) Action values in respect of the daily noise exposure and maximum sound pressure are fixed at:
.1 Upper action values
$L_{EX,8h}$ = 85 dB(A)
P_{max} = 130 dB(C)
.2 Lower action values
$L_{EX,8h}$ = 80 dB(A)
P_{max} = 130 dB(C)
When applying the action values, the determination of the worker's effective noise exposure shall <u>not</u> take account of the attenuation provided by the individual ear protectors worn by the worker. If the action values are exceeded, the measures stated in regulations 8, 10, 11 and 13 shall be taken.

Regulation 4 Area-determined noise limits

1) On new ships with a length L of or above 15 metres and a scantling number of or above 100, the maximum noise levels stipulated in Annex 1 shall be observed and compliance with the recommended noise levels shall be sought. Furthermore, the values for air sound insulation and impact sound insulation in Annex 1 shall be observed.

2) In connection with the planning of new ships, it shall be documented by calculations, qualified assessments or the like of the expected noise level in the affected areas, that it is possible to observe the recommended noise limits in Annex 1 for these areas. The documentation shall be submitted to the Danish Maritime Authority.

3) Should the shipowner, on the basis of the documentation mentioned in subparagraph (2) above, find that the recommended noise limits stipulated in Annex 1 cannot be complied with, despite reasonable technical initiatives, this shall be documented to the Danish Maritime Authority on request.

4) On existing ships with a length L of or above 15 metres or a scantling number of or above 100 as well as on new and existing ships with a length L below 15 metres and a scantling number of or above 20, but below 100, efforts shall be made to observe the maximum noise levels stipulated in Annex 1.

Regulation 5 Noise measurements

1) Noise measurements shall be carried out when it is necessary to determine the noise exposure and they shall always be carried out
.1 on completion of a new ship,
.2 after alterations or modifications to

*2 For a 12-hour working day this corresponds to a maximum energy equivalent noise level, $L_{Aeq,12}$ of 83 dB(A).

an existing ship that are considered to affect the noise level,

.3 when an existing ship is transferred to the Danish register and the results of existing relevant noise measurements are not available,

.4 if there are other grounds for suspecting that the noise levels have altered, and

.5 if the Danish Maritime Authority demands them.

2) Noise measurements shall be carried out so that it is possible to determine whether the values stipulated in regulation 3 have been exceeded.

3) The measurements shall be carried out in compliance with the guidelines stipulated in Annex 3, Noise Measurements.

4) The noise measurements shall be carried out or supervised by an expert approved by the Danish Maritime Authority. The Danish Maritime Authority accepts measurements carried out by approved testing institutes, including testing institutes in other EU Member States as well as in countries covered by the EEA agreement and which provide appropriate and satisfactory guarantees of a technical, professional and independent nature.

Regulation 6 Risk assessment

1) The risk assessment, cf. Chapter I A, regulation 2, shall contain an assessment of the exposure of workers to noise.

2) In preparation of the risk assessment, the following shall be afforded special consideration

.1 the level, type and duration of exposure, including impulse noise,

.2 limit values and action values stipulated in regulation 3,

.3 any effects concerning the health and safety of workers belonging to particularly sensitive risk groups,

.4 any effects on the safety and health of workers resulting from interactions between noise and ototoxic substances and between noise and vibrations,

.5 any risk that, due to noise, the worker cannot hear warning signals or other sounds to warn of the risk of accidents,

.6 information on noise levels provided by manufacturers of work equipment,

.7 the existence of alternative work equipment designed to reduce the noise level,

.8 exposure to noise on board the ship after work, particularly in accommodation and sleeping quarters,

.9 relevant information collected in connection with health inspection, and

.10 use of ear protectors with adequate sound-reduction effect.

3) The risk assessment shall state which measures are to be taken in accordance with regulations 7, 8, 9, 10 and 11.

4) The risk assessment shall be revised regularly. A revision is particularly necessary if there are significant changes which make it obsolete or if the health inspection shows that it is necessary.

Regulation 7 Limitation of exposure to noise

1) Under no circumstances shall the worker be exposed to noise in excess of the limit values in regulation 3, subparagraph (1).

2) If the limit value is exceeded the shipowner shall immediately

.1 take steps to reduce the exposure to less than the limit value,

.2 determine the reason for the limit value being exceeded, and

.3 adapt measures to prevent the exposure in order to prevent the limit value from being exceeded again.

Regulation 8 Prevention of noise

1) Taking account of technical progress and the available measures, the noise level shall be reduced at the source or reduced to a minimum.

2) Unnecessary noise shall be avoided and the acoustic conditions shall be satisfactory. The noise level, including the level from infrasound and ultrasound shall be kept as low as is reasonable, taking account of technical progress.

3) Limitation of noise exposure shall be carried out on the basis of the general principles on prevention in Chapter I, taking particular account of:
   .1 technical means of noise reduction by which the origin, radiation and spread of noise is prevented or reduced:
      i) reducing airborne noise, e.g. by shields, enclosures, sound-absorbent coverings,
      ii) reducing structure-borne noise, e.g. by damping or isolation,
   .2 alternative working methods that require less exposure to noise,
   .3 choice of appropriate work equipment, taking account of the work to be done, emitting the least possible noise,
   .4 the design and layout of workplaces,
   .5 information and training to instruct workers to use work equipment correctly in order to reduce their exposure to noise to a minimum,
   .6 maintenance of work equipment and workplaces,
   .7 noise reduction by technical means:
      i) limitation of the duration and intensity of the exposure,
      ii) appropriate work schedules and adequate rest periods.

4) On the basis of the risk assessment, if the upper action values are exceeded, the shipowner shall establish and implement a programme of technical and organisational measures intended to reduce the exposure to noise, taking into account in particular the measures referred to in subparagraph 3.

5) The shipowner shall ensure that when choosing the measures, account is taken of workers belonging to particularly sensitive risk groups.

Regulation 9 Sign posting

At the entrance to rooms with a noise level above 80 dB(A), signs shall be posted in accordance with the regulation on safety sign posting, etc. on board ships in force at any time. This sign shall, by means of suitable symbols or in Danish text and, where relevant, English text, clearly state the directions given in Annex 2. Rooms or areas where the noise level exceeds 115 dB(A) shall not normally be entered.

Regulation 10 Personal protective equipment

1) If the risks arising from exposure to noise cannot be prevented by other means, appropriate, properly fitting individual ear protectors shall be made available to workers and used by them under the conditions set out below:
   .1 where noise exposure exceeds the lower action values, the employer shall make individual ear protectors available to workers;
   .2 where noise exposure matches or exceeds the upper action values, or where noise exposure is otherwise harmful or a great nuisance, individual ear protectors shall be used.

2) The personal ear protectors shall comply with the provisions of the relevant executive order from the Danish Working Environment Authority on the design of personal protective equipment.

3) The shipowner shall ensure the wearing of ear protectors when relevant pursuant to this regulation, and shall be responsible for checking the effectiveness of the measures taken in compliance with this regulation.

Regulation 11 Information and training

1) The shipowner shall ensure that workers who are exposed to noise at work at or above the lower action values, receive information and training relating to risks resulting from exposure to noise concerning, in particular:
   .1 the nature of such risks,
   .2 the measures taken to eliminate or reduce to a minimum the risks from noise,
   .3 the limit values and action values,
   .4 the results of the assessments and measurements carried out pursuant to regulation 5 and of the injuries which can arise,
   .5 the correct use of ear protectors,
   .6 how to detect and report signs of hearing damage,
   .7 the circumstances in which workers are entitled to health checks,
   .8 safe working practices to minimise exposure to noise.

Regulation 12 Consultation of workers

1) Workers and the safety organisation shall be consulted in deciding matters concerning noise, in particular
   .1 the risk assessment referred to in regulation 6,
   .2 the measures against exposure referred to in regulations 8 and 9, and
   .3 the choice of individual ear protectors referred to in regulation 10.

Regulation 13 Occupational medical examinations

1) If the risk assessment indicates a risk to the health of workers, these workers shall be ensured an occupational medical examination in accordance with the provisions of Chapter IX, part A.

2) A worker whose exposure exceeds the upper action values shall have the right to have his/her hearing checked by a doctor or by another suitably qualified person.

3) A worker whose exposure exceeds the lower action values shall have the right to a hearing test.

4) Where, as a result of a hearing check, a worker is found to have hearing damage, a doctor or a specialist if the doctor considers it necessary shall assess whether the damage is likely to be the result of exposure to noise at work. If this is the case the shipowner shall
   .1 review the risk assessment,
   .2 review the measures taken pursuant to regulations 8, 9 and 10,
   .3 take into account the advice from the doctor or other suitably qualified person, and
   .4 arrange new health examinations of any worker who has been similarly exposed.

Regulation 14 Exemptions

In exceptional circumstances, the Danish Maritime Authority may grant derogations from the provisions of this part when it is deemed reasonable and appropriate in a health and safety context and to the extent it conforms with Directive 2003/10/EC of 6 February 2003 on minimum health and safety requirements regarding exposure of workers to the risks arising from physical agents (noise).

Annex 1 - Area-determined noise limits

1. Maximum and recommended noise limits

	Work areas:	Maximum dB(A)	Rec. dB(A)
1	Engine room, incl. steering machinery	110	105
2	At stopped machinery in the engine room *3	85	85
3	Workshops	85	80
4	Separate separator room	85	85
5	Engine control room and manoeuvre room	75	70
6	Galley	75	70
7	Wheelhouse	65	65
8	Radio room	60	60
9	Listening posts *4	70	70
10	Offices in accommodation and deck control room	65	65
11	Shop areas and newsagent's	65	65
12a	Other work areas, fishing vessels	85	85
12b	Other work areas, other ships *5	90	85
	Recreational areas etc.:		
13	Infirmary (hospital)	60	60
14	Sleeping quarters	60	55
15	Leisure and exercise rooms	65	65
16	Dining room and other living rooms	65	60
17	External leisure areas	75	70
18	At rescue stations *6	75	70

2. Sound insulation

Bulkhead and deck constructions shall be made of materials with sufficient sound insulation in order to avoid disturbance from activities in adjacent rooms, including human activities such as music, conversation, steps, etc. The structural elements shall comply with the following requirements:

Airborne sound insulation, cf. ISO 140/3 and ISO 717/1		
Bulkheads in accommodation in general	R_w :	min. 35 dB
Decks in accommodation in general	R_w :	min. 40 dB
Between sleeping quarters and open deck, living rooms, galley, pantry, leisure and hobby rooms and engine rooms	R_w :	min. 45 dB
Impact sound insulation, cf. ISO 140/7 and ISO 717/2		
From passageways on open deck, galley, pantry or other rooms with loud impact sounds to sleeping quarters and living rooms	$L'_{n,w}$:	max. 65 dB

The airborne sound insulation of the final construction measured in the ship (the weighted apparent sound reduction index, R'_w) may not be lower than the laboratory values (those stipulated above) by more than 2 dB.

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*3 The noise in the service area at a stopped main or auxiliary engine may not exceed 85 dB when the other machinery is operating normally. *4 According to the Convention on the International Regulations for preventing Collisions at Sea, 1972, as amended (COLREG). In fishing vessels a wheelhouse with open windows may be acceptable as a listening post, provided all deck machinery is stopped. *5 If the noise level exceeds 85 dB(A), ear protectors shall be used, cf. regulation 10. *6 Measurements at rescue stations may be made at reduced speed, cf. annex 3.

Annex 2 - Sign posting at the entrance to noisy rooms

80-85 dB(A)	HØJT STØJNIVEAU - BRUG HØREVÆRN HIGH NOISE LEVEL - USE EAR PROTECTORS

85-110 dB(A)	FARLIG STØJ - HØREVÆRN SKAL ANVENDES DANGEROUS NOISE - USE OF EAR PROTECTORS MANDATORY

110-115 dB(A)	ADVARSEL: FARLIG STØJ - HØREVÆRN SKAL ANVENDES KUN OPHOLD I KORTERE TID CAUTION: DANGEROUS NOISE USE OF EAR PROTECTORS MANDATORY SHORT STAY ONLY

>115 dB(A)	ADVARSEL: MEGET FARLIG STØJ HØREVÆRN SKAL ANVENDES HØJEST 10 MIN OPHOLD FOR INSPEKTION CAUTION: EXCESSIVELY HIGH NOISE LEVEL USE OF EAR PROTECTORS MANDATORY NO STAY LONGER THAN 10 MINUTES FOR INSPECTION

Annex 3 - Noise measurements

1 General

1.1 Upon completion of a ship, and when otherwise required pursuant to regulation 5, noise levels shall be measured in the areas specified in Annex 1. The noise measurements shall be documented in a noise report.

2 Operational conditions at sea

2.1 Noise measurements shall be carried out at sea with a minimum load of 90 per cent of the continuous propulsive power installed, MCR. Measurements at rescue stations may, however, be carried out at reduced speed "Dead Slow Ahead" and with nearby ventilation running.

2.2 Auxiliary machinery, such as generators, hydraulic systems, boilers, refrigeration and air compressors, mechanical ventilation, including air-conditioning systems, navigational instruments, radio and radar installations and other equipment intended for use during normal operational conditions, shall be running. Conditions that are thus of importance in connection with noise measurements shall be recorded in the noise report.

2.3 Special operational situations that may occur for longer periods of time, such as dynamic positioning, shallow water operation, fishing and similar, shall be measured separately.

3 Operational conditions in port

3.1 Noise measurements shall be carried out of the ship's loading gear, cargo pumps, inert gas systems, cargo refrigerating systems, hydraulic systems, hydraulic mooring winches, noisy cargo (refrigerating/freezing containers) and similar running in the areas in question and in the accommodation. Instead of noise measurements of refrigerating/freezing containers, the Danish Maritime Authority may approve a calculation of the expected noise level.

3.2 On car decks on board ro-ro ships, noise measurements shall be carried out during loading/unloading operations with the car deck ventilation running.

4 External conditions

4.1 Results of measurements could be affected by external conditions such as depth of water, weather, external sources of noise, or similar. Therefore such conditions shall be reported in the noise report.

4.2 If the depth of water is more than five times the ship's draught, the conditions shall be deemed satisfactory. In operational situations, for example in the case of regular service between the same ports with low depth of water, the measurement shall be carried out under the actual conditions.

4.3 Weather conditions, such as the wind, precipitation and seas (wave height) may not affect the results of the measurements. The wind speed and the seas should not exceed eight metres/second and sea state 3 (wave height 1.25 metres),

4.4 External sources of noise, such as traffic, workshops and shipyards, may not affect the noise level at the measuring positions. If necessary, the results of the measurements shall be corrected for the effect from such sources of noise.

5 Measuring equipment

5.1 Equipment meeting the requirements for "Precision Grade Sound Level Meter", according to IEC publication 60651, shall be used for the noise measure-

ments. Frequency analyses shall be performed in 1/1 octave frequency band, cf. IEC 61260. If integrated sound pressure gauges are used, they shall comply with the provisions of IEC standard 60804.

5.2 The noise level shall be measured as A-weighted sound pressure level in decibels, reference 20µ (micro) Pascal. In frequency analyses, 1/1 octave frequency band with centre frequencies from 31.5 to 8,000 Hz shall be used.

5.3 In cases where the noise level fluctuates by more than 5 dB, a measurement shall be carried out using an integrated sound pressure gauge over a period of at least 30 seconds.

6 Measuring positions

6.1 Only the necessary operational crew and persons carrying out noise measurements may move about in the actual measuring area.

6.2 The noise measurements shall in general be carried out in the middle of rooms at a height of 1.5 metres above the floor and, if possible, not less than 0.5 metres from large reflective surfaces or surfaces on running machinery. In large rooms where the sound pressure varies by more than 6 dB, measurements shall be carried out at several positions on each deck at a reciprocal distance of less than 10 metres. In engine rooms and wheelhouses, additional measurements shall be carried out at operator positions where persons move about regularly.

6.3 All doors and windows shall be kept closed when noise measurements are being carried out.

6.4 In radio rooms, noise measurements shall be carried out while the radio installation is running, but without making an acoustic signal.

6.5 Measurements at listening posts shall be taken with and without a signal from the ship's whistle. Measurements shall also be taken in accordance with the relevant IMO Recommendation on Methods of Measuring Noise Levels at Listening Posts.

7 Reporting

7.1 The results of the measurements shall be submitted to the Danish Maritime Authority in the form of a standardised report containing the following:
- a plan of the ship on which the measurement values and measuring positions are indicated;
- conditions of importance to the evaluation of the noise conditions, including:
  1) draught fore and aft,
  2) wind and seas,
  3) speed and course,
  4) load and revolutions on main and auxiliary machinery,
  5) other sources of noise running during the measurements, such as ventilation in engine rooms and holds and ventilation in the accommodation,
  6) the make and type of the measuring instrument and the microphone,
  7) information about the person who has carried out the measurement,
  8) depth of water under the keel.

7.2 The results shall be recorded as total A-weighted sound pressures in the measuring table of the standardised report. In cases where the noise exceeds the maximum dB(A) or where annoying, low, frequency noise or easily distinguishable pure notes occur, frequency analyses shall be carried out in 1/1 octave frequency band.

Appendix 3 Cases

1. ”LIDEN KIRSTEN” T 229

A revolution

- I believe that noise reduction will become a revolution – also in other vessels, says Mr. Karl Moeller Bekhoej, master on “LIDEN KIRSTEN” T 229.

“LIDEN KIRSTEN” is a beam trawler for clam fishing. It is the first vessel for clam fishing build and is from 1910. Mr. Karl Moeller Bekhoej bought it in 1974. Last year Morsoe Shipyard put on a new wheel house and at the same time the vessel was noise insulated. Something he and his son Mr. Lars Bekhoej, who will be taking over the vessel when the current master retires are very pleased about.

- Noise on board is a terrible thing. Earlier we could not even talk to each other in the wheel house. It made my head swim and we actually had to shout at each other to be heard. Another annoying thing is that you automatically start shouting even when you are on shore, says Mr. Karl Moeller Bekhoej and adds that most likely his ears are damaged from 30 years of fishing.

- Now there is no noise on board. We can hear the engine running but there is not much more noise in our wheel house than in a new car. It is one of the best things we have done and we are very happy about it. You do not feel nearly as tired after a day on board.

Therefore, his advice is that if you are rebuilding your vessel it would be a good idea to have it noise insulated at the same time.

- It is a bit more expensive but the money is well spent. It is a pleasure to get rid of the noise.

An 11.9 dB(A) reduction

After rebuilding and noise insulating ”LIDEN KIRSTEN” the noise is reduced by 11.9 dB(A) in the wheel house forward – it is now 66.2 which is only 1.2 dB(A) above the threshold limit value. However, the authorities take into consideration the often difficult conditions on smaller vessels. In the wheel house abaft – i.e. combined galley and mess – the noise was reduced by 8.9 dB(A) and is now 66.5.

Even before the re-building the vessel was below the threshold limit value at the main engine. But with the noise insulation the noise was reduced even more and is now 101.5 – compared with the allowed 110. Also in the new bath and toilet the noise is below the threshold limit values – it is 65.8 dB(A) compared with the allowed 75.

Facts - How ”LIDEN KIRSTEN” was noise reduced

- The floor was silenced with 1mm DG-U1 + 15mm latex concrete. On top PVP 2.0/3.0-50mm floating floor. Floor heating is also installed.
- The raw aluminium wheel house is silenced with 4mm DC-P 500 silencing mass.
- Inner bulkhead and lining has been silenced with TNF panels.
- The wheel house ceiling has been silenced with metal boxes filled with mineral wool type Inexa.
- Inner and middle bulkhead is fixed on the floating floor and the mounting on the steel structure is flexible.
- For noise reduction of the wheel house 100 mm marin slab 80 from Rock wool has been laid wherever possible.
- It has been covered by Maylar film and a pierced steel plate.
- The exhaust is flexibly mounted.
- A noise lock has been made between wheel house and engine room.

2. ”REYKJANES” E 157

From Trabant to Mercedes

- We do not experience any noise any more. It is like coming from a Trabant to a Mercedes – we do not have to shout any more, says Mr. Kim Barth master and shareholder of the trawler “REYKJANES” E 157. The vessel has had a new wheel house, new cabins and has been noise insulated. At the same time a new forecastle, four new propeller blades and a new propeller nozzle has been mounted.

- Before the noise from the propellers and engines was really bad. In general we are very impressed by how much the noise has been reduced. It is hard to believe that it is the same vessel because it is much more silent on board. There is peace and quiet and we get a good night’s sleep – almost too good he adds with a smile.

Fully noise insulated

The old master cabin was partially noise insulated and the noise level was reduced by 3 dB(A). The two new cabins were fully noise insulated and the noise level is now 62 and 63.8 dB(A), respectively. The former cabins at the bottom of the vessel are now storage room. The noise level in these rooms is the same – 84.4 and 82.2 dB(A).

The noise has also been reduced in the wheel house, the combined galley and mess, the front cabin and in toilet and bath.

”REYKJANES” was originally built at Oerskov steel shipyard in Frederikshavn in 1974

3. ”KAP FARVEL” T 216

Danish Noise Record

New building with a value of DKK 4 million and a noise level of 24.7 dB(A) above threshold limit value when launched.

- It was impossible to stay on board due to the noise level. You get tired and your head is spinning. You do not feel well and it is difficult to concentrate, says Mr. Knud Kristensen.

His newly built vessel ”KAP FARVEL” T 216 was according to the Danish Fishermen’s Occupational Health Service the holder of the Danish noise record in fishing vessels. It is a combined gill netter and lur-fishing and it did not fulfil the current noise requirements when launched from Faeborg Shipyard in 1999.

Not until the master contacted the Danish Fishermen’s Occupational Health Service and the fishermen’s association in Hanstholm the Danish Maritime Association demanded that “KAP FARVEL” as all other vessels – should aim to fulfil the current requirements set by IMO. Then noise reductive measures were taken on board but the master had to pay more than half of the costs himself – i.e. DKK 200,000.00. But still he says today:

- It is amazing how much the noise has been reduced. Now the noise level is acceptable but there is still resonance noise. You can feel it as vibration in the body and I can still not hear the telephone ringing in the wheel house.

Therefore, his aim is further noise reduction in the vessel. Among others he wants the engine mounted on rubber blocks.

Unhealthy

Before the noise level in the cabin was at 84.7 dB(A), i.e. 24.7 dB(A) above the threshold limit values. In the wheel house it was 87.8 dB(A) – i.e. 22.8 dB(A) above the threshold limit values. In the holds it was 102.7 dB(A) – i.e. 12.7 dB(A) above the threshold limit values. On the deck amidships it was 107.4 dB(A) – i.e. 17.4 dB(A) above the threshold limit values. On deck abaft it was 105.5 dB(A) – i.e. 15.5 dB(A) above the threshold limit values.

As a consequence the master asked the Danish Fishermen's Occupational Health Service to provide some solutions. The Occupational Health Service then carried out noise measurements and went through the vessel.

Mr. Flemming Nygaard Christensen concluded that - according to the requirements set by the Danish Maritime Authorities – the noise level on deck, in the engine room and in the holds were characterised as "dangerous". In the cabin, toilet, bath and wheel house it was "high". All together it was "unacceptable and unhealthy".

Still above the threshold limit values

Having noise insulated the noise was reduced by 20.9 dB(A) on deck abaft, 19.1 dB(A) on deck amidships, 15.3 dB(A) on deck forward, 4.2 dB(A) in holds and 4 dB(A) in cabin and wheel house.

The noise in the cabin was reduced to 80.7 dB(A) – however the threshold limit value is 60. In the toilet and bath it is still 87.9 dB(A) even though the threshold limit value is 75. In the wheel house the noise is reduced to 78.7 dB(A) but the threshold limit value is 65.

Facts - How "KAP FARVEL" was noise reduced:

- Sound absorber was replaced
- The ventilation system in the engine room and the rest of the vessel was partially rebuilt.
- Extra insulation in parts of the vessel.
- The previous sound absorber has been replaced by a flexibly mounted 35 dB(A) sound absorber from Silentor.
- The exhaust system has been mounted flexibly to reduce noise and vibration in the rest of the vessel.
- The new sound absorber is build-in in a new casing. In addition it has been insulated on the inside with an absorber to prevent noise from the engine room from transmitting onto the deck.
- On top of the new casing a spoiler is placed reflecting the noise away from the vessel.
- The ventilation system has been moved to the front part of the engine room and has been provided with a new casing – designed to fit the vessel.
- The new ventilation system has been noise insulated to reduce the transmission of noise through the ventilation casing.
- Cavities not yet insulated have been insulated.

4. ”Langholm” L 320

Name of vessel: ”Langholm”
Type: Trawler
File Number: H 581
Registration letters: L 320
Building place and date: Rosslauer Schiffswerft 1969
Main engine: Detroit diesel
Vessel size: 251 BT
Geometrical classification: Se Ga Plan

Measurements carried out by The Danish Fishermen’s Occupational Health Service on 10 May 2000.
Prepared by: Flemming N. Christensen

The report includes the following:

- Noise measurement locations, before and after, incl. conclusion, acc. to app. 1
- Special conditions during measurements, acc. to app. 2
- Operational conditions during measurements, before and after, acc. to app. 3 A
- Engine data, before and after, acc. to app. 3 B
- Description and photos of the noise reduction measures taken, acc. to app. 4

Appendix 1 - Measurement locations and values measured

Pos. no. acc. to GA. Plan	Measurement location	* The Pos. No. of the working area acc. to Technical Regulation	Maximum dB(A) IMO Res. A468(XII)	Measured values (dB(A)) prior to rebuilding	Measured values (dB(A)) after rebuilding	Noise level improve-ments – measured in dB(A)
1	Wheel house	7 See app. 2	65	61,9	64,5	-2,6
2	Master cabin	14	60	64	64,4	-0,4
3	Hallway at mess	15	65	72,1	71,2	0,9
4	Combined galley/mess at dining table	6	75	70	67,7	2,3
5	Combined galley/mess at the galley area	6	75	68,8	68,1	0,7
6	Toilet/bath	16 See app. 2	65	73,3	75	-1,7
New no 7 Old no 7	Hallway at new galleys (crew galley in the middle of galley)	14 15 See app. 2	60 65	76,8	73,3	3,5
New no 8 Old no 9	Front galley on the port side (Officer's galley)	14	60	78,8	68	10,8
New no 9 Old no 7	Abaft galley in port side (crew galley in the middle of galley)	14	60	76,8	65,6	11,2
New no 10 Old no 7	Abaft galley on the star-board side (crew galley in the middle of galley)	14	60	76,8	67,7	9,1
New no 11 Old no 9	Front galley in the star-board side (Officer's galley)	14	60	78,8	67,0	11,8
New no 12 Old no11	Storesroom on the star-board side	12	90	85,9	84,4	1,5
New no 13 Old no 12	After side main engine	1 See app. 2	110	110,2	115,8	-5,6
New no14 Old no 13	Starboard side main engine	1 See app. 2	110	108,4	112,2	-3,8
New no 15 Old no 14	Front edge main engine	1 See app. 2	110	107,2	112,2	-5,0
New no 16 Old no 15	Port side main engine	1 See app. 2	110	108,3	112,5	-4,2
New no 17 Old no 16	Storesroom on the port side	12	90	81,3	81,3	0

* The number in this column refers to the area numbers in Technical Regulation No. 5 of 3 July 1997 on noise in ships.

Appendix 2 - Special conditions during measurements

Prior to rebuilding:

- During measurements the fishing tackle were dismantled.
- Trawl gallows and winch was dismounted.
- All fuel and fresh water tanks in the vessel were almost empty.

After rebuilding:

- During measurements the fishing tackle were dismantled.
- There were not carpets in the wheel house during measurements
- There was approx. 35000 litres of fuel in the tanks. There was no fuel in the stern tanks.
- There was approx. 3000 litres of fresh water in the stern tanks on the port side.
- New and thinner floor in bath/toilet.
- In the engine room the noise level after replacing the engine had in general increased by 5 dB(A).

Appendix 3A - Operational conditions during measurements

The measurements are carried out during navigation with a load above 90% of the installed continuous operational effect.

	Before rebuilding	**After rebuilding**
Draught forward/abaft	Forward: 2.05 m Abaft: 3.5 m	Forward: 2.0 m Abaft: 3.5 m
Water depth below keel	14.0 m	14,0 m
Wind/weather/ sea	Wind: W 8 MS Sea: 0.5 m	Wind: NE 6 MS Sea: 0.5 m
Course/speed	Course: 130 Speed: 10.5 Knot	Course: 180 Speed: 9.1 Knot

Appendix 3B - Engine data

		Before rebuilding	**After rebuilding**
Main machinery	Max rpm for main engine	1800 rpm	1800 rpm
Auxiliary machinery	Max rpm for auxiliary machinery	1500 rpm	1500 rpm
Load/rotations per minute (RPM)	Rpm for main engine	1600 rpm	1600 rpm
	Fuel consumption per hour	115 litres	115 litres
	Rpm for auxiliary machinery	1500 rpm	1500 rpm
Other noise sources	1 engine room ventilator	Low speed	Low speed
	1 auxiliary engine	Scania 99 BHK	Scania 99 BHK
Instrument type	Brüel & Kjear 2238 Mediator		

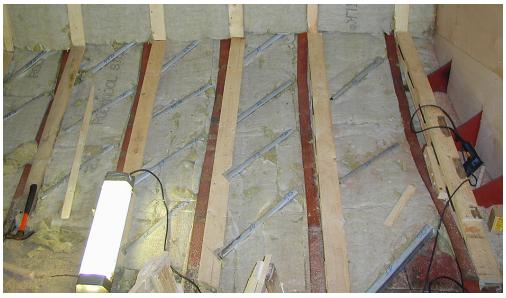
Appendix 4 - Noise reduction measures taken in the vessel cabin in connection with the rebuilding

1)
On the floor of the cabin a U10 system has been laid consisting of an approx. 2mm visco elastic layer onto which latex concrete has been laid. The concrete is laid around the entire piping placed on the floor.

2)
On top of the concrete PVP 2.0/3.0-50 floor has been laid consisting of a 50mm marinslab with a laminated steel plate on top, onto which a 15mm veneer sheet has been mounted to keep the floor sections together.

3)
On hull sides, abaft and forward bulkhead in the cabin silencing cassettes have been welded on from the floor to the deck (but not in the deck house) at intervals of approx. 50cm. The cassettes are shown in the picture and have been divided into halves. Due to the curvature of the hull it is possible to weld them on in full length – this has no impact on the silencing abilities. The purpose of the cassettes is to reduce structure borne vibration and to make the steel dead.

4)
The cassettes have been insulated with 100mm Rock wool.



5)
Then the cabin has been formed up by a system specifically designed for this vessel. The purpose is to ensure that there are no fixed connections between accommodation and the hull. This prevents noise and vibration from transmitting from the accommodation and into the rest of the vessel.

6)
Having insulated and formed up the accommodation 24mm laminated Plywood sheets (veneer sheets) has been mounted in the entire accommodation. The purpose of laminating the Plywood sheets is to remove all noise and vibration transmission features. As shown in the below picture the bolt is countersunk in the laminated sheet and is only screwed into the inner plate.

7)
Facing material in the accommodation is in this case white laminate to make the cabins bright and nice to stay in. In all cabins separate ventilation systems have been installed to improve the indoor climate.

8)
Here the vessel is shown before and after the rebuilding and as you see the change is obvious.

Before the rebuilding

After the rebuilding

The crew of "LANGHOLM" L 320 has for the past year enjoyed the peace and quiet on board.

- We are very, very pleased. It is so great because when we get up in the morning we feel fit and rested. You sleep twice as good when the vessel is properly noise insulated, says Master Mr. Henry Vrist from Thyboroen.

Last year he invested DKK 4 – 4.5 million in the rebuilding of his vessel "LANGHOLM". The company Frederikshavn Bedding put on a new abaft vessel and reconstructed the vessel to make it capable of fishing trash fish and edible fish. In addition it was rebuild to make room for single person cabins for all five crew members and the bath and toilet facilities were also improved.

At the same time the noise on board was reduced and a new engine was installed. It is a Detroit diesel engine equal to the old one as the master was very satisfied with it.

- The noise on board is now so low that when you go into your cabin and close the door you cannot hear any noise. It is so quiet that you hardly feel that you are sailing – not even in the wheel hose. When working on deck we do not need loud speakers because we can easily speak to each other, he says and adds:

- The change is amazing. The crew has told me many times that it is a true joy. We can talk to each other in a normal way in the mess and we do not even have to turn up the volume when we watch TV. It is just like in your own living room at home. It was expensive, yes but it was worth all the money spent and we should have done it 20 years ago.

"LANGHOLM" was built in 1969 and Mr. Henry Vrist bought the vessel in 1993.

5. The Danish Fishermen's Occupational Health Service cooperates with ship yards, fishermen and tradesmen

Hands-on solutions

The Danish Fishermen's Occupational Health Service cooperates with ship yards, fishermen and tradesmen all over the country in order to reduce the noise.

- When we contact the Occupational Health Service they come right away. They are not afraid to get on board the vessels or put on a boiler suit and go into the engine room. A solution is found in very short time. It means a lot that we do not have to wait for several months. They also assist in getting the necessary approvals from the authorities and offer to attend meetings with the DMA, says Mr. Martin Larsen.

He is technical manager at Hvide Sande Skibs- og Baadebygggeri (ship yard). The ship yard has for the past 3-4 years cooperated with the Danish Fishermen's Occupational Health Service in reducing the noise in a series of vessels – both rebuildings and new buildings.

The work continues

The four recent new buildings were "MARITANA", "STANLEY", "NANNA BECH" and "MARYANNA". The following is said by Mr. Martin Larsen about the last-mentioned vessel:

- The result is very good. The noise insulation was built into the accommodation, floor and bulkhead. A floating floor was constructed and the accommodation material was suspended with rubber. The result was that the noise level was kept within the threshold limit values and in two of the cabins it was reduced to 57 dB(A).

The Occupational Health Service gets around. They have carried out a lot of noise measurements and gathered a lot of experience. This experience is transformed into useful, constructive and hands-on solutions from which we all benefit. The good cooperation between yards, vessels and the Occupational Health Service continue, Mr. Martin Larsen finishes.

6. ”Blue Lady” HM 408

Noise infernal reduced

Vibration from a new engine, damaged radars, computers and instruments. The noise was inhuman and after 3 months the bodies of the crew members gave up. Flexible mounting of the engine solved the problem.

- It was a noise infernal. Everything vibrated all over the vessel. It was close to impossible to be on board. Doors and instruments fell down and our entire gear was smashed. Lights and even the monitors on our three computers were destroyed. The fittings onto which our radar was mounted broke.

This is told by Mr. Arne Soerensen, master of “Blue Lady” HM.408. A 65 tons steel trawler built in 1995.

- The conditions were inhuman. It sounded as a jetfighter and even your pillow vibrated and we did not get much sleep. Our whole body reacted but we managed to keep it up for 3 months before we broke down. We were so tired and exhausted that we could not go on anymore.

Noise is torture

The problem occurred on board ”Blue Lady” when the old Volvo engine had been running for 25,000 hours and needed replacement. The new engine was also a Volvo but a computerized model saving fuel.

There had not been any noise problems with the old engine. But even though the crew complained right from the start the technician mounting the new engine would not listen. I did not even help when Volvo engineers from both Sweden and Denmark came to look at the problem.

In the mean time the problem evolved so dramatically that the crew members started to turn on each other.

- Every thing was a problem. We were unbelievably tired due to the constant lack of sleep. Noise is torture and we could not stand it anymore. Luckily the Danish Fishermen’s Occupational Health Service came and then things started to happen, says Mr. Arne Sorensen.

The noise was unacceptably high

The noise and vibration on board was unacceptably high. This was proved by noise measurements carried out on board “Blue Lady” by Mr. Flemming Nygaard Christensen from the Health Service.

- With regard to new buildings the law stipulates a threshold limit value of 60 dB(A) in the cabin. On board “Blue Lady” the noise level was 79.4 dB(A). The threshold limit values are not statutory requirements in existing vessels but you are obliged to reduce the noise level to the extent possible when rebuilding or changing the engine, says Mr. Flemming Nygaard Christensen.

On the working deck the noise level must not exceed 85 dB(A). On board “Blue Lady” it was 88.2 on the after side of the wheel house, 91.2 dB(A) at the cleaning table and 92.8 at the winch. In the engine room the noise level must not exceed 110 dB(A) but the actual noise level on board was 114.1 dB(A).
- The most efficient measure to take is reducing the noise at the noise source. This has been done by mounting the engine flexibly and by

insulating off the gear with a highly flexible coupling. Furthermore, the exhaust system has been flexibly mounted. In doing that the vibration has been removed and thereby also the noise transmission into the hull, Mr. Flemming Nygaard Christensen explains.

Noise reduction of more than 50%

Today the master Mr. Arne Sorensen and the two other crew members on board ”Blue Lady” are happy and satisfied. They can carry out their job and get a good night’s sleep.

- The difference from then and now is huge and cannot be described. We got rid of the noise and the vibration – it is a true pleasure. It is like being in a car and we can work, sleep, talk and watch TV. All due to a significant noise reduction, says Mr. Arne Sorensen. He continues:

- When looking back I seriously do not understand how we could stand that noise for 3 months. We are lucky that the Occupational Health Service found a solution for us. If not we had not been sailing today – so we are very pleased.

- The assistance provided from the Occupational Health Service has been unique. They did not settle for less and that we benefit a lot from today. The dues for the Health Service are money well spent, for sure! Mr. Arne Sorensen finishes.

Remove vibrations - No more noise

The solution on board ”Blue Lady” was to remove the vibration from the new engine and thereby the noise was reduced.

Initially the new engine on board ”Blue Lady” was mounted directly onto the engine bedplate. This transmitted noise and vibration into the entire vessel.

The company Skaarup & Salskov A/S in Thyboroen has mounted the engine flexibly. The four engine feet have been put onto rubber sockets delivered by Volvo Penta and all connections have been insulated off the vessel.

Before the exhaust system was fixed onto the bulkheads. Now they have been flexibly mounted. In addition a highly flexible coupling between engine and gear has been mounted. It is delivered by Centa.

Facts - Noise reduction obtained on board ”Blue Lady” after having flexibly mounted the engine:

Location	Before dB(A)	After dB(A)	Statutory requirement for new buildings dB(A)
Wheel house	72,8	67,1	65
Cabin	74,9	61,9	60
Toilet	75,3	66,7	75
Working deck on the after side of the wheel house	88,2	82,7	85
Working deck at the cleaning table	91,2	84,7	85
Working deck on the after side of the winch	92,8	87,1	85
Shelter deck at the exhaust	85,1	84,8	85
Engine room	114,1	111,6	110

The article was published in Fiskeri Tidende (a newspaper for the members of the Danish Fishermen’s Association)

7. ”Viking” H 190

Noise reduction in the first wooden vessel

”Viking” H 190 is the first wooden vessel having its engine mounted flexibly. It was an experiment which turned out to be a success. The crew members can now hear the water splash outside.

The wooden vessel ”Viking” H 190 is from 1983 and is one of the last wooden vessels built in Hvide Sande. As the very first wooden vessel in Denmark it has an engine mounted on rubber sockets. This is done at the same time as the engine is replaced.

The noise has been reduced by 7 dB(A) in the wheel house. In the combined mess and cabin it has been reduced by 5.9 dB(A) and in the toilet by 2.7 dB(A). On the working deck the noise is reduced by 8.8 dB(A), in the holds by 10.6 dB(A) and in the engine room by 8.3 dB(A).

The improvements are caused by both the new engine and the flexible mounting.

Can hear the water outside

- Before the noise from the engines drowned everything and the vibration was transmitted into the entire vessel. The noise was really bad – especially in the wheel house and on deck. It was a problem as we got tired and had to speak really loud. It was also difficult to get any sleep due to the noise.

This is how Master Mr. Christian Rasmussen remembers the nine years he has been the owner of “Viking”. But now both he and the two crew members feel the improvements. The master says:

- the new engine and the fact that it is mounted on rubber sockets has reduced the noise so much that we can even hear the water splash outside. Before the radio and VHF was turned up but now we turn it down – this also goes for the radio and the TV in the mess. It is really a pleasure to sail now compared with the previous conditions.

Mr. Christian Rasmussen adds, your hearing cannot be put in money terms.

- Even though I am only 36 years old I can feel the consequences of sailing with the Guascor engine for all those years.

- However, he continues, it is common that fishermen experience problems with the hearing. Earlier you just accepted it. But it is really nice that we are now able to do all these things. You quickly get use to the situation and see the little things – for instance a hydraulic valve vibrating, but then we fix it.

Not only the noise was removed on board “Viking” – the vibration has also been reduced significantly. Only the vibration from the screw and propellers is left.

The master is a pioneer

Mr. Flemming Nygaard Christensen from the Danish Fishermen’s Occupational Health service has carried out noise measurements both before and after the improvements. He has also participated in finding the solutions. Having seen the results he is proud of Master Mr.

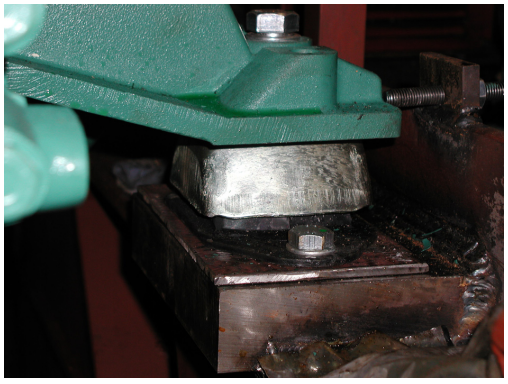
Christian Rasmussen and says:

- The master is a pioneer. His wooden vessel is the first of its kind being noise insulated in this way. He has proven that even in wooden vessels it is possible to mount the engine flexibly and obtain a significant noise reduction. It is worth taking into consideration if you are to replace your engine.

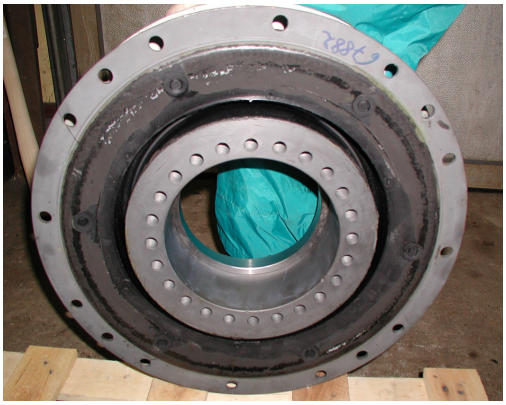
New engine flexibly mounted

”Viking’s” old engine was a Guascor F240 with 299 Hp – 1800 revolutions per minute and was mounted directly onto the bed-plate.

The new engine was a Volvo Penta type TAMD165A. It has 299 Hp – 1800 revolutions per minute. The difference is that the new engine has been flexibly mounted. This means that the engine has been mounted on rubber sockets to avoid any direct connections between engine and bed-plate.



At the same time ”Viking” replaced the old Centa-coupling with a new Vulkardan.



The cost of the new flexible suspension of the engine amounts to DKK 6,000.00. The highly flexible coupling between engine and gear amounts to DKK 26,000.00. In addition are the costs related to the actual mounting and the preparation of an engineer’s report. Exhaust suspension, exhaust, etc is the same.