INSTALLATION DESIGN FOR LOW NOISE

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ABSTRACT

Acoustic signature management and suppression is a key aspect in the modern Combatant vessels/ Warships in order to minimize the interferences between various sound critical instruments and also to avoid detection by enemy sonars. Moreover Warships are designed for all year-round operation, hence requires a high level of crew comfort to optimize the performance of the personnel onboard on duty. The Underwater Radiated Noise (URN) is mainly sourced from the Structure Borne Noise (SBN) generated by transmission of vibrations from rotating/ reciprocating machinery to the hull structure. Ships contain a multitude of noise generating machinery and some of them are coupled to distributed systems like pipes, ducts or shafts that transmit the structure-borne noise over large areas. A clear understanding of the significance of individual noise sources, its transmission path and radiating surface is critical for efficient noise control engineering. Whilst due care is taken at the functional design stage for acoustic stealth management, the detailed design phase is when focused attention is required to ensure that the requisite parameters are within the stipulated thresholds.

Control of noise and vibration onboard ships is a topic of increasing importance to the international shipbuilding industry. Extensive efforts are being put to obtain a quiet ship. The process of noise control and management begins from early design stage and continues through the equipment ordering, detailed design and construction, factory acceptance tests, onboard measurements and culminates during underwater ranging of ships. Various noise mitigation measures such as selection of low-noise equipment, usage of resilient/ shock absorbent mounts for machineries; use of flexible bellows, flexible couplings and hoses for connection of distributed systems to noise critical equipment to avoid noise shorts, etc. can be adopted during the Ship design. This presentation on "Installation design for low noise" elaborates the noise prediction methods during the detailed design and production design of ships, the acceptance criteria as per standards and typical measures adopted for mitigation of noise with major focus on Structure Borne Noise (SBN).

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INTRODUCTION

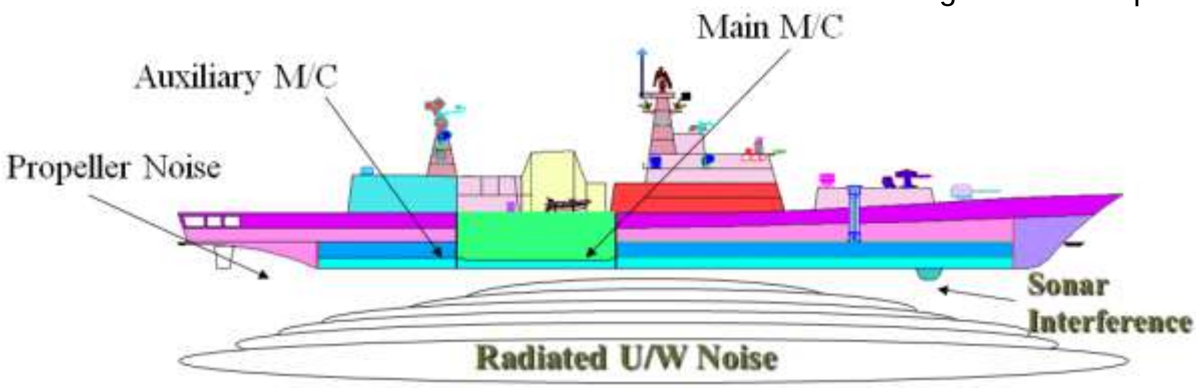
1. Noise has a major impact on Ships, Ship systems and the environment. High levels of noise can ruin hearing if exposed to it for a long time. Constant low level noise and vibration can also have a major impact on working life of humans because it leads to poorer quality sleep, lack of rest and stress. Crew members are, to greater or lesser extent, exposed to noise and vibration all the time. The ships designed for year round operation like warships requires higher level of comfort in order to optimize the performance of the crew on duty.

2. In case of modern Combatant vessels/ Warships, acoustic signature management and suppression is a key aspect to minimize the interferences between various sound critical instruments onboard and also to avoid detection by enemy sonars. In order to contain the noise within pre-defined limits in the amplitude frequency domain, extensive efforts are required right from the early design stages. Noise reducing measures have to be applied both in sourcing of equipment and during the design of accommodation and also the distributed systems.

3. Control of noise onboard ships is a topic of increasing importance in the international shipbuilding industry. This paper elaborates the typical measures that can be taken for mitigation of noise in general, with main focus on Structure Borne Noise (SBN).

UNDERWATER RADIATED NOISE

4. The Underwater Radiated Noise (URN) is one of the most important factors affecting the stealth characteristics of a Ship/ Submarine. The fulfilment of URN limits is often connected to contractual requirements and is mandatory to achieve stealth features in terms of least levels of noise radiation emanating from the ship.



5. The URN is mainly sourced from the Structure Borne Noise (SBN) generated by transmission of vibrations from rotating/ reciprocating machinery to the hull structure.

NOISE CRITICAL EQUIPMENT

6. There are a number of sources of noise present in a Ship or marine vehicle. Usually they are distributed over a large part of the ship structure but most importantly in the engine room. The noise from the machinery has the most significant contribution to SBN in the speed range where the propeller cavitation is avoided.

7. The noise critical equipment that primarily contributes to SBN are as follows:

(i) Prime movers viz. diesel engines, gas turbine engines, generator sets
(ii) Gear box
(iii) Thrust block
(iv) Steering gear
(v) Stabiliser
(vi) Centrifugal pumps including FW pumps
(vii) HP Air Compressors
(viii) Sewage Treatment Plants
(ix) RO Plant
(x) Centrifuges
(xi) AC Plant and associated pumps
(xii) Refrigeration plant

8. The secondary sources of SBN are the auxiliary systems attached to the machinery viz. distributed systems like piping and ventilation ducts.

NOISE PREDICTION

9. Generally, the URN is predicted during the early design phases for a Naval ship. The spectrum frequency range is usually divided into two regions. The methodology that can be followed for calculation of URN is as given below.

(a) **<u>FEM-BEM coupled analysis for low-medium frequency range:</u>** The usual approach consists of a direct calculation taking into account the fluid-structure interaction viz. the effect of elastic behaviour of the hull structure on the underwater sound radiation. A modal analysis of the relevant ship structure is carried out in the Finite Element (FEM) environment and then those results are imported into the Boundary Element (BEM) environment, where a frequency response of the structure under the excitations of input forces due to each of the noise critical equipment calculated and the URN radiated to the far field is evaluated, taking into account the fluid structure coupling.

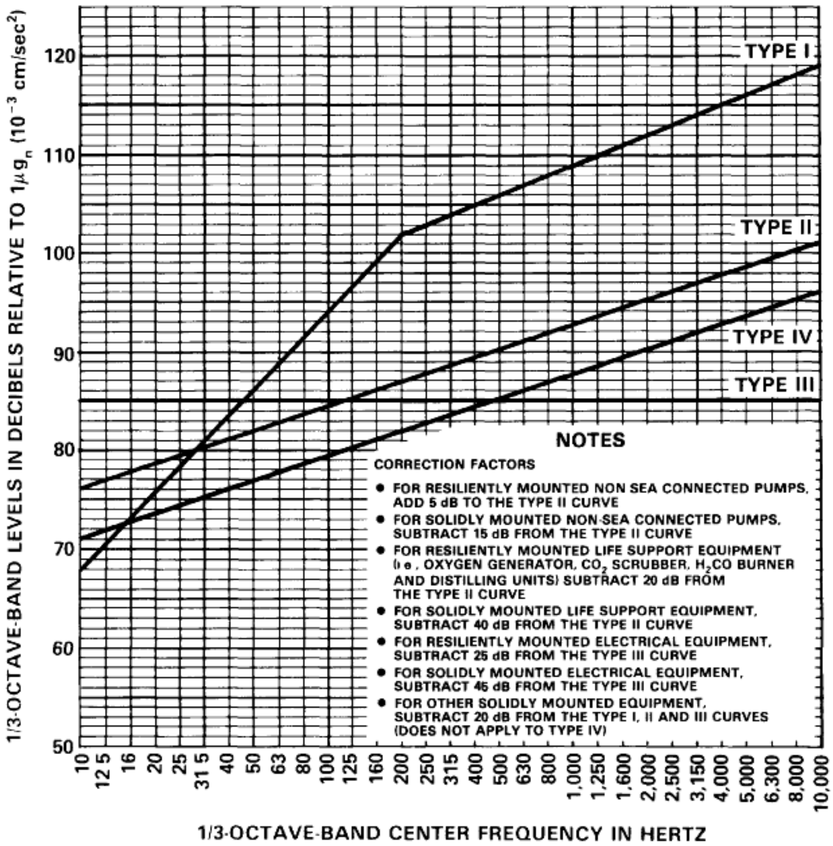
(b) **<u>High frequency approach:</u>** The estimation of URN is carried out based on a semi-empirical approach. The input accelerations from MIL standards and the dynamic stiffness of the resilient mounts are considered to determine the slope of the spectrum. This analysis is carried out in 1/3rd octane bands.

NOISE LIMITS/ ACCEPTANCE CRITERIA

10. For Naval vessels, MIL-STD-740-2 standards shall be met for structure borne noise. The limits are shown in one-third octave band levels and divided as per the type of machinery as given below and type of onboard mounting.

(a) Type I - Reciprocating compressors and internal combustion engines
(b) Type II – Pumps, valves and life support equipment
(c) Type III – Equipment not covered under type I, II and IV
(d) Type IV – Vaneaxial fans

11. The following graph depicts the acceptance criteria for the various type of equipment specified:



NOISE MITIGATION MEASURES DURING INSTALLATION

12. To silence a vessel to the lowest noise levels is cost intensive and requires specialized machinery and noise control measures. A clear understanding of individual significance of each source, transmission path and radiating surface is important in order to perform efficient noise control engineering.

13. The various noise mitigation measures adopted in a Ship during the design and construction are elaborated below:

(a) **<u>Use of Resilient mounts:</u>**

(i) When the machinery is directly fastened to the ship's hull, its vibrations are transmitted and propagated along the ship. Therefore attenuation of structure-borne noise is very important to reduce the overall noise levels of the ship.

(ii) Resilient mounting of the machinery can help reduce the structure-borne noise. However, thorough analysis has to be carried out while using the resilient installations. The following factors have to be taken into consideration:

(aa) Response of the system in six degrees of freedom
(ab) Flexibility of connections
(ac) Alignment requirements
(ad) Self-induced vibrations
(ae) Facilities for inspection
(af) Reliability

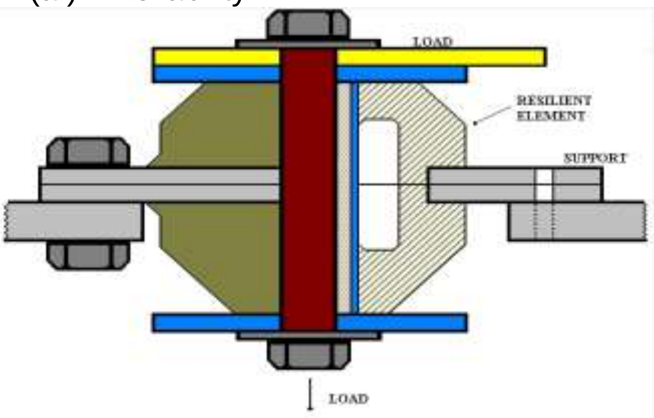


Fig. Resilient mounts

(b) **<u>Use of Shock and Vibration Mounts:</u>**

(i) Shock and Vibration mounts are mechanical fasteners that are used to connect two parts elastically. This helps to absorb shock, reduce transmission of vibration from machinery to the Ship's structure or

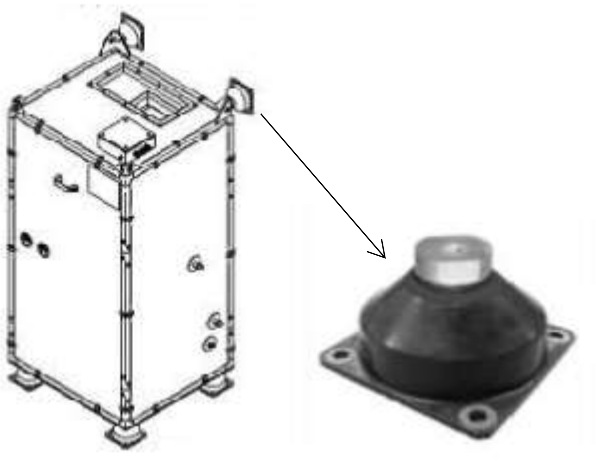


Fig. Shock mounts used in ATU/ HE

(ii) Shock and vibration mounts shall be kept unpainted as they tend to age with time.

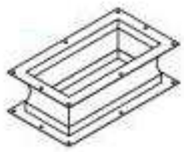
(c) **<u>Noise Shorts:</u>** The reduction of noise from machines which are installed on resilient mounts can be seriously impaired if the isolation is bypassed by vibration transmission through piping/ventilation system and other connections to the hull structure. Such vibration paths are termed as 'noise shorts'. Care shall be taken at design stages to avoid such noise shorts.

14. The various noise reduction measures for the secondary noise sources/ auxiliary systems and ship are as follows:

(a) **<u>Piping and Ventilation System:</u>**

(i) During detailed design, the piping and ducts shall be routed in such a way so as to avoid sources of noise and also not touch/short with each other or any equipment or with hull structure.

(ii) All connections to the machinery on resilient mounts shall be fitted with flexible connector with sufficient allowable movement to provide for the full check deflection of the machine. These flexible connections and rubber inserts shall be kept unpainted.



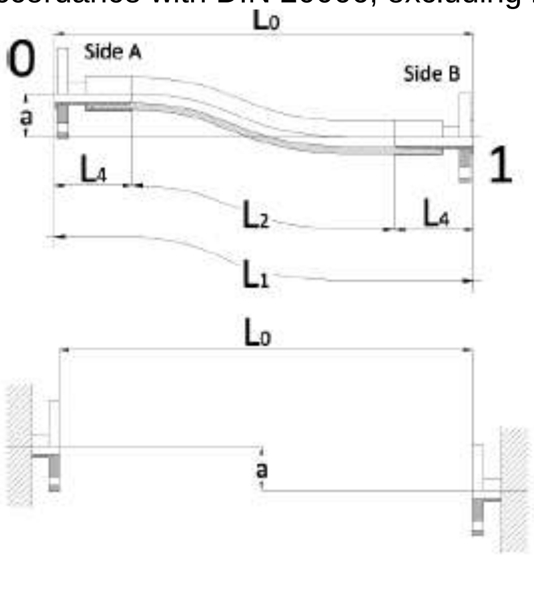
Flexible sleeves

Flexible hoses

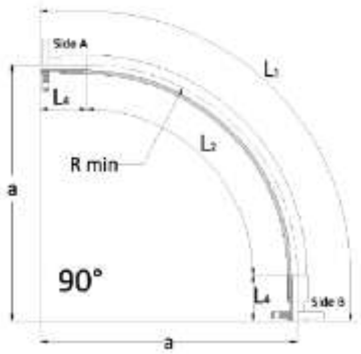
Fig. Flexible connectors

(iii) The hoses are generally divided into four groups:

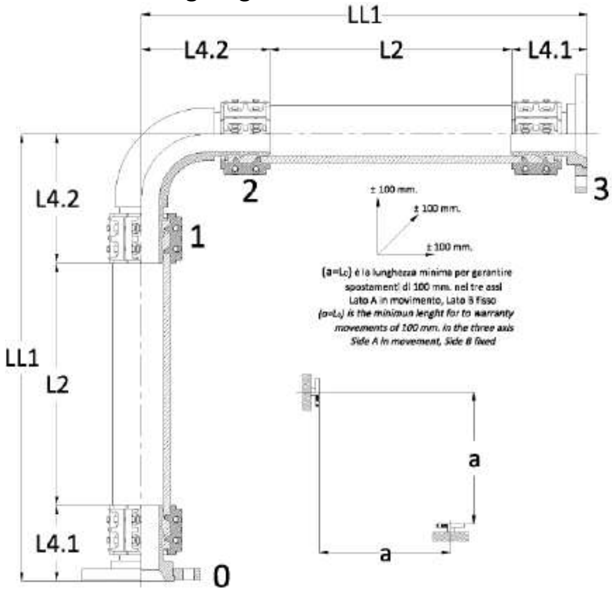
(aa) Type 1 – Anti-vibration (Par. 3.1.6.7 Type 1 Fig. 3) fitted in accordance with DIN 20066, excluding installation at 90°



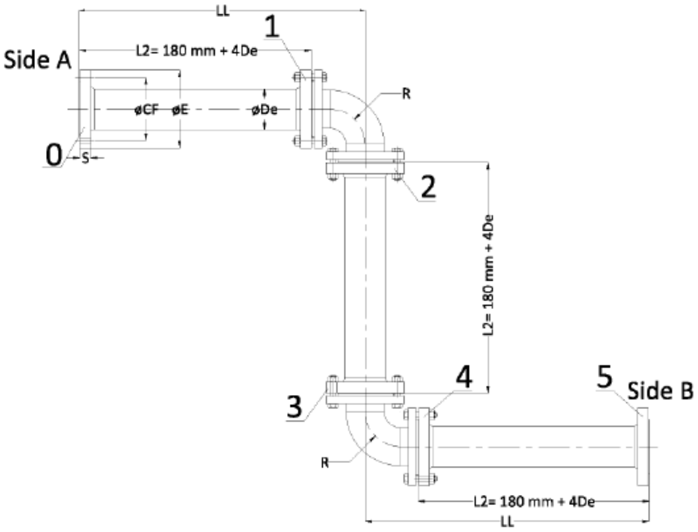
(ab) Type 2 - Shock resistant and anti-vibration at high attenuation (Par. 3.1.6.7 type 2 Fig. 5) mounted at 90° in accordance with DIN 20066



(ac) Type 3 - Shock resistant, anti-vibration at ultra-high attenuation Dog-leg mounts



(ad) Type 4 - Shock resistant, anti-vibration at an extremely high attenuation and high pressure (Par. 3.1.6.7 Type 4 Fig. 9)



(iv) Connections to the resiliently mounted machines shall be fitted with the flexible lengths of piping.

(v) Flexible connections shall not be used to overcome misalignment since the noise isolation properties of a flexible connection are seriously impaired if it is under stress. In systems fitted with flexible lengths which are thermally lagged, gap of flexible connection shall be provided in the lagging at each end of flexible lengths to avoid 'noise shorts' through the lagging.

(vi) Piping and ducts shall also be studied with the aim of reducing fluid dynamic noise. Flow noise through pipes shall be reduced by preventing throttling in valves especially in sea water and hydraulic systems.

(vii) Expansion joints consisting of rubber bellows and rotating flanges shall be used for reducing thermal and mechanical tension in pipes and their system components:

Fig. Rubber expansion joints

(viii) Unwanted technological structures, like supports or other arrangements fitted during initial installation of the equipment, that may form acoustic bridge shall be avoided.

(ix) Pipe brackets shall have corrugated rubber inserts and the same shall be adequately tightened.

(x) Ventilation system shall be adequately balanced to maintain air borne noise level at par with design levels.

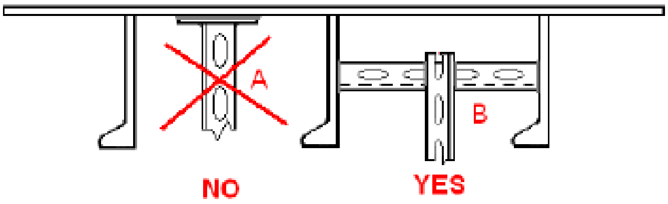
(xi) Shorting of air ducts with hull/other system piping shall be avoided.

(xii) Load hangers shall be provided where required.

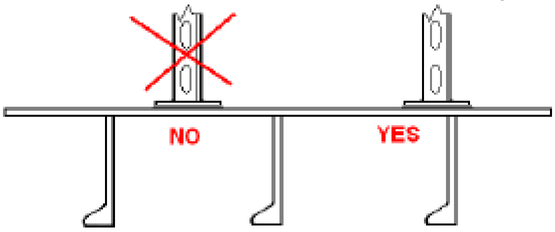
(xiii) Silencers and baffles shall be applied where appropriate.

(b) **Supports for Piping and Ventilation:**

(i) Supports shall be fixed to hull stiffeners and not to bulkheads or decks.



(ii) Supports fitted on the other side of stiffened structures shall be fixed next to stiffeners and not in the centre of the spacing

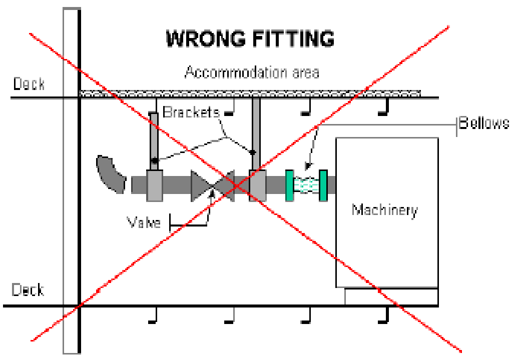


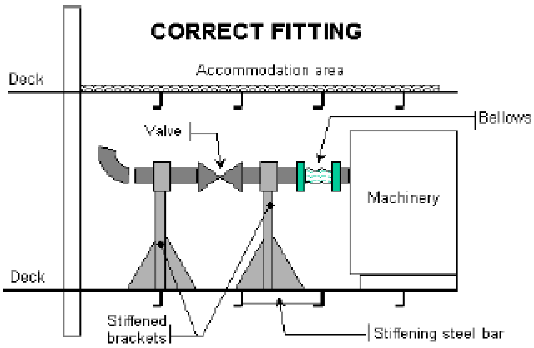
(iii) Supports shall not to be excessively long, if not properly stiffened.

(iv) Supports next to elbows shall be properly stiffened in order to avoid in any direction the transmission of vibrations.

(v) For pipes conveying liquid, 10 mm EPDM rubber or polymer with equivalent elastic characteristics shall be used between the clamp and the pipe itself or proper two halves rubber clamps shall be used.

(vi) Steam plant valves shall not to be fixed to ceilings contiguous to accommodation areas. They shall be fixed to deck or to bulkhead stiffeners.





(vii) For resiliently mounted machineries, a rigid bracket shall be used immediately upstream/ downstream the machinery inlet/ outlet expansion joint/ bellows.

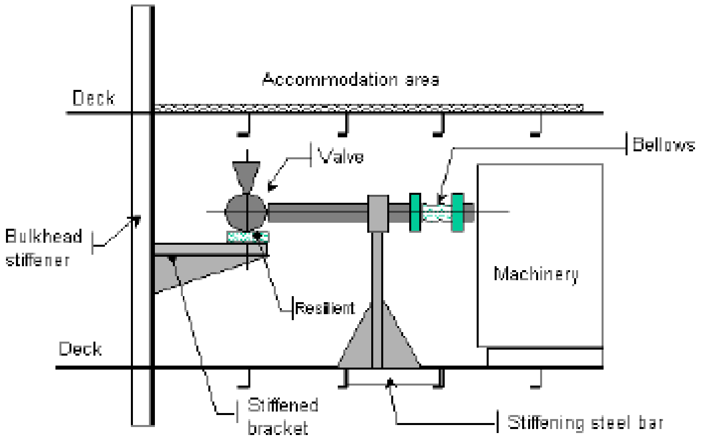


Fig. Brackets between the structure and machineries

(c) **<u>Welding of Supports:</u>** The general shipyard practices for welding of supports to the structure are illustrated below with figures:

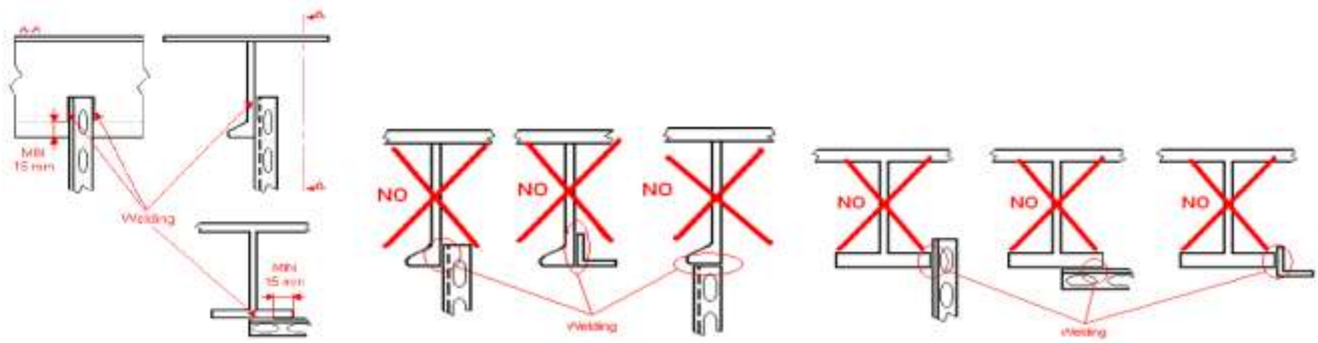


Fig. welding connection of support to structure

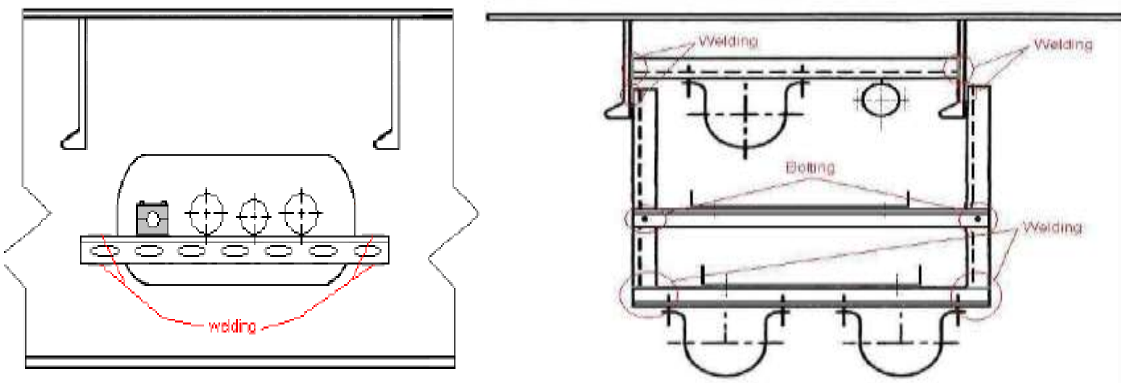


Fig. Multi fitting arrangement

(d) **<u>Electrical Connection:</u>**

(i) Bond straps shall be installed to accommodate the full deflection of each resilient mount. Electrical cables and earthing straps connecting resiliently mounted equipment to rigid structure shall be kept slack so as to prevent noise shorting.

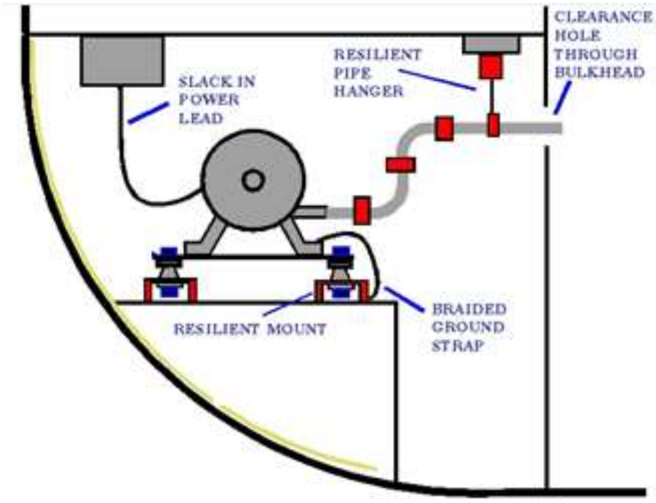


Fig. Noise control measures for electrical connection

(ii) Electrical wires/conduits shall be secured with clamps.

(iii) Cables routes shall not be below or in contact with the pipelines.

(e) **Bilge Plates:**

(i) The bilge plates of machinery spaces shall have rubber coaming and shall be secured tightly to the frames.

(ii) Bilge plating frame structure shall not be welded/ fused with any machine foundation below/above the mountings.

(f) **Floors:** Floating and viscose-elastic noise absorbent material may be used for flooring.

(g) **Windows:**

(i) Usage of laminated windows in the bridge.

(ii) Providing additional inner windows.

(h) **Insulation:** Special insulation is used to reduce the transmission of noise. The typical noise absorbent materials used for insulation are as follows:

(i) Open Celled Foams

(ii) Fiberglass

(iii) Mineral Wool

(iv) Quash

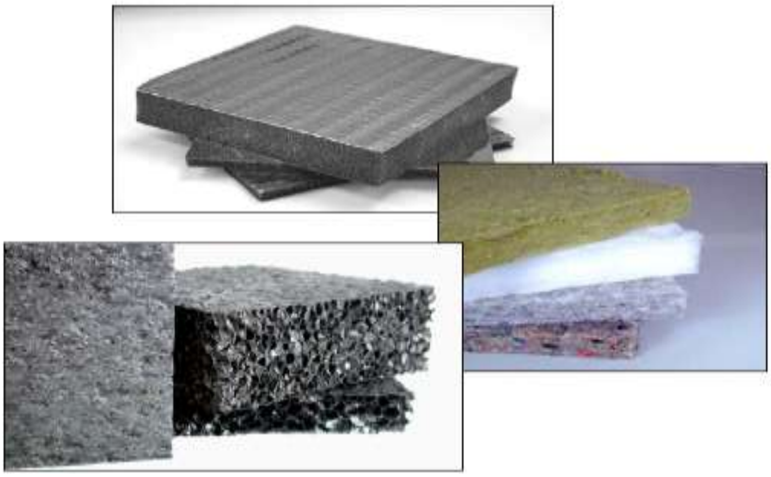


Fig. Noise absorbent insulation materials

(i) **Ceiling:**
- (i) Usage of perforated plate ceilings.
- (ii) Usage of special woven glass material above ceilings.

(j) **Miscellaneous:**
- (i) Ball and roller bearing shall be inspected for rust and pitting.
- (ii) External crew heads, calibration/maintenance pins, allan head bolts of pedestal and mountings shall be cleaned and greased.
- (iii) Rubber beading of all WT doors, WT hatches, HWTC flaps, cold rooms and cool rooms shall be intact and never painted.
- (iv) WT doors, NWT doors and hatches retaining hook shall not be let loose.
- (v) Guardrail stanchion shoe shall not be let loose.
- (vi) Bonding strap of guardrail stanchion shoe, WT doors, WT hatches shall be connected at both ends.
- (vii) Ladders, railings and bilge plates shall be fully tightened.
- (viii) Helo hangar shutters (if fitted) shall not be left loose when closed to avoid generation of excessive noise.
- (ix) Panels including junction and distribution boxes shall be secured.
- (x) SPTA boxes and stores shall be secured.

NOISE MEASUREMENT

15. SBN level measurements onboard are carried out with a vibration meter that can measure various frequencies and can also measure third octave band and linear narrow band. The vibration meter being used shall be calibrated both at the laboratory and at the field.

16. Accelerometers shall be attached to machined mounting blocks or directly to the equipment surface. Blocks shall be oriented such that the most sensitive axis of each accelerometer is in the main direction of the equipment under test. These accelerometers shall be fixed at following locations to verify the SBN levels:

(a) For equipment - feet of mounted equipment or above/ below resilient mounts

(b) For vibrations of machinery, accelerometers shall be fixed on bearings
(c) For noise transmitted by pipes or ducts - critical points like flanges, before and after flexible connections, rigid connections, discontinuity, 90°turns

Fig. Measurement setup with block and accelerometers

17. During the test, the background noise levels are first measured to ensure that the same is at least 10 dB lower than SBN level emitted by equipment under test. If the difference between background noise and SBN measured with the equipment in operating condition is less than 3 dB, it is not possible to correct the levels measured and such measurement cannot be considered as valid.

18. The testing procedure for measurement of SBN is as follows:
(a) Set up vibration analyser and calibrate accelerometers.
(b) Record serial numbers of SBN equipment.
(c) Attach accelerometers to first block.
(d) Record lowest possible background SBN levels in 1/3 Octave bands between 10 Hz – 10 kHz at first block.
(e) Set up of equipment under test and start measurements in operating conditions
(f) Record SBN levels in 1/3 Octave bands between 10 Hz – 10 kHz.
(g) Verify if the results are meeting the acceptance criteria.

CONCLUSION

A number of techniques are available to assist in determination, calculation and mitigation of the noise levels in Ships. Even minor changes as elaborated above can have quite an influence on SBN and improve the acoustic quality and comfort in Ships.