

# SURFACE SHIP NOISE REDUCTION

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## Introduction

A hydrophone placed in the sea will receive a wide range of sounds generated by a variety of sources over a large sea area. These sources could be shipping, marine life, flow noise around the hydrophone, weather effects, etc., and as such are variable in nature. The noise produced by ships and submarines has to be identified from this background before underwater (UW) noise can be used as part of a detection and weapon system.

The physics of sound wave propagation in the sea has been the subject of considerable study and is discussed in detail in many books and reports, including references 1 and 2. Under ideal conditions, sound waves can travel many hundreds of miles. Ideal conditions, however, seldom exist over large areas and so the path of a sound wave can be distorted and modified many times between the noise source and the receiver. Factors such as:

- (a) refraction of the sound waves due to thermal and pressure gradients;
- (b) reflections from the surface, seabed, or layer boundaries within the water;
- (c) different attenuations associated with various frequencies;
- (d) scatter due to foreign bodies in the sea;

may all be relevant when considering the noise path to the receiver. The greater the length of the noise path, the more likely it is that the sound wave will be affected by at least one modifying effect.

For naval surface ships, the two areas in which underwater noise is of particular interest are anti-submarine warfare (ASW) and mine countermeasures (MCM). This article describes the background to the need for UW noise reduction and some of the methods that can be used to achieve low signatures. The opinions expressed are those of the authors and do not necessarily represent official MOD policy.

## Anti-submarine Warfare

The potential of submarines to play a decisive part in a future war is well known and is discussed in many publications, including reference 3. If Britain is to survive, an effective counter to the submarine must be maintained.

Historically, the balance of advantage in ASW has generally been small and frequently has been reversed by changes in technology or tactics. Many of the factors restricting the ASW effectiveness of surface forces are different from those which impose constraints on the performance of the submarine. One requirement common to both is, however, their need for low acoustic signatures. As always, it is the responsibility not only of the designers but also of the operators and maintainers to ensure that best use is made of available noise-reduction (NR) techniques.

The noise of a vessel can degrade its ASW performance in a number of ways: by interference with its own sonars (active or passive) and those of its consorts and escorts, or by giving the submarine a prior detection capability that allows it to evade or destroy its surface opponents.

## Mine Countermeasures

The noise signature of a MCM craft must neither interfere with its mine detection system nor be high enough to activate a mine before it is detected. In this age of sophisticated electronic circuits, there is the capability of tuning mine actuation to the signature of types of craft. This makes the noise characteristics of MCM craft even more important.

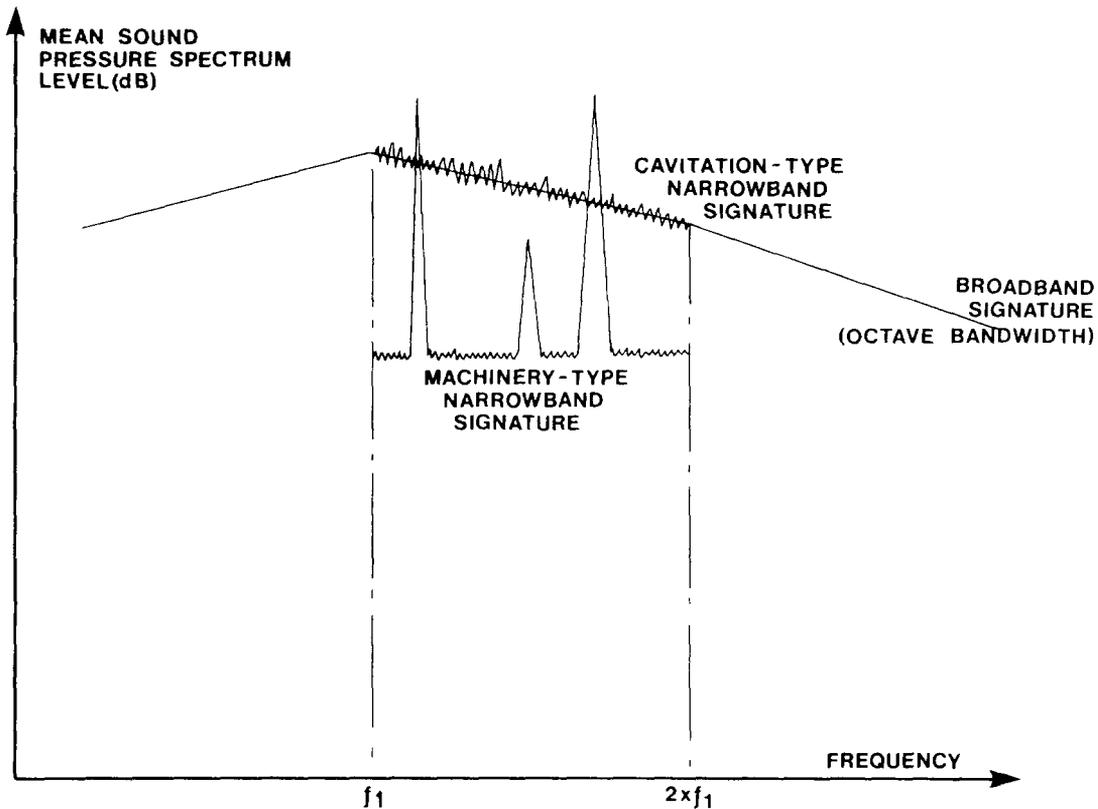


FIG. 1—CHARACTERISTIC NOISE SIGNATURES

## Noise Targets

Early in the design stage of a ship, the noise target must be formulated based on the criteria considered to be most relevant to that ship. All those factors already mentioned—interference, detectability, noise risk, together with others such as homing-torpedo acquisition—will be given some weighting. Any target will involve certain assumptions including, for instance, the operating speeds, the signatures, and the characteristics of the sonars and weapons, etc. both of our own and of the enemy's forces.

The characteristics of our own and our enemy's weapons and sensors are likely to be such that these various possible targets will cover only parts of the frequency range. The probable shapes of a ship's noise signatures under various operating conditions are, however, sufficiently well known that a knowledge of the desired target level at one frequency allows the likely level at other frequencies to be deduced. Thus, the most stringent target requirements can be identified, as can the penalties of choosing one predominant target and accepting shortfalls elsewhere, as may be desirable for other considerations.

The overall energy levels of a noise signature and its more detailed characteristics can both be important. The first of these tends to produce broadband and the latter narrowband targets, the difference coming in the width of the frequency bands which the sonars process. For example (see FIG. 1), in an octave bandwidth (from  $f_1$  to  $2f_1$ ) the same overall energy could come

either from relatively 'white' noise from cavitation or from a few high 'artifacts' associated with machinery items at discrete frequencies. These could register similarly on a broadband analyser, but be completely different in a narrowband presentation. Narrowband analysis can therefore generally be of greatest use in classifying contacts, while initial surveillance in broadband can have its own advantages.

### **Noise Reduction Principles**

Noise reduction can involve:

- (a) minimizing noise at source;
- (b) maximizing the loss between the source and the sensor of interest.

At any speed or operating condition, the likely major contributors to the noise signature, over various parts of the frequency range, must be identified. Their probable noise levels can then be compared with the targets to enable appropriate NR measures to be selected. Unless this assessment is performed successfully at the design stage, the ship will be found to require subsequent modification. This is inevitably more difficult and costly than incorporating the equivalent measures during the initial build, and may on occasion be altogether impossible.

While, ideally, machinery would produce no noise or vibration, the energies involved in generating them are generally minimal in comparison with overall power (the total radiated sound power from a ship typically being only a few watts). The expensive redesign that would be needed to produce further reductions will frequently be less effective than improving isolation.

There are several transmission paths for machinery noise and those most dominant are not always obvious. Paths can be:

- (a) airborne—direct from the machine, from intakes, exhausts, fans;
- (b) structure borne—through mounts, along shafting, pipe walls, cables, ducting;
- (c) fluid borne—along the medium within the pipes.

Various techniques available, or being developed, are described in reference 4. To identify the effect of each path, it must be isolated from any others. Experiments where loudspeakers reproduce the airborne noise of machinery demonstrate the importance of this component. For other contributors, use can be made of the reciprocity principle: under certain conditions, an identical transfer function is obtained when the positions of source and receiver are interchanged. By this technique, a noise source in the sea can be observed at the machine and paths between them can be investigated in turn. This is obviously a more practicable proposition than attempting to run a diesel generator with all its pipework disconnected and its fuel lines drained! Although initial experiments in this direction have yielded useful information for specific cases, much further work is needed before general statements can be made on the relative importance of paths under various levels of noise reduction.

As ship speed increases, so does the relative importance of hydrodynamic radiated noise from sources such as propeller and stabilizer cavitation. Additionally, for self-noise, local-flow and bow-wave effects may become significant. Unlike the machinery case, initial design of hull, propulsor, and appendages is the most powerful technique for minimizing hydrodynamic noise; but, here too, other measures can be incorporated to achieve the best performance within the constraints of the original design.

### **Noise Reduction by Design**

One of the most useful ways of reducing noise at any point is to keep all

significant sources as far from it as possible. Thus, a sonar can either be placed in a bow dome or be towed behind the ship and, to reduce radiated noise, some machinery items may be mounted above the waterline.

Machinery noise can be reduced at source by improving the manufacturing process (e.g. tightening gearing tolerances), by making the flow into machines such as fans and turbines as uniform as possible, by balancing installations, etc. Selection of machinery also has a part to play, rotating machinery with continuous loading being intrinsically quieter than reciprocating machines where components are subjected to impulsive forces. Choosing an electrical transmission system for main propulsion can give benefits by removing gearbox noise altogether and the main engines can be more completely isolated in the absence of continuous shafting.

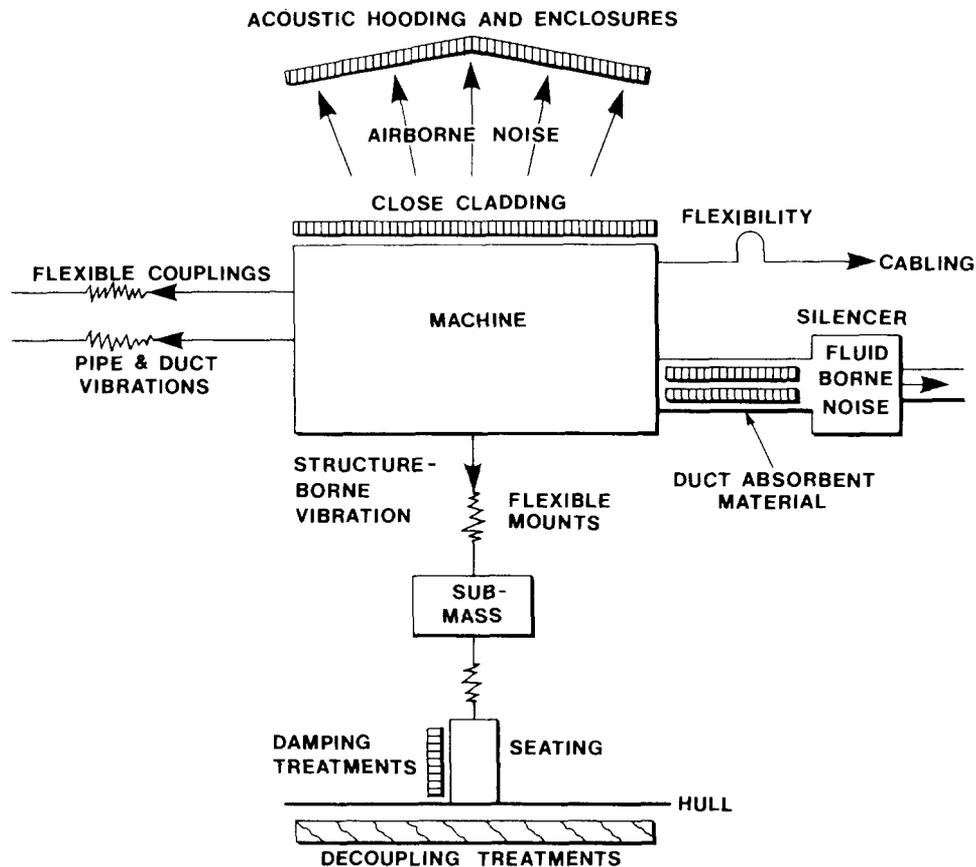


FIG. 2—MACHINERY NOISE PATHS AND TREATMENTS

Other methods of reducing noise from machines are shown in FIG. 2. All can be more or less sophisticated, ranging, for example, from a single level of shock and vibration mounts with just sufficient flexibility in other connections to let the mountings operate freely, up to placing one or more items in a complete acoustic enclosure. This would have walls insulated against airborne noise, a sufficiently high mass to make resilient mounting both between machine and enclosure and between enclosure and seatings worthwhile, and silencers in its flexibly connected pipework and ducting.

The design of seating arrangements must be treated as a whole, with successive stages mismatched in stiffness or impedance, sufficient to allow them to react independently. For example, if a machine is to be double mounted, the two flexible mounts must be separated by the largest possible intermediate mass to prevent them from operating as a single spring. For

practical reasons, this mass is usually between 50 and 100 per cent. of that of the equipment supported. At its most sophisticated, it may be designed and analysed so that the optimum positions for attachments can be chosen. If nodes or points of minimum vibration for such a raft can be identified, then connections at these points will transmit to or receive from the raft a minimum of energy, further improving the overall noise reduction of the system. Such techniques are, however, still in their infancy.

Acoustic mismatch may also involve decoupling the hull from the sea, the most extreme case of this being the hovercraft. The underwater noise signature of a commercial SRN 4 compares very favourably with even the quietest states of our current conventional MCM craft. Conventional ships can provide acoustic mismatch by fitting tiling or by using an air emission system such as Masker. Even relatively low concentrations of air in water can dramatically affect the speed of sound, producing a reflective layer which also has absorbent properties. Damping treatments can be used on machines themselves and on their seatings; for self-noise, damping can be applied around the sonars and in bands between the sonars and the main noise sources. As with mounting selection, these measures must be matched to the appropriate frequencies.

Hydrodynamic noise must be carefully considered when the initial design decisions are made on hull and sonar shape, propeller design and shaft speed, and the number, size, and position of the stabilizer. Propeller cavitation is a deadly enemy of a low radiated noise signature. Though air emission systems, such as Prairie and Agouti, can mitigate some of its effects, delaying the inception of cavitation by fitting large, lightly-loaded, low-revving propellers into which there is uniform flow is a much more satisfactory alternative. In extreme cases, when the highest possible cavitation inception speed is required, pump-jets may be fitted. Controllable-pitch propellers have enabled designers to optimize the running conditions of the main engines at low ship speeds. This involves programming the propeller to come off design pitch as the ship speed reduces. However, if UW noise is important, such a programme must be treated with care as CP propeller off-design pitch can produce early cavitation. Stabilizers may raise radiated noise levels themselves when operating at large angles, and the down stream disturbances can also affect the propellers; this makes it worthwhile to ensure that under most conditions only small fin angles are required. Internal stabilization, using tanks or weights could also help with noise reduction.

Hydrodynamic self-noise can be reduced by keeping the sonar out of the line of sight of noise sources by careful positioning of sonars, propellers, and stabilizers or by fitting baffles in sonar domes. This can minimize the inevitable blind arc in coverage and give the best performance in all other directions. For hull-mounted sonars near the bow, the bow entry angle and subsequent shape can be chosen to reduce flow and bow-wave noise. Local excitation of the structure by waves and flow can be reduced by adding stiffening and damping treatments.

### **Noise Reduction in Service**

Noise reduction is not cheap in weight, space, or money. It is, however, of great and increasing importance to the operations of the surface fleet. Its effectiveness in practice depends on a number of factors, all of which need to be fulfilled. The designer must use his knowledge and skill to produce an appropriate NR package; the manufacturers and shipbuilder should follow the installation specification with care; and the operators and maintainers must preserve the performance of noise reduction measures. The benefits of a complex raft may be substantially lost by shorting out the mounts with a

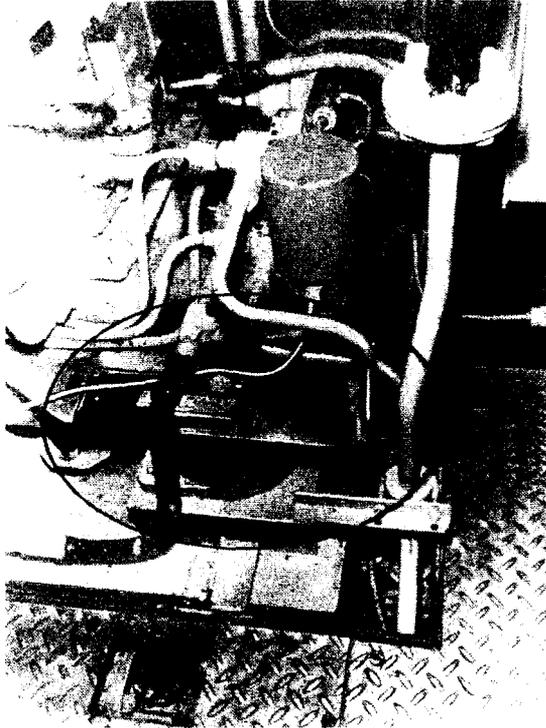


FIG. 3—EXAMPLE OF NOISE SHORT

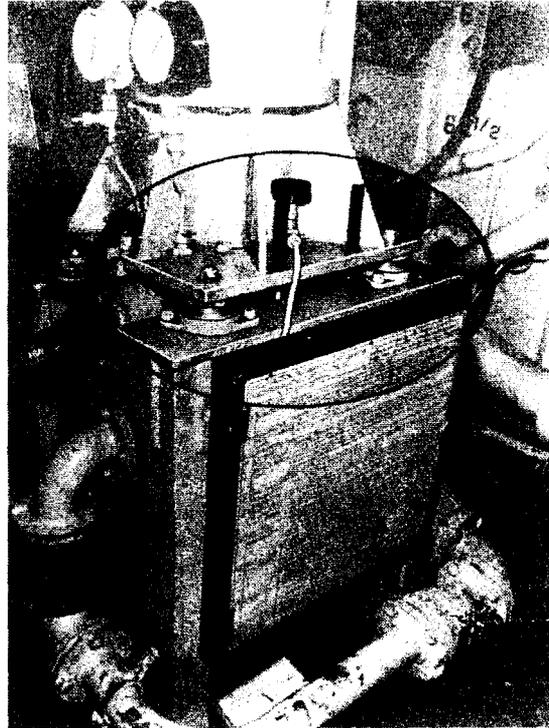


FIG. 4—EXAMPLE OF NOISE SHORT

Even a minor rigid connection can render the noise reduction mount ineffective

casual spanner or by minor modifications that leave components in unwanted contact. Two cases of noise shorts are shown in FIGS. 3 and 4. Flexible connections of all sorts need to be checked for deterioration due to aging or contamination (the latter includes painting!) and be replaced as necessary. Replacement machinery should be installed as carefully as the original equipment.

Air emission systems have small holes which are prone to blockage by dirt or marine fouling. Regular blowing through can help to prevent this and also provides warning of defects. Relatively minor damage to propellers and other underwater fittings may not noticeably affect any other aspects of ship performance but will still markedly reduce the speed at which cavitation starts; such defects should therefore be rectified at the earliest opportunity. Stabilizers should be left at their recommended settings, as increasing the gain does nothing for seakeeping but may drastically increase noise levels.

At present, it is not easy for operators to know how successfully they are maintaining the noise signatures of their ships, but various developments should significantly improve this situation in the near future. Adequate air system flow-measuring equipment is gradually being introduced. This will give information both on day-to-day variations in status and on the possibility of more closely tuning the systems to different operating conditions, benefits of which have been shown by recent trials' results. A ship's hull-mounted sonars in their passive modes can to some extent monitor the ship's own noise, and towed sonars have a much greater potential in this role. Other dedicated monitoring systems are also under consideration or development, and combinations of these may shortly offer commanding officers instant information on the levels of their own ship's noise signatures and on the effects of alterations in speed or machinery line-up. Meanwhile, routine and special noise trials provide essential information on the success of our present noise-reduction techniques, and point the way ahead to a still quieter future.

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