THE TYPE 23 FRIGATE AND NOISE REDUCTION OF MACHINERY

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ABSTRACT

The Type 23 frigate's primary role is centred around the towed array sonar and consequently close attention has been paid to noise reduction measures for its machinery. Cost constraints have dictated that only machinery used at speeds needed for effective towed array operation has received the extensive treatment. A systematic noise reduction process has evolved which allows machinery noise problems to be identified, design solutions specified and incorporated into the ship during build, with the final installation being fully inspected. The process will become iterative as the results of prediction exercises, machinery vibration surveys and noise ranging become available. The main features of noise reduction in the Type 23 centre on electric motor propulsion, which allows gearing, gas turbines and lubricating oil systems to be shut down. Other measures include the use of an upper auxiliary machinery room, rafted diesel generators and extensive treatment of auxiliary systems. Problems were experienced in setting vibration target levels for commercially based equipments and designing double mounting systems. Development of quiet machinery may be too expensive so future improvements should include extending the range of vibration attenuators and eliminating the noisiest systems by design changes. Improvements in information and analytical noise prediction methods will be needed both within Ministry ship projects and by Industry if better and more cost-effective noise reduction measures are to be achieved.

Background

The Type 23 frigate's primary role will utilize the towed array sonar at low speeds for long periods[1]. This means that the ship will need to be built with close attention being paid to incorporating noise reduction features into her design. The basic machinery fit to meet the towed array roles has been described by Blackman[2] whilst Plumb[3] has made some general observations on machinery selection for a noise-reduced warship. This will be elaborated on further; but the process whereby the noise reduction measures were conceived, are engineered into the ship, and will be evaluated, is discussed first.

Cost against Noise Reduction

Before embarking on a description of the noise reduction process and measures, a brief mention of the cost constraint of the Type 23 and its impact on noise reduction should be made. As is well known, the ship is highly cost-constrained[1], but noise reduction measures are expensive because they mean either:

(*a*) Special quiet machinery, which will be unique and hence far more expensive than commercial equivalents,

or

(*b*) Extensive noise reduction systems such as rafting, double mounting and hooding which, while rather cheaper than (*a*) above, initially do have a significant impact on ship size and weight.

The underwater noise target was tailored to what could be achieved using as far as possible commercial type equipments, with minimal redundancy in reliable noise-reduced equipments and no special noise reduction for equipments needed to achieve speeds above that obtained by 'diesel electric' drive.

The Noise Reduction Process

A systematic noise reduction process was evolved, initially based on submarine design practice but amended to take account of the Lead Shipbuilder's (Yarrow Shipbuilders Limited—YSL) methods of working. The process is summarized in FIG. 1. It was embodied into a Statement of Technical Requirements for Noise Reduction Measures for the Type 23 frigate[4].

The first stage was to derive an underwater noise target. This was based on the deliberations of a special working group who set target levels for warships, but it was subsequently modified to reflect the effects of cost and the actual towed array sonar to be fitted to Type 23 frigates. This target was incorporated into the Type 23's Naval Staff Requirement (NSR).

An overall equipment package was drawn up for the ship. The equipments and principal noise reduction measures were selected on the basis of underwater noise information recorded for each equipment in existing ships on noise ranges, and knowing what effect those equipments had on signatures. A typical example that received special attention, was that of diesel generators. They were selected for economy and cost of ownership primarily (compared with other prime-movers) but would need to be rafted, double-mounted and hooded if mounted low down in the ship. All likely noise sources were detailed in a document known as the List of Potential Noise Sources (LPNS). The Type 23 LPNS runs to 850 items and is included in the datum pack for the ship so that it can be used by ship's staff in their task of noise control. Some indication of the data coverage is given in TABLE I. Concurrently with this exercise, machinery line-ups in both the Patrol Quiet and Ultra Quiet states were detailed.

TABLE I—*Information contained in the List of Potential Noise Sources*

Equipment description
Quantity
Prime mover type
Power
Speed
Drive Type
Weight
Location
Shock Grade
Notes and NRM DDS No.

TABLE II—*Some of the information contained in Design Description Sheets*

Equipment shop vibration target
Airborne noise target
Mounting guidance/loading/natural frequency criteria
Piping guidance: lengths, pipe-clips, velocity, pressure reduction, inlets, discharges
Seating stiffness criteria
Flexibles
Appendages
Hull treatments including extent

The next step was to derive the noise reduction measures to enable the target to be met. These measures ranged from specifying the shop test vibration targets for the equipment in accordance with MOD specification G10008 to nominating the use of cascade orifices or quiet valves for noise containment in fluid systems during pressure reduction and the use of noise reduced pipe clips or hangers. These measures are all detailed in the Design Description Sheets for the Statement of Technical Requirement for Noise Reduction Measures (known as NRM DDS). Typical examples of subject matter are covered in TABLE II.

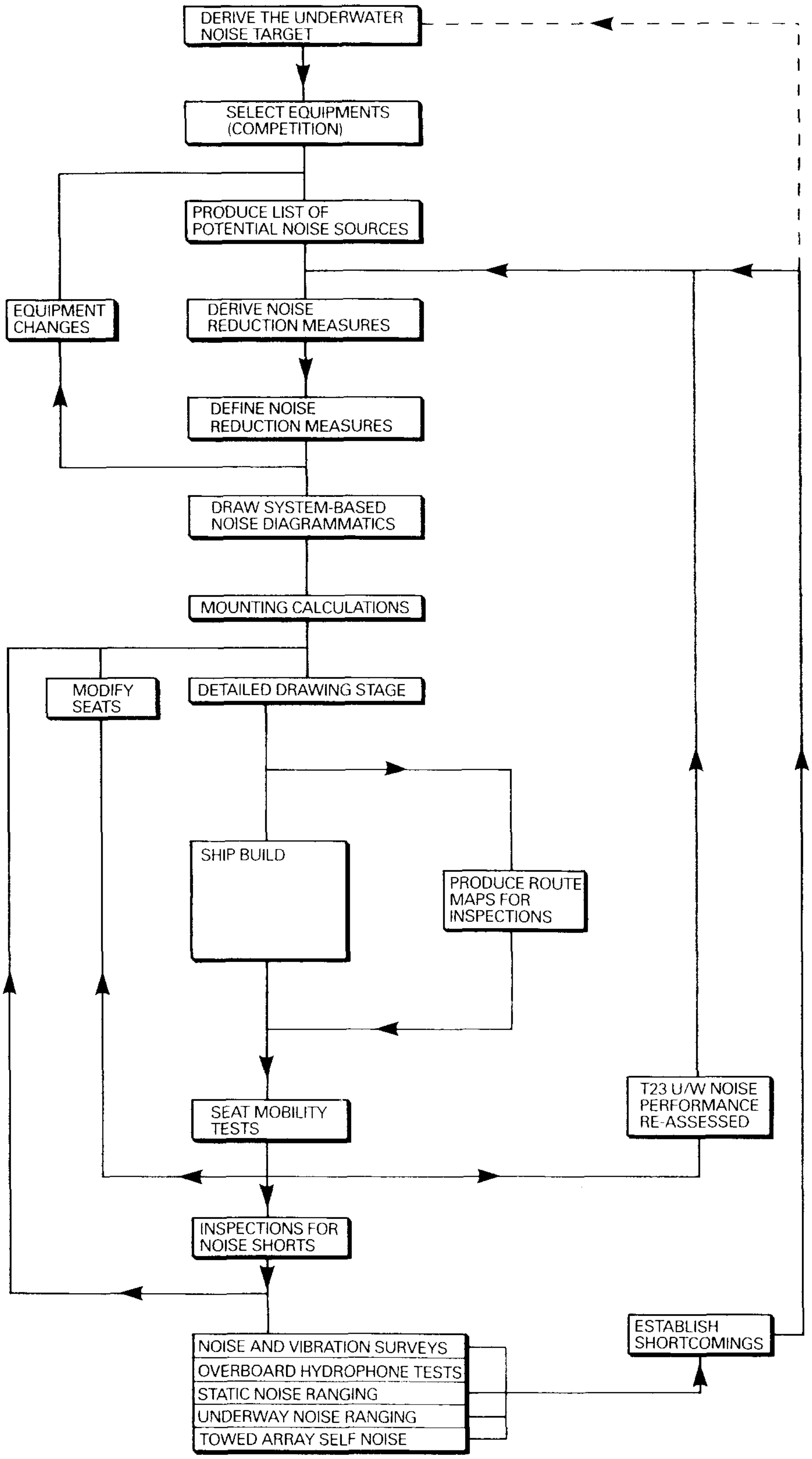

FIG. 1—THE TYPE 23 NOISE REDUCTION PROCESS

The Lead Shipbuilder was reluctant to take full responsibility for meeting the underwater noise target detailed in the NSR because he did not have comprehensive access to all the data that is needed to undertake the activities and investigations with confidence. As a result MOD retained responsibility for specifying the NRM whilst YSL were responsible for incorporating those measures correctly into the frigate design and build.

From the NRM DDS, YSL produced System-based Noise Diagrammatics (S-BND). In fact, rather than draw another set of diagrammatics just for noise work, the shipbuilder chose to incorporate noise reduction information on existing system diagrammatics which will form part of the datum pack. These diagrammatics show all the material features called up in the NRM DDS ranging from type and number of mounts to cascade orifices and special pipe clips. An example of part of one system is shown in FIG. 2.

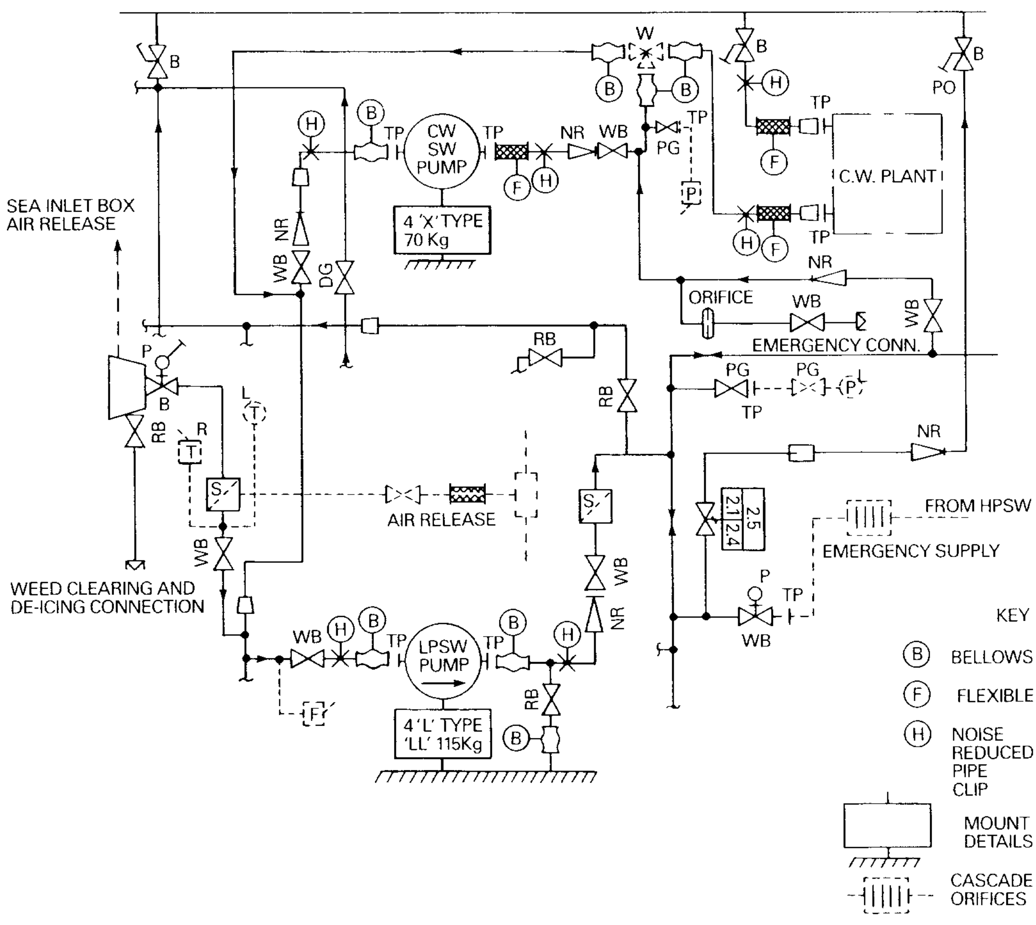

FIG. 2—EXAMPLE OF NOISE DIAGRAMMATIC FOR LP SEA WATER SYSTEM

In parallel, YSL and their sub-contractors carried out seating and mounting design and calculations. These had to satisfy natural frequency criteria and establish behaviour under shock and for seaway motions. Any seating or mounting arrangements that could not meet the NRM DDS criteria were referred to MOD for decisions. The list was extensive because, as the best attenuation at low frequencies is achieved by having mounting systems with low natural frequencies, this clashed with forcing frequencies originating from propeller and hull vibration. Other significant problem areas included:

(*a*) The natural frequency of the mounting system clashing with the fundamental forcing frequency of the equipment.

(*b*) Seaway motions for the ship, which are largely due to the specified operational roles, with soft mounting systems mean large movements of equipments and the extensive use of snubbers at extremities.

(*c*) Rafts where the complexity of the natural frequencies (12 for a double-mounted equipment) means compromise is necessary.

Next, the ship build stage commenced following completion of production drawings. As machinery seats were built and installed in *Norfolk*, they were subject to a 'mobility' test. This test was basically to establish seat stiffness, as the seat should be much stiffer than the associated mounting system. The seat was vibrated with a shaker and acceleration measured at various points to derive 'inertance' and hence the difference in stiffness between mounting and seating. A clash exists for seating design in surface warships between making seatings light to keep the ship weight within budget and making them massive enough and hence stiff for noise reduction purposes. An advantage of lightweight seatings is that the shock levels seen by equipments are much reduced if controlled yield occurs. A significant number of seats were modified to make them stiffer at certain forcing frequencies of the equipments (FIG. 3).

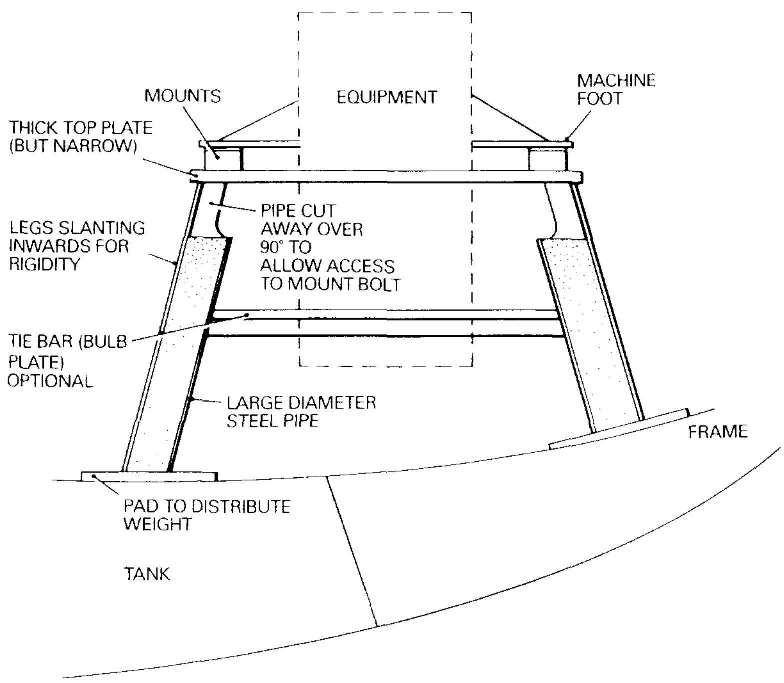

FIG. 3—TYPICAL SHORTCOMINGS IN MACHINERY SEATINGS, AND MODIFICATIONS NEEDED TO IMPROVE STIFFNESS

YSL were commissioned as part of the contract to inspect for noise shorts as they built *Norfolk*. Lectures were arranged at YSL by the Fleet Noise Reduction Team, and YSL staff accompanied the Team on their inspections of in-service Type 22 frigates. YSL are producing Noise Reduction Measures Inspection Packages, commonly called Noise Route Maps, for each equipment which has noise reduction measures specified for it. Typically noise route maps show the clearance envelope around the equipment and all noise reduction measures such as mounts, flexibles, noise-reduced pipe clips or hangers and cable bight size, etc. This will allow the inspector to make a methodical check of all noise reduction measures. Mount deflections will be established and checked. Towards the end of the build and testing period, a more formal noise inspection will be carried out jointly between MOD and YSL. The extensive route maps will be useful documents for ship's staff and other noise inspection teams to use later on.

Plans are being formulated for the next stage of the process, namely the measurement and assessment of the noise reduction measures. The first aim will be for the lead shipbuilder to carry out extensive vibration measurement within the ship in the vicinity of noise sources to ensure that mounting systems are effective and that known secondary paths through flexibles and pipe systems are not significant. Source forcing frequencies will be determined to enable identification of sore thumbs at a later date. An extensive array of accelerometers, a dual channel analyser and tape recorders will be used to record and analyse the data. One aim is to use 'go/no go' criteria to be derived in advance so that problem areas are highlighted almost as soon as tests have been completed.

The next stage under investigation will be overboard underwater noise measurements using hydrophones placed near the hull, to be made while the ship is alongside the wall with 'brakewheels' fitted in lieu of propellers. The primary aim here is to establish the position in the hull whence discrete frequencies emanate. This technique is not suitable for establishing absolute levels of underwater noise for comparison with targets because of distortion and reflection.

Noise ranging will consist of four stages, namely:

(*a*) Static and underway noise ranging during Contractor's Sea Trials (CSTs) directed at machinery noise to establish whether the noise reduction measures within the shipbuilder's control are satisfactory.

(*b*) Cavitation inception checks for propellers as part of CSTs.

(*c*) Static and underway noise ranging during Part IV trials to establish whether the noise target has been met.

(*d*) Self-noise trials to establish the effect of machinery noise on the performance of both hull mounted and towed array sonars.

Up to 12 days have been set aside during CSTs for noise investigations. Hull Vibration Monitoring Equipment is part of the ship fit of equipment and will be set up during noise ranging.

Noise Reduction Measures Incorporated in Type 23 Frigates

The principle features of noise reduction revolve around the use of electric drive and fixed pitch propellers, enabling the gearing to be disconnected by a shaft mounted SSS Clutch[5] and as a result allowing the lubricating system to be shut down. The lower diesel generators are extensively treated for noise reduction, involving the use of a raft, acoustic hood and double mounting system (FIG. 4). The other two diesel generators are mounted in the Upper Auxiliary Machinery Room (UAMR) which is thought to give additional vibration attenuation because of the mass of the structure inserted between noise source and keel. The shipwide hydraulic system has been dispensed with altogether and motors and small hydraulic power packs are used instead.

Other equipments have been rafted and double mounted including chilled water plants, steering gear and stabilizers. For a number of equipments, improved mounts have been used including the newly introduced 'Y' mount which is effectively an 'X' mount with an extra rubber element incorporated. A 'vee' mounting arrangement has been used for the Reverse Osmosis Plant incorporating soft Silentbloc mounts. The 'vee' arrangement was required because of the high centre of gravity of the plants but it adds significantly to the complexity of ship installation.

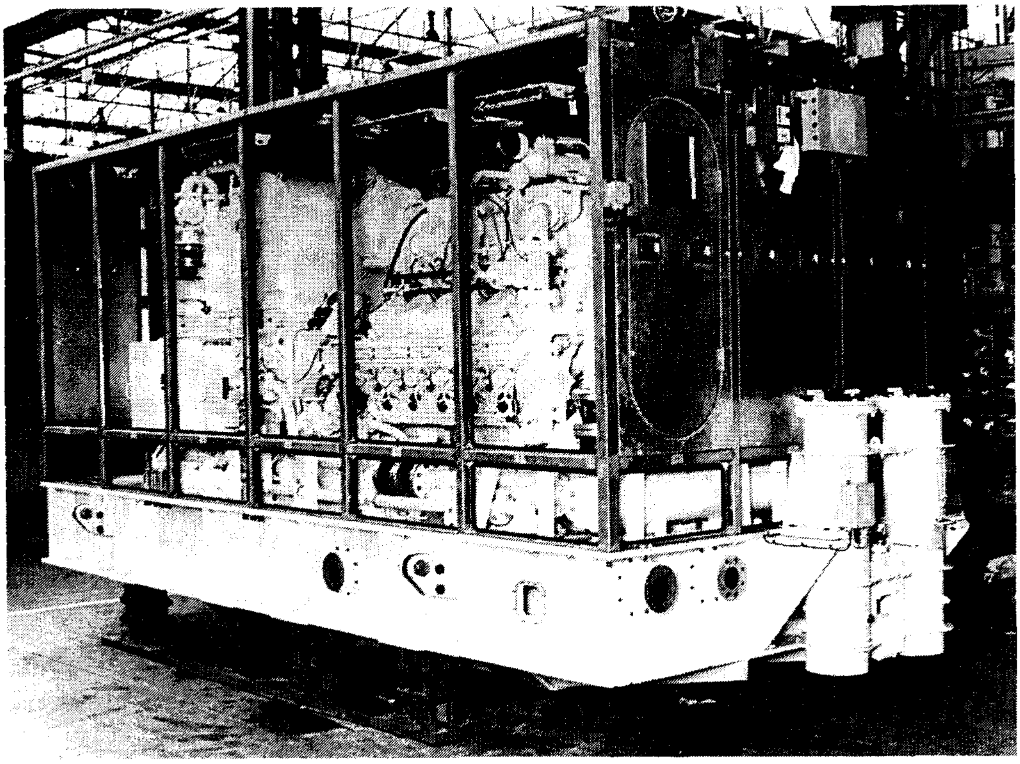

FIG. 4—A RAFTED AND HOODED DIESEL GENERATOR MODULE FOR A TYPE 23 FRIGATE
Photograph by courtesy of Paxman Diesels Ltd.

Pipe system noise reduction measures include the use of noise reduced pipe clips or hangers near each noise source (FIG. 5). Cascade orifices are used to reduce fluid pressure in small steps without cavitation occuring. Only two major cascades will be in use in the sea water systems and these are high up in the ship, because most main and auxiliary machinery is cooled by a low pressure sea water system with its own pumps, which is inherently much quieter. The high pressure sea water system has been so designed that the pumps will work at high flow and hence will not need continuous leak-offs. Diameters of pipe bends are controlled and fluid speeds are kept low. No pump impeller is directly 'visible' from the sea through the use of pipe bends and double suction chambers, needed to eliminate air ingress as well (FIG. 6). Overlapping grillage is used on suction and discharge grills whilst discharges are located just below the waterline to minimize the effect of pressure pulses.

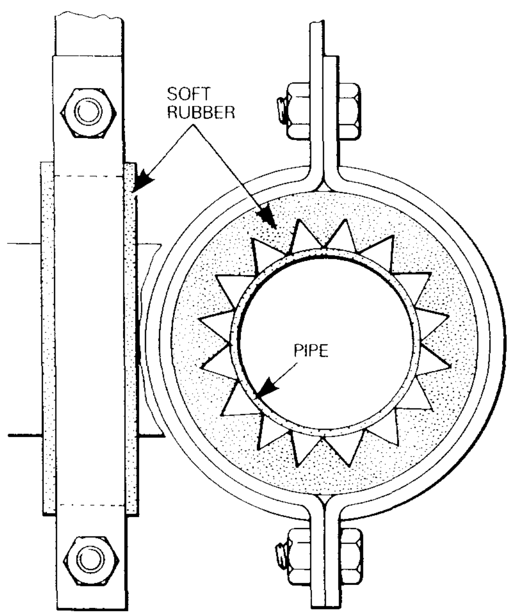

FIG. 5—A 'NOISE REDUCED' PIPE CLIP

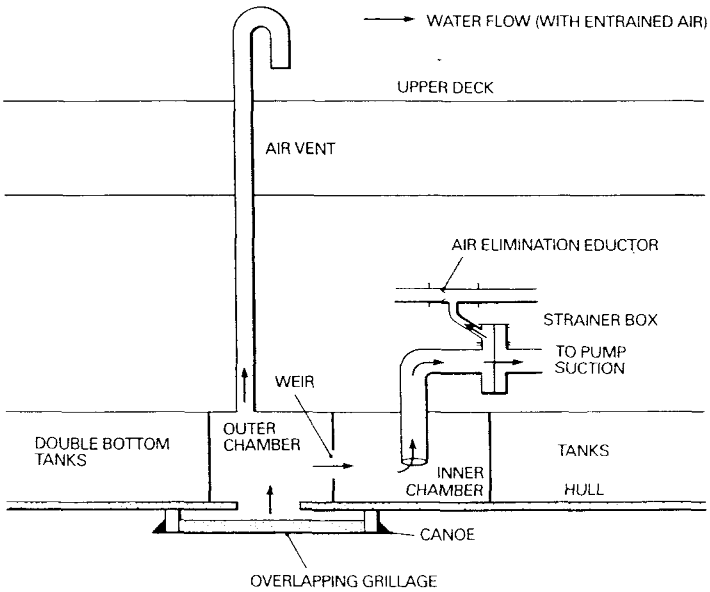

FIG. 6—AIR ELIMINATION IN SEA WATER SUCTIONS

Problems in the Procurement Process

Two areas need to be addressed as part of the procurement process in future ship designs and improvements. The first is that the use of near commercial equipment, procured under competition, often clashes with the need for the control of noise reduction. A typical example is that the Type 23 frigate machinery uses the GEC ALPAK motor instead of the traditional Naval Standard Range motor. The ALPAK motor is far cheaper but lighter and, due to its construction, vibrates more. As a result some equipments failed to meet the shop vibration targets set in the NRM DDS which were based on traditional SYMES range equipment data. This leads to the observation that instead of using traditional data to set shop vibration target levels, the NRM designer needs to have an 'analytical' tool at hand that allows him to work backwards from the underwater noise target to the equipment vibration level target for a variety of mounting systems. A cost balance can then be struck between quiet but expensive machinery with a simple mounting system and near commercial machinery with a more complex mounting system. The cost balance will normally favour the latter arrangement.

The second area concerns mainly the topic of double mounting system design, but also includes unusual mounting systems. This has been a traumatic area in the Type 23 design because the method of mount selection in the case of double mounting systems is little understood outside specialist acoustic consultants. As a result, the more minor double mounting systems in the frigate will need changes to make them effective now that shop vibration data has been obtained and the mounting systems analysed in more detail. The problem lay with the highly competitive nature of the tendering process and the lack of clarification occuring on technical matters which led to product design finance being squeezed in what is a complex area. The number of double mounting arrangements will increase in future noise-reduced warships and, as shipbuilders prefer to get subcontractors to provide total 'rafted' packages, better control of this design process will be needed. A simple step-by-step design guide for rafted and double mounted systems will be a starting point.

Developments in Surface Ship Noise Reduction

Noise reduction in warships has been essentially an evolutionary process. A ship has been built, evaluated and tested in the operational role to reveal the shortcomings which are then corrected by modifications or Alterations and Additions. Time for evolution is reducing rapidly as sensor and weapon developments occur ever quicker. The underwater noise performance of the Type 23 frigate is likely to be significantly different to a Type 22 because its hull form is very different, its machinery spaces are further forward, thicker steels are used, and the distance between frames has been reduced. Other differences are shown in TABLE III. Nonetheless prediction techniques that will enable the NRM designer to select the optimum mounting system and quieter machines and to detail the secondary measures are becoming available. They will be particularly useful in an environment where cost has to be controlled. These developments should mean that design responsibility for meeting underwater noise targets can be placed on industry, preferably the lead shipbuilder because his is the only organization that has complete control up to final installation.

TABLE III—*The major changes between Type 22 and Type 23 frigates with respect to underwater noise*

Type 22 Noise Problem	*Type 23 Solution*
Noise generated by CPP system and propellers	Eliminated by use of electric drive and special 'noise reduced' propeller
Rattling tubes in shafts	None fitted
Diesel Generator noise	Rafted, double mounted and acoustic hood, or mounted high up in ship
'Ringmain' Hydraulic system	Electric motors and small hydraulic power packs used instead
HP Sea Water system (leak offs/pressure reduction)	Pump output used to cool UAMR equipments (via cascaded orifices) only. LPSW system used to cool most machinery
Gearing tones	Eliminated by electric drive
Lub Oil System noise	Shut down in electric drive
Fridge Plant	Smaller equipment mounted in a less sensitive position
Air Compressors	Mounted high up in ship. LP Air Compressors are of hydrovane type
Auxiliaries (Boilers, Evaporators, etc)	Reduced in quantity with RO Plant

The prediction systems require an extensive data base, so better knowledge of the performance of all mounts, flexible pipes and noise reduced pipe clips will be needed. The effect of flexibles are normally left out of calculations at present. Means of incorporating them into predictions should be established. Ideally all manufacturers of vibration attenuators should supply information to a standard proforma if their product is to be accepted for use in warships. The optimum can only be achieved if the range of mounts and flexibles available to the designer is increased so that there is more choice to enable specific problems to be overcome. Double mounting systems will feature more in the future so standard acoustic design guidance is needed in this area for use by sub-contractors with limited acoustic experience. Other 'novel' vibration transmission reduction systems such as tuned vibration absorbers, suitable for treatment at specific frequencies, or variable tuned absorbers[6] or active vibration cancellation technology should be investigated.

However robust 'passive' systems do offer advantages in terms of simplicity and through-life costs in terms of power consumption, maintenance effort and reliability. Passive systems that have even lower natural frequencies and dynamic stiffnesses than the current range of mountings should be developed whilst the standing wave problem found in rubber mounts at mid frequencies should be overcome. A typical mount of the future may be based on air bag technology, but not necessarily incorporating a constant position mounting arrangement. Attention must also be paid to machinery seatings, with better guidance being made available to resolve the conflict of weight reduction versus stiffness. An improved seating may be similar to that shown in FIG. 7.

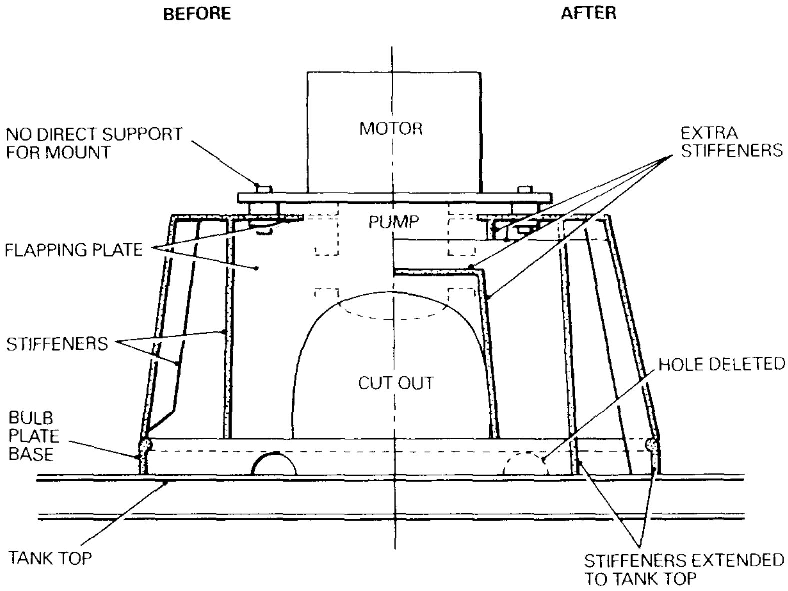

FIG. 7—AN IDEA FOR AN IMPROVED AUXILIARY MACHINERY SEATING

Noise reduction is also achieved by altering the requirements of systems (aimed at reducing pressure) and flow speeds, and ensuring cavitation does not occur. For instance noise produced by centrifugal pumps is associated strongly with tip speeds. High tip speeds are needed for high pressure systems so the designer will need either to eliminate high pressure systems or possibly to use multi-stage pumps. There is no reason why high pressure salt water systems should provide cooling water in existing ships so this system should be dead-ended with no flow take-off in the future and 'fire' pumps arranged to cut in automatically on loss of pressure. Low pressure sea water pumps should provide cooling water for all machinery and other domestic users, with engine-driven booster pumps for equipments such as UAMR Diesel Generators. Although air can produce problems in heat exchangers, a small bleed of air into sea water systems can be beneficial in reducing cavitation and hence vibration. Another development, in fresh water systems, is to use a pressurizer so that in the silent hours overnight, pumps can be shut down and the number of equipments in use reduced. There may be advantages in using heavier, slower speed machines, but these will have to be examined closely with respect to the frequencies generated and mounting performance. Obviously the avoidance of reciprocating machinery reduced the NRM designers's problems. Acoustic cladding may have to be provided around certain areas of the machinery spaces. Cladding the modules of diesel generators and gas turbines are obvious examples but attention should also be paid to stabilizers, steering gear and similar equipments.

Industry must be encouraged to produce low vibration machinery as a matter of course because benefits will also be realized in terms of machinery reliability. Vibration is destructive as it shortens bearing life, increases wear rates, fractures pipes and promotes failure of electronics and electrics needed for sensors and control.

Knowledge of noise reduction methods and technology must be widely disseminated to all concerned. Clear techniques, solid guidelines and step-by-step approaches should all be available to the NRM designer. The challenge to a noise engineer specifying the measures to be taken in surface ship noise reduction is not just to achieve the underwater noise target but to do so in the most cost-effective way.

Acknowledgements

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