# NOISE REDUCED OUTBOARD MOTOR

## A MEAC DESIGN-AND-MAKE PROJECT

BY

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*This article is based on project work carried out by the authors as part of a design-and-make group, whilst attending the 1981 February Marine Engineering Application Course at the Royal Naval Engineering College, Manadon. The design-and-make project forms about one fifth of the 30-week course, and is intended to complement the formal course content by providing the opportunity for graduate engineer officers to tackle a practical engineering problem whilst still in a training environment. The project also ensures that junior engineer officers become aware of the nature of typical practical problems and the financial, programme, and material constraints that affect their solution.*

### Introduction

Tests undertaken by the Royal Navy have shown that the standard outboard motor used to propel the 16-ft Gemini dinghy for minehunting and clearance diving operations has an unacceptable underwater acoustic signature for use against modern mines. One possible solution proposed by D.G. Ships but not developed due to lack of funds was the production of a non-cavitating outboard motor to replace the super-cavitating units currently in service. This idea was forwarded to the Royal Naval Engineering College and given to a Marine Engineering Application Course (MEAC) design-and-make group to design and produce a noise reduced outboard motor to be evaluated by noise trials to assess the principle of a non-cavitating outboard motor.

FIG. 1—'DESIGN-AND-MAKE' GROUP WITH COMPLETED PROJECT

This article identifies the main features of the project and describes the non-cavitating outboard motor prototype produced, shown in FIG. 1. Imperial units are used throughout as this is still the custom in the Gemini and outboard motor field.

## The Problem

The first step of the design-and-make team was to identify the requirements of the standard outboard motor and its problem areas. When a 16-ft Gemini is used for mine disposal, it not only carries a fully-equipped diving crew but also has a mine-disposal weapon suspended underneath. The required speed for this role is 4 knots, but it has to maintain good directional control. The noise trials carried out by D.G. Ships on the standard propulsion units showed four major sources of noise and these are, in order of magnitude:

(*a*) Propeller cavitation.

(*b*) Underwater exhaust.

(*c*) Gear meshing.

(*d*) Engine firing.

The Evinrude 35-hp engine supplied to RNEC from D.G. Ships for the project had already had the exhaust noise eliminated by the use of above water exhausts. Thus, the major concern of the project was the design of a non-cavitating propeller and a noise-reduced transmission system. The design also had to maintain the standard outboard's acceptable magnetic signature and allow the fitting of a propeller guard for diver safety.

## Design Options

A towing test of a fully-equipped minehunting Gemini showed that it required a thrust of 315 lbf to propel it at the desired speed of 4 knots. For this, preliminary design showed that it would require a three-bladed propeller of 24-in diameter running at a speed of 400 rev/min if blade pressures were to be reduced below those that could cause cavitation. The power input for this propeller would by 7·4 hp, the standard 35-hp engine producing this at approximately 2000 rev/min. Several methods of transmitting the necessary power and shaft speed were therefore investigated. These included drive by:

(*a*) Belts.

(*b*) Silent chains.

(*c*) Hydraulic transmission.

(*d*) Electrical transmission.

(*e*) Direct drive.

The advantages and problems to be overcome with each of these drives were assessed and for several reasons the direct-drive solution was pursued. It was further decided to base the design around an 'add-on' kit for a standard unit so that it could be converted quickly and with minimum cost for use in minehunting. The direct-drive solution also offered least restriction to underwater flow, and other advantages were minimum change to the standard engine, utilization of naval stores components, and the ability to employ the same refit and maintenance techniques.

## The Chosen Design

The detailed propeller design as carried out by AMTE (Haslar) was a three-bladed 24-in diameter propeller with 0·8 blade-area ratio and a 0·95 pitch ratio. In order to reduce surface effects and noise, this propeller was designed to run with the blade tips at least 12 inches below the water level. In order to achieve this the engine leg had to be extended by 14·5 inches.

It was decided to retain the standard bevel gearbox at the bottom of the leg as this already contained very accurately machined gears and the reduced input speed would reduce meshing noise. This gearbox already incorporated a forward, neutral, and reverse capability which had to be retained for manouverability.

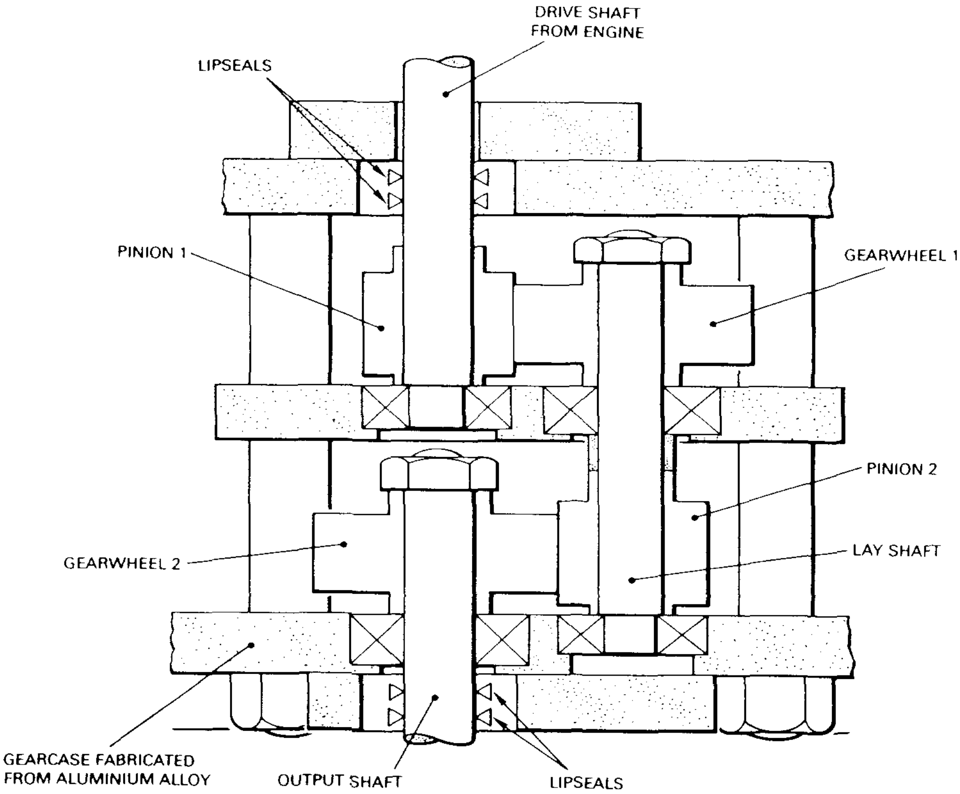


FIG. 2—PRIMARY REDUCTION GEARBOX

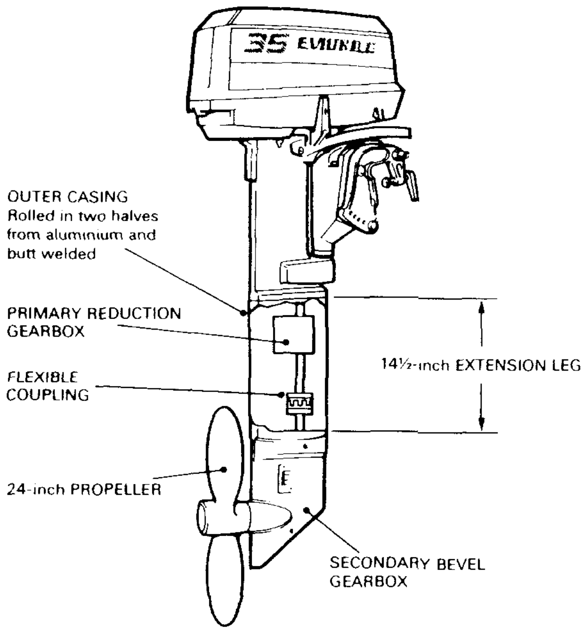


FIG. 3—MODIFIED TRANSMISSION SYSTEM

To match the propeller speed to the engine speed, an overall reduction ratio of 5 to 1 was required. The reduction ratio of the bevel gearbox was 2 to 1 and therefore a further gearbox with a 2·5 to 1 ratio had to be included in the transmission system. This extra gearbox would have to be mounted in the extension to the engine leg and was therefore constrained to its hydrodynamic shape. There was a choice between two types of gearbox, epicyclic or layshaft: after comparing respective sizes for the power and the reduction involved, the layshaft was found to be the more suitable. Therefore, it was decided to design a gearbox of a double-reduction layshaft design (FIG. 2). Workshop facilities constrained the design to the use of straight cut spur gears and calculations showed the optimum diametral pitch to be 14 using case carburized steel.

A flexible coupling was incorporated between the gearboxes to prevent noise being transmitted down the drive train. The transmission system as designed is shown in FIG. 3.

**Manufacture**

All the necessary parts were produced in the workshops at the RNEC by the design-and-make team of five MEAC officers.

Detailed propeller drawings were produced and from these a wooden pattern and an aluminium alloy casting were manufactured with the help of the workshop staff. The rough casting was then ground and hand finished to the standard required for a non-cavitating propeller.

The standard engine drive shaft material was analysed in the RNEC materials laboratory and was found to be sufficiently strong for the increased torque in the modified shafts. It was therefore possible to manufacture all the new shafts from two standard 35-hp drive shafts, thus restricting the materials to naval stores items.

The gearbox structure was manufactured from three 0·5-inch aluminium-alloy plates separated by stainless steel spacers with a bearing layout to utilize splash lubrication. The gearcase was fabricated from aluminium-alloy sheet, and the input and output shafts sealed by lip seals. The gears were machined to a high degree of accuracy on a horizontal mill and were then case carburized to a depth of 10 thousandths of an inch.

**Trials**

The modified engine was completed in October 1981 (FIG. 4) and was first tested in the outboard motor test tank in Devonport Dockyard to run-in the new gearbox. After a close inspection of all gears, seals, and bearings, a bollard pull test was run to check the thrust produced by the engine. The engine produced the required thrust of 315 lbf at an engine speed of 1960 rev/min.

The engine was then mounted on a fully-equipped minehunting Gemini and was found to provide both the required speed of 4 knots and the high manoeuvrability achieved with the standard engine.

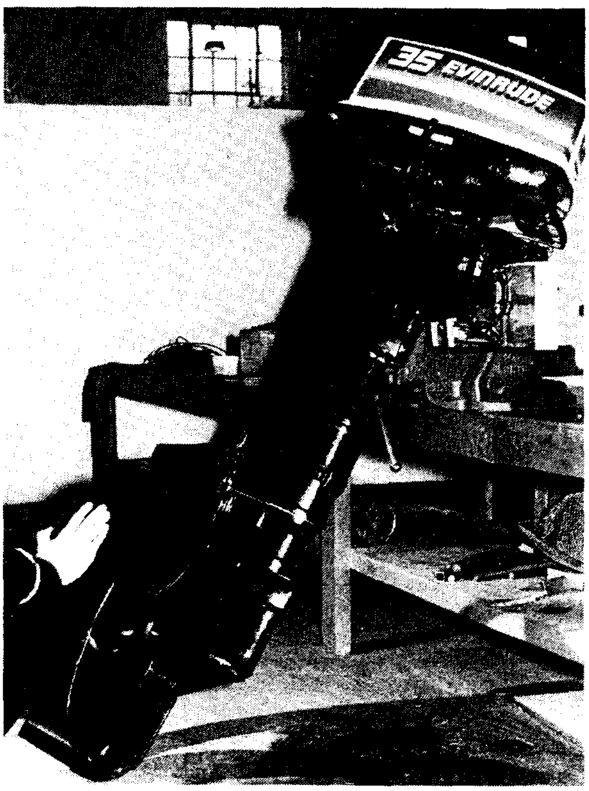

FIG. 4—COMPLETED PROJECT

Within the eight-month time-scale and cost limitations on the project, it was not possible for the engine to be run on a noise range, but a comparison test with a standard engine was arranged with the help of H.M.S. *Sovereign*. Two minehunting Geminis, one with the standard and the other with the modified engine, were driven between two buoys at a set distance from the submarine's bow sonar. The resulting sonar traces shown in FIG. 5 were analysed and showed that the modified engine had a considerably reduced noise signature.

The engine has now been returned to D.G. Ships for further tests which will include a full set of noise-range tests to obtain a more detailed noise signature analysis.

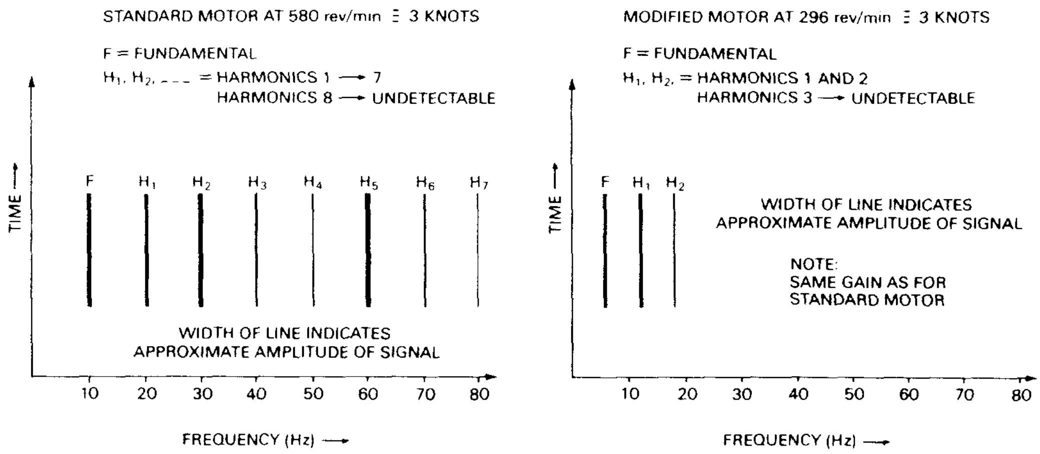


FIG. 5—SONAR TRACES OF THE STANDARD AND THE MODIFIED OUTBOARD MOTORS

**Discussion**

The redesigned outboard motor offers a greatly reduced noise signature with the minimum of change from a standard engine and it can be incorporated as an add-on kit. In addition the redesigned motor involves no change to the standard Gemini and can use the same maintenance techniques and refit cycle as current units. All the advantages and inherent manoeuvrability of the existing outboard motor have been retained and no additional training is required by operators. The major advantage of this redesign is the low cost involved in achieving a reduced noise signature.

**Conclusions**

It is possible to make a non-cavitating outboard motor for mine clearance operations. The new engine, although only a prototype, has achieved the operational requirements and has a considerably reduced noise signature. Full noise trials of this prototype will give a more detailed indication of the improvement in noise signature that the redesign has achieved.

**Recommendations**

The following recommendations have been made to D.G. Ships for the further development of the redesigned motor:

(*a*) By making the propeller of a lighter material it could be mounted further away from the engine leg without uprating the bevel gearbox bearings and so further reduce the noise produced at the blade passing frequency and its harmonics.

(*b*) Non-metallic, possibly helical, gears could be used in the primary gearbox to further reduce both gear meshing noises and the magnetic signature.

**Acknowledgements**

The team would like to acknowledge the assistance of H.M.S. *Sovereign*, Section 154 of the Ship Department at Bath, and the Project Supervisor and workshop and other staff at the R.N.E.C., Manadon.

**Postscript by R.N.E.C. Manadon**

The work reported in this article was presented to the Design and Make Adjudication Board in November 1981 and was coupled to a successful demonstration of the noise-reduced outboard motor. This presentation was subsequently repeated at the Ship Department for the benefit of interested Staff, at which point the design was transferred back to D.G. Ships D154 for further development.

This design exercise is a good example of design-and-make projects currently being undertaken at the R.N.E.C., and proposals for similar work are always welcome, and should be addressed to the Head of Marine Engineering at the College in the first instance.

**Ship Department Comment**

D.G. Ships in conjunction with Plessey Marine carried out noise-ranging trials with the Manadon modified outboard motor in January 1982. The venue was Plessey Marine's facility at Waterlip Quarry near Shepton Mallet.

The results showed that there was a large reduction in noise at lower frequencies which is now at an acceptable level. At higher frequencies, the signature was greater than anticipated. D.G. Ships will be carrying out a detailed study on the results obtained, but at this stage it is not possible to comment further.

The work done by the Manadon team has made a significant contribution to D.G. Ships's task of procuring a propulsion unit suitable for use on a minehunting Gemini. Coxswains have expressed favourably on the good directional control of the craft at slow speed when powered by the Manadon modified outboard motor. Components designed and manufactured by Manadon have performed without fault during the trials.

It is still envisaged that, with further refinements, the outboard motor will be able to meet D.G. Ships's requirements.