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# TECHNICAL NOTES AND RESEARCH BRIEFS

13.9

## QUIET POWER WHALEBOAT

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*For use in underwater acoustics, an effectively inaudible inexpensive workboat was achieved by a simple arrangement of the propulsion machinery.*

About 15 years ago, we became convinced that the ordinarily available ship's boats were not suitable for our work of approaching whales and porpoises closely for observation or capture (our observations include underwater listening). In listening to and recording underwater sounds at sea, one's own ship or boat is usually effectively the noisiest thing present, especially underway. There are various ways of quieting a ship (stopping everything, for example), but here we address ourselves to the special problem of quiet propulsion for a sea-going small boat. The unsuitability of most motor boats is primarily a matter of noise in the water, which not only interferes with the ambient sound field, but also may at times frighten away the animals we seek to approach. We therefore sought a boat with quietest propulsion possible; at the same time, we decided on a plastic (fiberglass) hull so as to reduce maintenance and the probability that it would leak upon being put in the water. A small budget excluded expensive developments, so that we were somewhat restricted in our choices. We considered several sorts of propulsion that approach silence in the water.

We did not seriously contemplate the traditional rowing whaleboat, suitable as it had proved in the past. The main reason was the improbability of finding and maintaining the power plant (4 or 5 dedicated athletes), which moreover would nowadays be expensive beyond our means; besides, it leaves little room in the boat.

Sailing we gave up early; for one thing, calm and windless weather is the best (quietest) time for listening, and for another, whales and porpoises seem so often to run dead to windward. We briefly contemplated a wind-driven Savonius rotor drive (with a screw propeller), which attracted us as seeming to have its best point of sailing into the wind, but indications of excessive rotor size discouraged us. We'd still like to try it, though.

An airscrew (as used in swamp boats) was suggested, but did not appeal to us, for it seemed an awkward arrangement for hoisting on davits.

We even toyed with the idea of an oscillating fin (like a fish or whale tail), such as had been used for some fresh-water sport fising boats.

Outboard motors were rejected because all those we could find cavitated (and thus were inherently noisy) at operating speeds.

Gas turbines have recently become a possible solution, but are very expensive, and have high fuel consumption and dangerous exhaust.

In the end, we settled on a shock-mounted air-cooled inboard engine turning a large propeller slowly through reduction gears and belt drive.

Ship or boat noise in the water has three major components. One is caused by the propeller (or the now rare paddle wheel), another is caused by the engine, and the third by the passage of the hull through the water. Propellers are most noticeable when they cavitate, at which point, they often outweigh the other components. Engine noise emanates from the moving parts, and may range from the rather slow thumps and clanks of a reciprocating engine to the high whine of reduction gears or turbines. Hull (water) noise is ordinarily the least of the three, especially at slow ship speed and in low sea state. Individual characteristics or defects may make each component stronger; for example, damaged or singing propellers, worn bearings and squealing shafts, and clanks and creaks in the hull. Ruling out damage, we can eliminate or mitigate the inherent noise sources by such precautions as keeping the propeller turns below cavitation speed, and acoustically isolating the engine from the hull and hence the sea by shock-mounting it and disconnecting it mechanically. This last involves at least two steps: (1) separation of the engine from the propeller by some form of "soft" transmission, such as hydraulic pumps and flexible hoses, perhaps, or, as in the type XXI U-boats and our more modest arrangement, belt drive (which does impose some restraint on the compliance of the engine shock mounts); (2) elimination of acoustic coupling through pipes and liquids by air cooling the engine and exhausting direct to the air.

For a hull, we obtained a wreck left in New Bedford by the 1954 hurricane. It was a 5.5-m fiberglass Palmer–Scott bass boat, designed for a large outboard motor. While this was by no means the ideal hull for a high-seas whaleboat, it was what we could get. The bow has a good flare, there are no hard chines or spray deflectors to make noise, but the stern is a flat transom the entire width and depth of the hull. Had it been of any conventional wooden build, it would have been a total loss, for the hull was split nearly the entire length, but being fiberglass, it was easily repaired. The hull was decked over forward for 1.4 m, forming a storage cuddy. The rest of the boat was left open, except for two small lockers in the quarters. The cockpit (3.8×1.5 m) was floored over, and the space beneath filled with styrofoam blocks for flotation in case we were swamped or stove. Hoisting pads were fitted, and the outboard well filled in with a plexiglass bottom that permitted observation of the various propellers with which we experimented. A 16 hp Wisconsin air-cooled gasoline engine (generously supplied by A. C. Vine) was set on neoprene shock mounts. After 2:1 reduction gears were employed, the propeller shaft was belt driven. In order to obtain maximum reduction, the engine was set backwards with the power take-off forward, so that the increased shaft clearance permitted a 33-cm diam pulley. This gave us 325 shaft turns at 2400 engine rpm.

We experimented with several propellers, finding as expected that large diameter and high pitch gave best results. Hull clearance limited us to 51-cm diam, and we are now using a 48.3-cm propeller with 61-cm pitch. Turning this large propeller at 325 rpm gave us 5 kt with no cavitation, except in very sharp turns. The plexiglass window over the propeller enabled us to watch this performance.

The engine was partially boxed in, and the exhaust, via an automobile muffler, was directed straight upward. In this way, the engine noise was hindered from reaching the sides of the boat. Although the air-borne noise was great, there was nearly none in the water.

Careful tests with sensitive listening equipment showed that this arrangement made a very quiet boat. In the open sea, even during flat calms, we were unable to hear the boat at its full speed of 5 kt, even within 3 m of the hydrophone. We ran controlled tests in a very quiet and sheltered inlet where the ambient background was only about −30 dB referred to a sound pressure of 1 μbar over a bandwidth of 10 000 Hz, using listening gear consisting of an AX-58 Rochelle-salt hydrophone with a sensitivity of −78 dB at 1 V/μbar, a WHOI "Suitcase" (a broad-band amplifier), and a tape recorder (system bandwidth 30–10 000 Hz). The boat was run at 5 kt past the hydrophone at a distance of 7 m. No distinct sound of any kind was detected, but the general ambient was raised only ½ to 1 dB. Spectrographic analysis revealed no distinct frequencies, such as are characteristic of ship signatures. In other words, this boat is so nearly impossible to detect by listening that we are tempted to call it silent. We used throughout the same equipment with which we measured underwater sound of ships and animals.

In quieting a vessel for listening and testing various sound sources, such as shipboard machinery, a practical rule is that if something does not hamper the sound man's listening, it does not matter if it's left running. Obviously, this threshold varies with conditions such as sea state (white caps, for example, can put one out of business in many kinds of listening) and required ship speed. By this criterion, our *GRAMPUS* is operationally inaudible. It has proved possible to leave the recording of the underwater sounds of whales to the stopped and silent ship while the *GRAMPUS* circulated freely among the animals, apparently without disturbing them and certainly without disturbing the recording. It is, of course, highly unlikely that even such a silent boat can always approach whales or porpoises unnoticed. This is not so much the point, which really is that we wish not to try to sneak up while banging on a dishpan.

The entire cost of this boat was just under $3000 as it was completed in March 1954. Her displacement with two men and all equipment, including whale craft (hand harpoons, harpoon gun, lances, tubs of line) and acoustic recording gear, was very close to 1 ton (metric), so that she was easy to handle on davits. Since 1955, *GRAMPUS* has been successfully used at sea on several cruises in the western North Atlantic from the R/V *BEAR* and the trawler *CAPTAIN BILL III*. Lately, there has been new interest in silent boats, and we hope and expect that newer boats will improve and outstrip *GRAMPUS*. To this end, we have made here particulars available to the two developers we know of, both building on 26-ft Coast Guard boats. The first of these is for the National Science Foundation (Antarctic Program), and the second is being modified for Dr. Roger Payne of Rockefeller University by the Electric Boat Company (General Dynamics Corporation) in a very elaborate extension of the principles outlined here. For the benefit of others, we have detailed our experience here; the use of such a boat is not limited to cetology.

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## INTERNATIONAL ROUND-ROBIN CALIBRATION IN UNDERWATER SOUND

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*A round-robin program of hydrophone calibrations was organized by a committee of the International Electrotechnical Commission to determine the sperad in values obtained by participating international agencies in calibrating the same group of hydrophones. The results were expected to permit specifying a practical figure for accuracy of measurement and to provide information that could be used to design an international standard hydrophone for underwater sound measurements. The average deviation of all data is ±0.6 dB.*

THE SUBCOMMITTEE ON ULTRASONICS within the Technical Committee 29 of the International Electrotechnical Commission has completed a round-robin calibration of hydrophones. Nine countries participated in the program:

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| Australia | R. A. N. Experimental Laboratory, Edgecliff, N. S. W. |
| France | Laboratoire de Détection Sous-Marine, Le Brusc |
| Germany | Physikalisch-Technische Bundesanstalt, Braunschweig |
| Italy | Ufficio Studi Elettro Acustici, San Terenzo (La Spezia) |
| Japan | Technical R. and D. Institute, Yokosuka-Shi |
| Netherlands | Physics Laboratory, National defence Research Organization, T. N. O., The Hague |
| United Kingdom | Admiralty Underwater Weapons Establishment, Portland, Dorset |
| U.S.S.R. | Institute for Physicotechnical and Radiotechnical Measurements, Moscow |