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Report on
Sound Analysis of U.S.S. S-20

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ABSTRACT

Some 1,000 quantitative measurements of the intensity of propeller noises of the S-20 were made under different conditions of water, speed, range, and depth of submergence to determine the effect of:

- (a) Covering the propellers with rubber by two different methods.
- (b) Insulating the starboard motor and reduction gear with compressed felt.

From a statistical treatment of the large quantity of data, it is concluded that on the average:

- (a) Covering the propellers with rubber increased the noise.
- (b) The anodic covering caused less noise than the vulcalock type.
- (c) The felt insulation installed by the Arthur D. Little Company increased the noise at 220 turns (3 kts) and decreased it at 260 turns (6 kts).
- (d) All the effects produced are small compared with the total noise level and they are therefore minor factors in the total noise reduction problem.

I. INTRODUCTION

(a) Authorization

This work was authorized by Bureau of Engineering letter, ref.(a). Additional references pertinent to this problem are listed as refs.(b) to (f) inclusive.

Reference: (a) BuEng let.SS174/S41(12-16-Do) of 20 Dec.1933.
(b) NRL let.S68/61 of 18 April 1934 to BuEng.
(c) BuEng let.C-NP14(4-18-Do) of 24 May 1934 to NRL.
(d) BuEng let.C-SS172/S41(12-18-Ds) of 14 July 1934.
(e) NRL let.C-S68/61 of 17 Dec.1934 to BuEng.
(f) BuEng let.P16-4(5-23-K) of 27 May 1935 to
Asst.Sec.Nav.

(b) Statement of Problem

The fundamental problem was to reduce the range at which propeller noises of a submarine could be heard by a listening ship. Since noise must be produced by some vibrating structure on the submarine, reduction in the vibration should reduce the noise. As explained in previous reports, there are certain obvious sources of vibration and two were selected for study, partly because they involved relatively simple changes and afforded an opportunity to develop the measuring technique.

(c) Description of Material

The submarine S-20 was used as a sound source or target ship throughout these experiments. The U.S.S. SEMMES was used as a listening ship. The S-20 has a standard low speed direct drive motor on the port shaft and a high speed motor driving through a reduction gear on the starboard side.

In the fall of 1934, a spare set of propellers for the port side of the S-20 was obtained and covered with rubber by the vulcalock process. After these had been installed at the Norfolk Navy Yard, the original set from the S-20 was covered with rubber by the anodic process.

In the spring of 1935, a compressed felt insulation was placed under the motor and reduction gear on the starboard side of the S-20. It was impractical to remove this for a comparison with and without the insulation, so the effect of the insulation was largely eliminated by placing steel wedges between the motor base and the hull bed plate.

II. METHOD OF TEST

Because of the many uncontrollable variable factors, absolute measurements are not practical. Comparison tests for the port and starboard motors were therefore made for each item under as constant conditions as possible. This assumes that the same motor will produce the same amount of noise in the water for the same number of turns under the same conditions, and that if conditions change they will effect both motors equally. The series of tests are shown in the table.

<u>Item</u>	<u>Port</u>	<u>Stbd.</u>	<u>Conditions</u>
Before changing	Bare	Bare	Deep water, 1934.
Rubber covering	Vulcalock	Bare	Deep water, 1934.
Rubber covering	Vulcalock	Bare	Stbd. insulated shallow water, 1935.
Rubber covering	Anodic	Bare	Stbd. insulated shallow water, 1935.
Effect of insulation	Anodic	Uninsulated	

For each test runs were made as follows:

<u>Run</u>	<u>Range</u>	<u>Motor</u>	<u>Speed</u>	<u>Turns</u>
1	1,000	Stbd.	3 kts.	220
2	"	"	6	260
3	"	Port	3	220
4	"	"	6	260
5	2,000	Stbd.	3	220
6	"	"	6	260
7	"	Port	3	220
8	"	"	6	260

For each run a series of 20 readings of the intensity of received sound were made at frequencies of 10, 12, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 30, 32, 35, 40, and 45 kilocycles. About 80% of the readings were checked by duplicate runs.

For each run the S-20 submerged to periscope depth on a specified course and the SEMMES took position on the designated side and adjusted the range by echo to within 50 yards of the specified distance. Ranges were checked at approximately 10 minute intervals and readings discarded if the error exceeded 10% of the range. The data from 1934 were obtained in deep water (over 1,000 fathoms) but at New London in 1935, it was necessary to operate in shallow water due to the limited time available and the distance out to deep water. An area in Block Island Sound was chosen having an average depth of 110 ± 20 feet and a smooth bottom. The course was reversed on alternate runs to confine operations to the same area.

The listening apparatus on the SEMMES consisted of a transceiver and a sound analyzer. The transceiver gives a flat response over a wide range of frequencies and a linear response over a wide range of intensities. The analyzer had uniform selectivity and sensitivity over the frequency range used and means were provided for rapidly and frequently checking the amplifier gain.

Readings were made in decibels defined by the equation

$$db = 10 \log \frac{W}{W_0}$$

where $\frac{W}{W_0}$ is the ratio of received sound energy, W , to some arbitrary

level, W_0 . In these experiments W_0 was taken as minimum audibility for the normal human ear. The practical advantage of the decibel scale for listening is that it corresponds roughly to the energy response of the human ear which is logarithmic. Also one decibel is about the minimum difference in the intensities of two sounds which the human ear can distinguish.

The SEMMES and the S-20 took water temperature readings at 15 minute intervals during tests and at least once each day the S-20 read the temperatures during a deep dive. The SEMMES used injection water temperatures and the S-20 had a thermometer mounted outside an eye port in the conning tower. This gave the data for horizontal and vertical temperature gradient studies.

III. DATA OBTAINED

For each speed and range a series of 20 readings at as many different frequencies were taken on the starboard and then on the port motor. The SEMMES was always on the operating side. For each frequency the algebraic difference, S-P, was found, and these values were averaged for the run. If S-P is positive, it means that the starboard side is noisier than the port side and conversely. There was considerable variation in individual readings, but it is believed that the large quantity of data taken warrants this simple statistical treatment.

The data taken in October 1934 are shown in Table I, as follows:

Table I

Bare vs. Vulcalock-covered Propeller Blades

<u>Date</u>	<u>Range</u>	<u>Speed</u>	<u>Ave.S-P</u>	<u>Remarks</u>
17 Oct.1934	700	3	+2.2	Both propellers bare
27 " "			<u>-8.0</u>	Port covered by vulcalock
			-10.2	Vulcalock minus bare Covering increased noise.
17 Oct.1934	700	5	+3.1	Both propellers bare
27 " "			<u>+3.8</u>	Port covered by vulcalock
			+0.7	Vulcalock minus bare No material effect.
17 Oct.1934	1400	5	+10.0	Both propellers bare
27 " "			<u>0.0</u>	Port covered by Vulcalock
			-10.0	Vulcalock minus bare Covering increased noise.
17 Oct.1934	Ave.of above		+5.1	Both propellers bare
27 " "			<u>-1.4</u>	Port covered by vulcalock
			-6.5	Vulcalock minus bare Covering increased noise.

For the 17th of October runs, both propellers were bare. For the 27th of October runs, the port propeller had been covered with rubber by the Vulcalock process. The data show that for the bare propellers, the starboard was consistently noisier than the port by an average of

5.1 db. When the port propeller was covered with rubber the results varied widely, but the average S-P is -1.4 db. showing that the port was noisier than the starboard. The algebraic difference of Vulcalock covered minus bare is -6.5 db which means that covering the port propellers made them noisier. A difference of 6.5 db. means that on the average the sound energy in the water from the propeller was increased by a factor of 4.5 ($6.5=10 \log 4.5$).

This result was rather disappointing but might have been attributed to the process used in rubber covering and that it changed the contour and smoothness of the blade, particularly on the leading edge. It was decided to cover a set of blades by the anodic process which is of the electroplating type and should cause less change in contour.

The next tests were made under different water conditions and after the starboard motor and reduction gear had been insulated from the base. It was necessary to repeat the test of 27 October 1934 and then substitute the port propellers covered by the anodic process. The summary of results is shown in Table II.

Table II

Vulcalock vs. Anodic Propeller on Port Side

<u>Date</u>	<u>Range</u>	<u>Speed</u>	<u>Ave. S-P</u>	<u>Remarks</u>
5 Aug. 1935	1,000	3	+0.1	Stbd. bare, port vulcalock.
8 " "	"	"	<u>+6.1</u>	Stbd. bare, port anodic.
			+6.0	Anodic minus vulcalock Anodic quieter.
5 Aug. 1935	1,000	6	+0.6	Stbd. bare, port vulcalock.
8 " "	"	"	<u>+6.7</u>	" " " anodic.
			+6.1	Anodic minus vulcalock Anodic quieter.
5 Aug. 1935	2,000	3	+5.7	Stbd. bare, port vulcalock.
8 " "	"	"	<u>+2.7</u>	" " " anodic.
			-3.0	Anodic minus vulcalock. Vulcalock quieter.
5 Aug. 1935	2,000	6	-6.8	Stbd. bare, port vulcalock.
8 " "	"	"	<u>-2.6</u>	" " " anodic.
			+4.2	Anodic minus vulcalock Anodic quieter.
Ave. of above			+3.3	Anodic minus vulcalock Anodic quieter.

In three of the four cases of Table II, the anodic covering was definitely quieter than the vulcalock by an average of 3.3 db. In the fourth case, 2,000 yards and 3 knots, an error in the range on the starboard run did not seem to be large enough to warrant discarding the data, but was in the direction to make A-V negative instead of positive. Although the anodic covering is definitely better than the vulcalock covering, it is not as good as the bare propeller.