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*A Survey Report:*

*Underwater Sound Reverberation*

*September 1962*

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**AVCO Marine Electronics**  
OFFICE

A SURVEY REPORT  
UNDERWATER SOUND REVERBERATION

By

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ABSTRACT

This survey report presents a commentary on recent work published on Underwater Sound Reverberation. The commentary is followed by a comprehensive bibliography covering current work available on the subject.

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## INTRODUCTION

This subject has been summarized by Urick and Pryce in 1954 and updated by them in 1960<sup>20,14</sup>. During 1962, a USAG Workshop has convened under the chairmanship of B. G. Hurdle (NRL) to consider sound reflection and scattering. It is the purpose of the present survey report to present a current bibliography and to comment on work reported since the SAD summaries.

The bibliography is organized under the headings General, Bottom, Surface and Volume, and these subject headings will be employed in the discussion below. The bibliography, taken together with those compiled by Urick and Pryce may be regarded as substantially complete as of this date.

### GENERAL

An examination of the chronological evolution of knowledge concerning reverberation discloses the fact that there is not and has not been a sustained program, but rather that information has been developed, often as a by-product, from ad hoc experiments. It is probable that one reason for this lies in the fact that reverberation is a technical concept intimately related to specific equipments. In the nature of things, it is ordinarily necessary to build a sonar set in order to be able to measure significant characteristics of reverberation as affecting that set. Another factor is the essential inseparability of reverberation from propagation. There is no satisfactory definition of "reverberation" as a whole, let alone definitions permitting partitioning into surface, volume, etc. Despite this, because the researcher is likely to have physical mechanisms in mind, there is an effort at least in semantics to employ such distinctions in describing the results of experiments. Unfortunately, our knowledge of mechanisms is very limited.

With these things in mind, the justification for the organization of this report is based solely on habit. It will be found in the sections below that some new work has been reported in each area. The work is mostly concerned with extensions of measurements to lower frequencies, with results reported as scattering coefficient or reverberation strength, according to the whim of the author, generally as a function of frequency and sometimes as a function of various angles or factors related to geometry.

Some new conceptual work has appeared. The report of Skudryzk,<sup>17</sup> which does not appear to have attracted the attention it deserves, is a general theoretical and experimental compilation of many factors in the scattering and fluctuation of sound.

Hasse<sup>3</sup> has presented theoretical and experimental results on bistatic reverberation, and Urick<sup>21</sup> has given a new point of view on the sonar equations for transients, including considerations of reverberation.

#### SURFACE REVERBERATION

Marsh et al, Chapman<sup>36</sup> and Patterson have reported experiments on the scattering from the apparent surface from deep sources (explosive in the first two cases; cw in the last). Marsh<sup>52</sup> has given a theory of reverberation produced by the sea surface and speculated on its effects in shallow water.

#### BOTTOM REVERBERATION

Several reports have appeared on this subject, which may reasonably be divided between shallow water and deep water. It was originally our intention to call this subject "Boundary Reverberation", since

it turns out that the work reported (excepting Hurdle) deals with situations in which "bottom" and "surface" effects have not been satisfactorily isolated. This fact takes on added significance since no suitable mechanism for "bottom-reverberation" has yet been presented. However, we have bowed to habit, but will state that at this time, by "bottom reverberation" we mean "not volume-not necessarily surface-reverberation."

Mackenzie<sup>25</sup> and Avco have reported results in shallow water which are in rough accord, although Mackenzie used a highly directional pulsed source in the Pacific and Avco reported on USL explosive measurements in the Atlantic. Avco reported a limited investigation concerning the effects of bandwidth on both reverberation and submarine target echos.

Mackenzie<sup>24</sup>, Urick<sup>27</sup>, and Fatterson<sup>26</sup> have reported results in deep water which are in rough accord, even though cw and explosive results are both involved. Hurdle<sup>23</sup> et al have reported some very interesting results concerning doppler effects on sound scattered by the bottom.

#### VOLUME REVERBERATION

Biological organisms are generally conceded to be the dominant cause of volume reverberation. No work in this field has been uncovered during the past three years, although reports by NADC<sup>82</sup> emphasize the continuing importance of the subject.

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