ABSTRACT. Breaking waves are recognised as a significant source of ambient underwater noise in the ocean yet the details of the causal physical mechanisms are poorly understood. This contribution describes the initial findings of a detailed laboratory study aimed at elucidating this process using simultaneous high speed photography and sound measurements under controlled conditions. It was found that the dominant noise occurred in the form of discrete tone bursts which appeared to be associated with the formation of bubbles and coalescing or splitting of bubbles.

1. INTRODUCTION

The earliest studies of noise in the ocean by Knudsen, Alford and Ewling (1948) recognised that breaking waves were a dominant source of noise. Indeed, with a hydrophone close to the water surface it is possible to hear the sound of an individual wave breaking. Wenz (1962) drew on a large amount of data to refine the spectral shape of noise from breaking waves, which he identified as "bubble and spray" noise, as having a broad spectral peak at about 500 Hz. The many experimental studies which have followed have obtained empirical relationships between noise and wind speed (and shown that the correlation was better than between noise and wave height) but there appears to be little experimental work aimed at identifying noise generating mechanisms. Laboratory experiments by Franz (1959) studied the impact noise of water droplets and Strasberg (1956) the noise generated by bubbles formed at a nozzle, in both cases in quiescent water. Theoretical work has also been limited. One of the difficulties is to know which of the many mechanisms to model - impact of water droplets, air entrainment, bubble oscillation, bubble collapse or bursting. Kerman (1984) and Shang and Anderson (1986) have addressed this problem in recent contributions. There is clearly a need for a better understanding because no existing empirical model is universally applicable.
except in very broad terms. For example, various observational studies show not only differences in noise levels at any wind speed but also differences in the rate of noise increase with wind speed (Cato, 1978).

This contribution describes the initial results of an investigation aimed at identifying experimentally the processes in wave breaking that contribute to the generation of underwater noise.

2. EXPERIMENTAL CONFIGURATION

The measurements reported here were made in the laboratory wind-wave flume shown schematically in Figure 1.

![Diagram of experimental wave flume configuration](image)

Figure 1. Experimental wave flume configuration: working length, 7.3 m; channel width 0.225 m; water channel depth 0.22 m; air channel depth 0.36 m. The measurement site was halfway along the channel.

The flume could be configured in either of two modes to provide (a) a propagating steep wave train on still water, generated by a constant frequency wavemaker at one end, with an absorbing beach at the other end (b) a quasi-steady wave train, held stationary against the steadily flowing current supplied from a constant head tank and with a quietened outfall. The wavetrain was steepened locally by a subsurface hydrofoil.

For the initial phase of the investigation, it was expedient to utilize the stationary wave configuration. The advantages were lower spurious background noise, and better control over the breaking and hence easier identification of the noise generating events. The applicability of this configuration to transient breaking waves at sea is discussed in some detail by Banner (1987) in a companion paper in this volume. This approach has been used successfully in previous studies relating to other breaking wave phenomena (Banner and Melville, 1976), Banner and Fooks (1985)).

The floor of the flume had a transparent section and a false glass bottom. A hydrophone (LC-10) was installed below the false bottom to