Changes in Raindrop Size Inferred from Underwater Noise

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Laws and Parsons (1943) and Marshall and Palmer (1948) have obtained raindrop size distributions for a number of rain rates. From both publications it follows that variations of rainfall rate may be associated with variations in the diameter of the drop rather than with changes in the number of raindrops of all sizes. Kelkar (1962) has shown that for low rain rates the distribution of drop sizes at fixed rain rates is subject to considerable variation. In the present communication this phenomenon was confirmed in a small series of underwater noise measurements. This technique may have relevance for a variety of other study areas. During studies of underwater noise generated by rain it was noticed that the short-term changes in drop size distribution with rain rate appeared to be different from the relationship obtained by averaging over all periods. The acoustic aspects of the study and the experimental details have been published elsewhere (Bom, 1969), but the implications with regard to the changes in drop size may be of interest to investigators in fields other than acoustics. The technique may also be of interest.

Franz (1959), during a study of splashes as sources of sound in liquids, deduced that below a large area subject to a spray of uniform sized droplets the sound spectrum level L [defined as the sound pressure (dB) in a 1 Hz bandwidth relative to a sound pressure of 1 dyn cm^{-2}] at depths greater than the wavelength could be described by

$$L = 10 \log(3\rho^2 a V^4 RE/4c^2), \qquad (1)$$

where ρ is the density, a the drop radius, c the sound velocity in water, V the impact velocity, R the volume of the droplets impinging on the free surface per unit time and per unit area, and E the dimensionless spectral density of sound energy radiated into the water by a single droplet or by a spray of water droplets. The spectral density E is a rather slowly varying function of V and a, and was determined experimentally by Franz. It is evident from (1) that the drop size and impact velocity play an important role. For raindrops of various diameters the terminal velocity has been measured and tabulated by Best (1944) and Gunn and Kinzer (1949). Both measurements are in fair agreement. Thus, knowing the sound pressure level as a function of rain rate, some inferences can be made about changes in the drop sizes.

During the course of the rain noise study the sound pressure level and rain rates were recorded for a number of 1-hr periods. For the analysis of each period a number of short intervals representative of various rain rates were selected. Care was taken to select intervals during which the rain rate was reasonably constant. The dots and crosses on Fig. 1 show the rain noise vs rain rate found during two of the 1-hr periods. Line 1 is the least-squares fit of all samples taken over a two-month period. The slope of line 1 is in agreement with that given by Eq. (1) if the average drop size distribution as a function of rain rate given by Laws and Parsons is used. The slope of line 2 was obtained from (1) by changing the number of drops falling per second, keeping the drop size distribution constant, while that of line 3 was obtained by keeping the drop rate constant, but changing

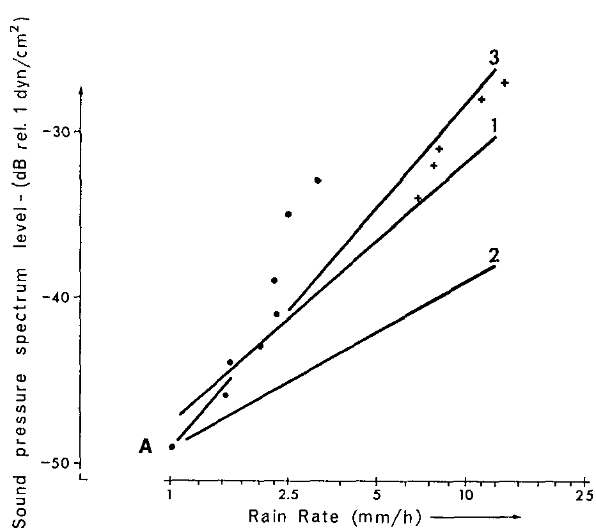

FIG. 1. Underwater sound pressure spectrum level vs rain rate in the frequency interval from 2400–4800 Hz for two 1-hr rain periods.

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the drop sizes by a constant ratio. Lines 2 and 3 were arbitrarily chosen to go through point A. It is evident that the slope of line 3 is the best fit. Data from the other rain periods analyzed showed the same tendency. We infer from these results that the changes in rain rate during the showers were due more to changes in the drop size than to changes in the number of drops falling per second. This would imply that the number of new drops reaching the surface per unit of time was more or less constant, or at least changed less rapidly than the rain rate. This result is based on measurements obtained by a technique which may be of interest for other applications. The result constitutes a confirmation of current knowledge about short-term variations of rainfall rate.

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