ESTIMATION OF UNDERWATER NOISE EXPOSURE LIMIT

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Introduction Divers are sometimes exposed by vibrations and noises radiating from working equipment in water, e.g., water jet tools, rock drills, stud guns and so on. From the viewpoint of ear protection for divers, we estimated the noise exposure limits in water from the values in air [1]. However, they were the extrapolated values obtained from the relation of perceived loudness between in water and in air. Then another approach for estimating the underwater noise limit becomes necessary. On the other hand, Al-Masri and Martin [2] have proposed an evaluation method for hearing damage risk criteria in water. They developed the “W-weighting scale” involving the subtraction between the threshold values in air and underwater and discussed the possibility of underwater permissible noise exposure limit in dB(W) by adapting the current accepted industrial noise limits to underwater situation in terms of the “W-weighting scale”. But it is far from the stage of practical application in water.

In this study, we measured precisely underwater hearing threshold and 120dB equal loudness contour in the audible frequency range. And we attempt again to estimate a suitable noise exposure limit for underwater use from another viewpoint on basis of the same concept as Al-Masri and Martin.

Experimental procedure Measurements of the underwater hearing threshold and the 120dB equal-loudness contour were carried out by listening experiments in a water tank with dimensions 1m×1m×2m equipped at a silent room. In the case of loudness, we adopted the signal sound of 120 [dB re 1μPa] at 1kHz as a standard stimulus for reasons that A-weighting scale was generally derived from the contour of 40phon in air and that the loudness of 40phon in air is experimentally equivalent to the loudness of 120 [dB re 1μPa] in water. Both standard and test signals were 1 sec burst tone pulses. The frequency was selected from the center of 1/3 octave band in accordance with ISO226. The subject, a man with normal hearing in air, put one’s whole head into the water and listened to the underwater sound. The subject’s head was suitably positioned in the water tank to minimize the influence of standing waves and the hydrophone was set up as close to the subject’s ear as possible.

Results Figure 1 shows the values of hearing threshold and 120dB equal-loudness contour in water obtained by the self- adjustment method. Whole aspect upon the frequency is considerably different between in water and in air. The maximum sensitivity of the ear is located at the low frequencies around 0.5kHz in water, whereas at the higher frequencies around 4kHz in air. However, it is notable that both the threshold and the loudness curves show the same frequency dependence in each medium, which is the

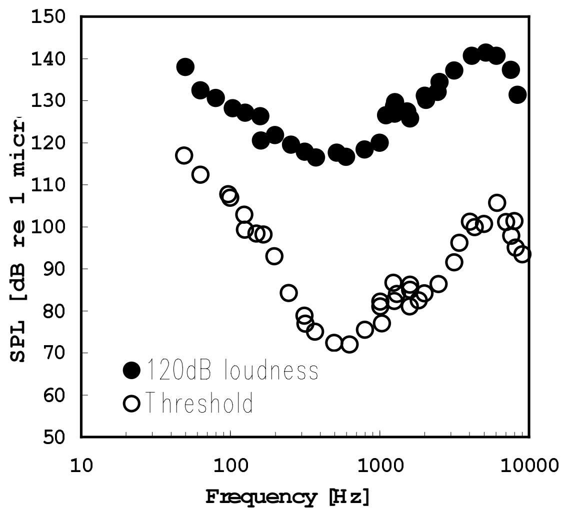

Fig.1 Hearing threshold and 120dB equal-loudness contour in water.

significant character linked into an assumption in the following section.

Discussion In order to estimate the noise exposure limit in water, we assume that the relationship between the 120dB loudness and the expected noise exposure limit in water is equal to that between the 40phon curve and the noise exposure limit in air. Hereupon, an estimation of limit in water is achievable by modifying the limit in air to an equivalent one for underwater use. Al-Masri and Martin [2] have taken notice of the subtraction between the threshold values in air and underwater. But the underwater threshold is greatly influenced by the background noises or the experimental conditions. As a result, the last estimated values come to include some errors. In the present study, we pay attention to the loudness curves, that is, subtraction between the 120dB equal-loudness contour in water and 40phon curve in air is performed as described in Fig.2. Here, SPL is denoted by [dB re 20 μPa] for convenience. Then, the value of difference (Δ) at each frequency thus obtained comes to be a correction value between the two media.

Now, we carry out the transposition of the current noise limit from air to underwater. Concretely, we add at each frequency the value of difference (Δ) to noise limit in air [3]. This criterion for exposure noises has been recommended by the permission concentration committee of Japanese Industry Sanitation Society and is widely adopted for the purpose of hearing protection in air. Figure 3 shows the estimated underwater permissible noise exposure limit, for example, on 480 min/day. Result obtained from the subtraction between the hearing thresholds is also described in Fig.3. Note that the SPL is return back to [dB re 1μPa] usually employed in water. Either of them nearly shows the same value as the previous result [1] but it seems that the present one estimated from 120dB loudness is more excellent and practical because it was reproduced from the actual frequency dependence reflecting the "W-weighting".

Keywords: underwater noise, noise exposure limit, hearing threshold, equal-loudness curve

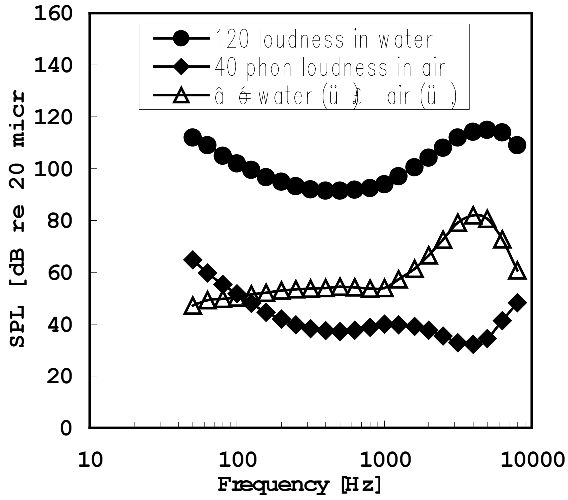

Fig.2 Subtraction between the 120dB loudness contour in water and 40phon curve in air at each frequency.

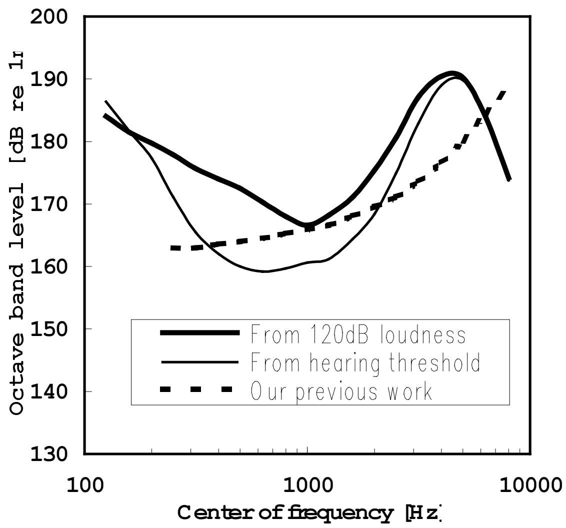

Fig.3 Estimated underwater permissible noise exposure limit on 480 min/day.

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