J. Acoust. Soc. Jpn. (E) **18**, 6 (1997)

Characteristics of headphones in hyperbaric Helium-Air gas mixture

Keywords: Headphones, Hyperbaric, Helium-Air gas mixture, Saturation diving, Artificial ear

PACS number: 43.38.Ja

Yasuhito Kawanishi, Yoshiyuki Satsukawa,
Takayoshi Nakai, and Hisayoshi Suzuki

*Department of Electric and Electronics, Faculty of
Engineering, Shizuoka University,
Johoku 3-5-1, Hamamatsu, 432 Japan*

(Received 4 October 1996)

1. Introduction

There are great deal of natural resources on the continental shelves whose depth are within a few hundred meters. The saturation diving is used when man dives at the continental shelves for exploitation in which the Helium-Air gas mixture is used as a respiratory gas to prevent the physiological disablement. To work safely in such environment, the divers and the supporters must have proper speech communication equipment. A serious problem in the speech communication equipment for divers is that the acoustic characteristics of microphones and headphones at such environment have not been known sufficiently yet. The authors had already measured the sensitivity of the microphones in hyperbaric gas mixture and explained the causes of change in the characteristic of microphones based on the computer simulation.¹⁻³⁾ We recently measured the sensitivity of six kinds of dynamic headphones and explained the general characteristics of the headphones in hyperbaric atmosphere.

2. Measurements

Free-field comparison method⁴⁾ and the artificial ear⁵⁾ were used so far to measure the sensitivity of headphones. The measurements by free-field comparison needs an anechoic chamber and many human subjects. However, no anechoic chamber can be filled with hyperbaric gas mixture and therefore it is not practical. On the other hand, using the artificial ear, it is possible to measure the characteristics of headphones that is in the hyperbaric gas mixture because the apparatus are small enough to put them in the small-sized hyperbaric chamber. Thus, we measured the sensitivity of headphones using an artificial head with an artificial ear.

Figure 1 shows a schematic of the measurement. The sinusoidal wave signal of 20 Hz-40 kHz was amplified by an input amplifier and inputted to a headphones that was set in the hyperbaric chamber. The gain of the input amplifier was adjusted so that the

microphone (B&K4134) could receive a signal of 1 kHz to be SPL 70 dB.

The output signal of microphone was amplified by 40 dB by an output amplifier. The signal analyzer calculated the transfer functions and sent the data to the computer through a GP-IB cable.

The pressure in the hyperbaric chamber was increased by adding hyperbaric helium gas to normal air in the chamber. The pressure of the hyperbaric helium gas mixture was increased up to 50 atm.

3. Results

We measured the characteristics of six kinds of headphones. Only the right-side unit of every headphones was measured. Figure 2-a, b and c show the characteristics of three kinds of headphones out of six. The first and second headphones, HP-1 and ATM-M7 PRO a, are close-air type. Only the third headphone, TH-50G, is open-air type. The characteristics of headphone tend to change by the increase in pressure as follows.

In the frequency region above 1 kHz, some peaks and dips shift to higher frequencies. The characteristic is complicated by a few peaks and dips in various frequencies.

In the frequency region below 1 kHz, the sensitivity of the close-air type headphone is lower (see Fig. 2-a) or does not change so much (see Fig. 2-b) when the pressure is higher. However, the open-air type headphone shows its sensitivity to be higher and the lowest peak frequency to be lower when the pressure is higher (see Fig. 2-c).

When helium gas was added to normal air to increase the gas pressure, peaks and dips shifted toward the higher frequencies because the sound velocity increased. When the pressure is higher than 30 atm, the change in sensitivity becomes less. This shows that the sensitivity of headphones are varied by the sound velocity, and less affected by the gas density.

In the low frequency region, the sensitivity of the open-air type headphone becomes flat by decreased leak resistance between the ear-pads and pinnae.⁶⁾ However, the sensitivity of the close-air type headphone becomes flat by increased leak resistance between the ear-pads and pinnae. The cut off frequency in the low frequency region decreases if the stiffness of the back cavity behind the diaphragm becomes smaller by increasing the apparent volume of the back cavity. As the pressure is getting higher, the third headphone, the open-air type, shifts its lowest peak frequency to the lower frequency region, because it is regarded that the apparent volume of the back cavity behind the diaphragm becomes larger. The second headphone, open-air type, has somewhat large back cavity. Therefore the lowest peak frequency decreases in several environment pressures. The first headphone, open-air type,

Fig. 1 Experimental setup.

Fig. 2-a Characteristics of headphone in high pressure atmosphere (HP-1).

Fig. 2-b Characteristics of headphone in high pressure atmosphere (ATM-M7 PRO a).

Fig. 2-c Characteristics of headphone in high pressure atmosphere (TH-50G).

has small back cavity, and therefore the lowest peak frequency does not change.

4. Conclusion

We measured the sensitivity of six kinds of dynamic headphones. When helium gas is added to normal air to heighten the pressure, the peaks and dips shift toward the higher frequencies. When the pressure is higher than 30 atm, the sensitivity does not to change any more. In the frequency region below 1 kHz, the sensitivity of the first headphones becomes lower, that of the second headphone changes very little, and that of the third headphone becomes higher when the pressure is high. The lowest peak frequency of the third headphone (open air type) becomes lower because the apparent volume of back cavity becomes larger when the environment pressure is heightened.

References

- 1) M. Ohashi, N. Umeda, and H. Suzuki, "Observation of membrane vibration in condenser microphones using an optical heterodyne interferometer," *J. Acoust. Soc. Jpn. (J)* **43**, 953-959 (1987) (in Japanese).
- 2) M. Ohashi, M. Andou, and H. Suzuki, "Effect of high ambient static pressure to condenser microphone response," *Trans. IEICE. Part A* **J71-A**(3), 537-544 (1988) (in Japanese).
- 3) H. Suzuki, Y. Uchida, M. Ohashi, and T. Nakai, "Numerical simulation of characteristics of condenser microphones at high ambient pressure," *Trans. IEICE. Part A* **J72-A**(5), 743-751 (1989) (in Japanese).
- 4) H. Miura, K. Muto, T. Takahashi, and H. Kado, "Calibration of headphones by the method of free-field comparison," *Tech. Rep. Electr. Acoust. Acoust. Soc. Jpn.* EA85-2 (1985) (in Japanese).
- 5) H. Miura, K. Muto, M. Minakawa, T. Fujimori, and H. Kado, "On the calibration of headphones for commercial use by IEC artificial ear and coupler," *Tech. Rep. Electr. Acoust. Acoust. Soc. Jpn.* EA83-22 (1983) (in Japanese).
- 6) M. Okahara, H. Nakajima, and A. Asakura, *Audio Handbook* (Ohm-Sya, Tokyo, 1978), Chap. 12 (in Japanese).