

INSTRUMENTATION METHODS FOR MEASURING DIVING HELMET NOISE

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ABSTRACT

For the past few years, the U.S. Navy Experimental Diving Unit (NEDU) has devoted intense effort to the establishment of a methodology and selection of apparatus for the assessment of (1) noise inside a manned diving helmet at depth and in the water; and (2) diver auditory threshold shifts as a function of this noise exposure. A simulated helium-oxygen saturation dive to 850 feet of sea water (FSW) was conducted during the spring of 1984 in NEDU's Ocean Simulation Facility (OSF). Follow-up dives were conducted to 1000 FSW in 1985 and the spring of 1986. The information discussed in the paper will be limited to the techniques used to obtain sound measurements in a diving helmet used on the two deep dives.

1. BACKGROUND

The task of developing a method to measure sound levels in a high pressure helium-oxygen environment began by a thorough search of the literature. It was discovered that very little work was conducted in this area. A few of the people who had published their work were Thomas, Presler and Farmer of Duke University (1) and Mullen of the Naval Coastal Systems Center (2). Their data was used to establish a basis upon which we were to develop our methods.

Noise levels in a hyperbaric environment were measured by Thomas, et al and by Mullen using a Bruel & Kjaer 1/2-inch condenser microphone. This microphone's response is linear from 60 Hz up to 12 kHz; therefore, it was ideal for our purposes. It also could be calibrated using an electrostatic actuator. The electrostatic calibration method uses a ring that is placed upon the microphone. A signal is imparted to the actuator, which in turn sets up an electrostatic field at the specific frequency and sound level desired. This procedure provided a method of calibrating the microphone in the hyperbaric environment since an electrostatic field is unaffected by high pressure. After much

deliberation on this procedure, it was decided to pursue this approach. Figure 1 shows the set up of the microphone in the diving helmet and Figure 2 shows the electrostatic actuator and set up. Unless noted, all of the equipment used is manufactured by Bruel & Kjaer (B&K), Marlborough, MASS. All of the numbers used in the figures are B&K model numbers.

2. MICROPHONE CALIBRATION

The electrostatic actuator was used to calibrate the helmet microphones before and after each diver's in-water dive. This was accomplished by removing the microphone grid and placing the actuator on the microphone. The signal generator was set to 500 Hz and the signal fed into the 2713 power amplifier. The power amplifier was adjusted until the voltage out of the 2713 was equal to a predetermined level. This level was established before the dive at 1 ATA and produced an electrostatic signal equal to 70 dB at 1 kHz. One kHz was used because a 500 Hz signal injected into an actuator will cause a corresponding 1 kHz signal response from the condenser microphone due to the fact that the actuator is not polarity conscious. The difference in the microphone response at depth in relation to that at 1 ATA was the correction factor used to compensate for the decrease in microphone sensitivity due to the increased gas density. This along with a correction for the increased speed of sound in a helium-oxygen environment was used to relate the microphone's response to a 1 ATA equivalent.

3. HELMET NOISE MEASUREMENT

Sound levels inside a diving helmet were measured by installing the microphone inside the helmet on the diver's right side with the microphone centered near the diver's right ear. The microphone signal was carried out of the helmet through the water via a special water blocked extension cable. The signal was then amplified by a Model 2807 microphone power supply.

The amplified signal was then sent to a 2131 Digital Frequency Analyzer (DFA) set up in a 1/3 octave filter mode. The 1/3 octave filter data was sent from the DFA to a desk top Hewlett Packard computer Model 9845 for storage and analysis. The microphone signal was also recorded on tape for future reference. Figure 1 shows a 2230 sound level meter used as a back up device in the event the DFA failed.

4. DIVER'S AUDIOMETRIC MEASUREMENTS

In addition to the helmet noise levels recorded at depth, divers' hearing thresholds were also measured. This was accomplished by using the electrostatic calibration method to calibrate a one-inch condenser microphone used in the artificial ear. The microphone was then placed inside the artificial ear and the left and right headphones were placed into the artificial ear and calibrated sequentially. The artificial ear is a device which acts as a receiver for signals emanating from the earphone. The earphones were attached to a standard audiogram machine being operated outside the chamber. The response of each headphone was tested at all of the standard hearing frequencies: 500, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz. Their responses were then compared to those obtained at 1 ATA before the dive. The response at each frequency could then be corrected for its attenuation due to the hyperbaric environment. After the headphones were calibrated, the divers were given a standard audiogram before and after each in-water dive. This allowed us to assess what effect, if any, the helmet noise was having on the diver's hearing threshold levels. As mentioned previously, the divers were given audiograms while in the chamber. In order to accomplish this, the background noise levels must be extremely low to prevent auditory masking. This is normally impossible inside a hyperbaric chamber, so a special hyperbaric audiometric sound booth was constructed for use in the chamber at depth. The booth met all of the ANSI S3.1 standards for surface audiometric tests and functioned well at depth. Both audiogram testing and microphone calibrations were carried out inside the booth during the dive.

5. HARDWARE MODIFICATIONS

To perform acoustic measurements and audiograms in a hyperbaric environment, modification of some of the hardware used is required. For example, the 1/2-inch electrostatic actuator, the cable carrying the signal from the 1/2-inch microphone mounted in the diver helmet, the audiometric booth, and the microphone calibration stand were all modified.

Half Inch Electrostatic Actuator

The 1/2-inch electrostatic actuator worked well on the surface except that each time it was removed and placed back upon the microphone the response from the microphone would vary from .5 to 1.5 dB. All instrument voltage levels were held constant, with only the frequency being varied to obtain a microphone response curve. This procedure was repeated many times using different operators in order to decipher what the discrepancy could be. It was noted that when the

same electrostatic actuator calibration method was tried with the one-inch 4144 microphone (using the one-inch electrostatic actuator), there was a variance of only a few tenths of a dB. It was decided that the 1/2-inch actuator was of too small a mass to sit properly upon the 1/2-inch microphone. Therefore, in order to increase the mass of the actuator, a brass collar was machined from naval brass, dynamically balanced upon a lathe, and a small set screw was inserted into the side of the collar to allow it to be secured to the 1/2-inch actuator, (Figure 3). The electrostatic calibration method was then repeated a multitude of times and the variance was found to be the same as that of the one-inch actuator. This modification has been used on all 1/2-inch actuators for the past three saturation dives with much success.

Diver Acoustic Cable

The cable carrying the signal from the diver was constructed by South Bay Cable Company, Idyllwild, CA. It was manufactured to the same electrical specifications as the Bruel & Kjaer extension cable A0 0028 except it was water blocked by filling the interior with polymerized rubber and constructing the outer jacket of polyurethane. The cable must be water blocked to prevent water intrusion into the inner conductors. Upon receiving the cable, it was cut to 50 foot lengths and attached to the diving helmet. Each 50 ft cable was then tested by plugging in the 1/2-inch microphone and using the electrostatic actuator to run a microphone response curve. The cable has performed well electrically; however, it does not handle day to day testing well. During the past three dives, there have been five separate failures in the three cables. The failures are due to a break in the small coaxial cable carrying the signal from the microphone. The failures are possibly due to the cable conductor layout. The coaxial conductor is in the center surrounded by the remaining 22 gauge cables. A new cable arrangement may eliminate the mechanical failures.

Audiometric Sound Booth

The audio booth was designed and constructed with particular emphasis on its assembly inside the hyperbaric chamber. This called for the booth to be made in modular sections which could be carried into the chamber, pieced together, sealed and still maintain the ANSI S3.1 standards required for audiogram tests. The booth also had to meet or exceed hyperbaric standards which do not allow paint that off gases, no glass inside, etc. The following is a list of the booth dimensions and specifications:

Construction Materials Specifications

Interior/Exterior walls, roof & floor: mild steel.

Insulation: Fire retardent sheet rock & compressed 3-inch fiberglass. Fiberglass covered completely with durrette gold, fire retardent cloth.

Paint: 2 part epoxy, i.e. IMRON

Caulking: Dow Corning or GE RTV silicone.

Carpet: None.

Weight: Not to exceed 1200 lbs.

Construction: Modular walls.

Exhaust vent outside booth: 4" ID width, 15 ft long, exhaust hose made of white neoprene impregnated cotton.

Window: 8" x 8" x 2" acrylic installed in door with shade to occlude light.

External Dimensions: 36" x 42" x 67.75.

Internal Dimensions: 28" x 34" x 58".

Vibration Isolators: 9 ea. neoprene, located on floor of booth.

Handles: Located as for ease on handling panels.

Electrical Panel: 2 B&K female bulkhead connectors
2 Pass thru holes
9 stucco jacks

This booth has worked well for attenuating noise inside the chamber complex. There is a certain noise level that is always present outside of the booth due to life support system components which must run during audiograms. The audio booth noise levels were below the ANSI maximum permissible levels at all frequencies from 1 Kz to 8 kHz. At 500 Hz, booth noise was marginal which could allow some masking of audiometric responses at this frequency.

Microphone Calibration Stand

To properly calibrate the microphone with the electrostatic actuator, the microphone had to be oriented vertically and isolated from any mechanical vibration. This was accomplished by constructing a metal stand, Figure 4, and shock mounting the stand on rubber insulators. This worked well and is an easy set up for the divers to use. The microphone can be placed into and removed from the clamp by turning a wing nut. The electrostatic actuator excitation cable is very light and can be supported by the microphone stand. This eliminates the possibility of the actuator cable falling and the weight of the cable causing one side of the actuator to be displaced off the microphone.

6. CONCLUSION

To date, this method of measuring noise inside a diving helmet has been found adequate. NEDU is investigating other methods of measuring noise levels inside diving helmets, i.e. hydrophones which would greatly simplify the measurement process.

7. REFERENCES

1. Thomas, W.G., Preslar, M.J. and Farmer, J.C., "Calibration of Condenser Microphones Under Increased Atmospheric Pressures". J. Acoust. Soc. Amer. 51, 6-14 (1972).
2. Mullen, W.W., Jr. "Condensor Microphone Calibration and Response in Deep Diving Environments". Letter to the Editor in Journal of the Audio Engineering Society, 1972, 20(2), 112-115.

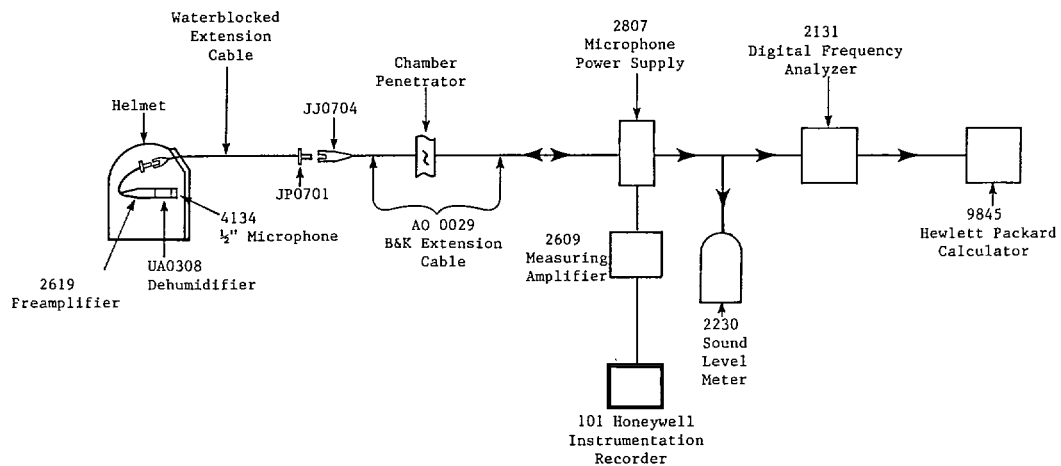


FIGURE 1. Instrumentation System For Recording Sound Inside Helmet

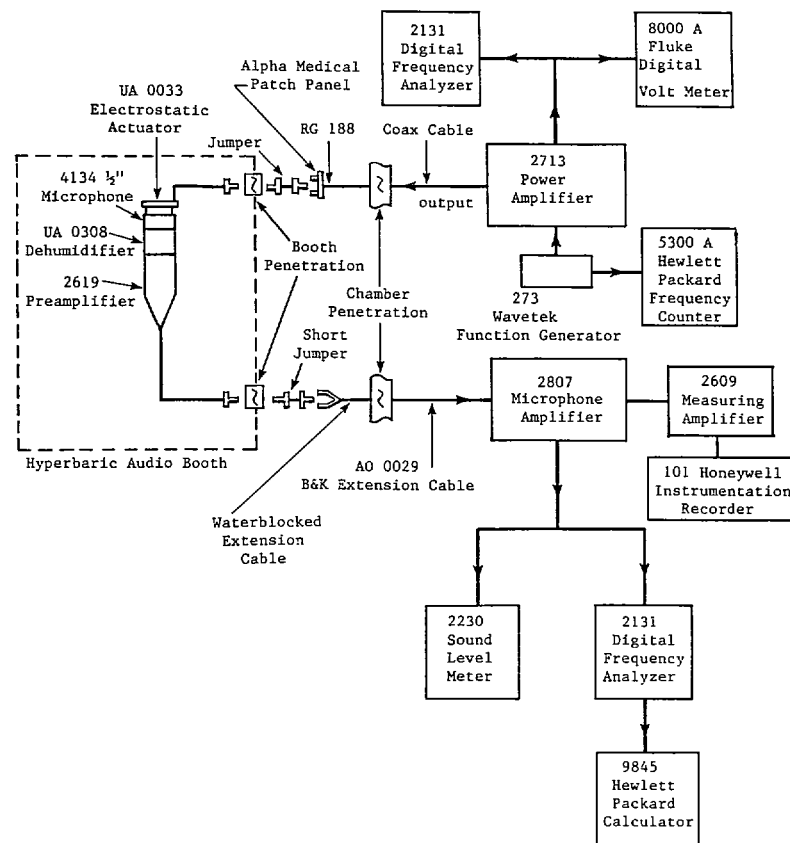


FIGURE 2
INSTRUMENTATION SYSTEM FOR ELECTROSTATIC CALIBRATION

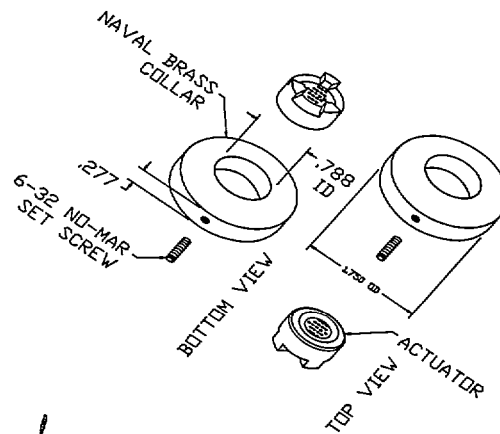


FIGURE 3. HALF INCH ELECTROSTATIC ACTUATOR

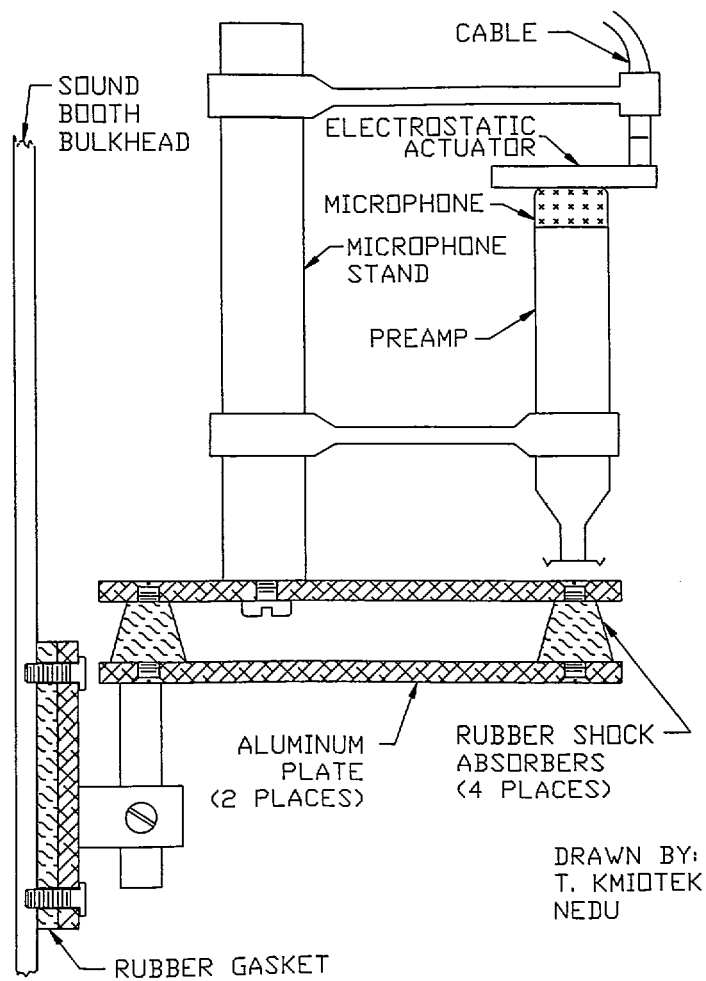


FIGURE 4. MICROPHONE CALIBRATION STAND