THE EFFECTIVE ACOUSTIC ENVIRONMENT OF HELICOPTER CREWMEN

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SUMMARY

Internal and external noise levels of helicopters are usually measured to determine the acoustic environment of the crewmen. These types of measurements alone are inadequate for assessing the real acoustic hazards of personnel. The attenuation characteristics of helmets and hearing protectors and the variables of the physiology of the human ear must be taken into account in determining the effective acoustic environment of Army helicopter crewmen. Also, the acoustic hazards of voice communications systems noise may influence the overall acoustic environment of the personnel. The composite acoustic environment can be determined only with complex acoustic measurements that are necessary to quantify the effective acoustic environment of the crewmen.

INTRODUCTION

Noise characteristics of helicopters should be given consideration in the design and purchase of aircraft for several reasons. The high sound pressure levels associated with the operation of military aircraft are hazardous to hearing by most damage risk criteria. Also, the high level sounds may interfere with communications and operational efficiency of crewmen.

The traditional approach to the task of ascertaining the acoustic environment that may affect the personnel is to measure sound pressure levels at various crewmen's positions under various operational conditions. In discussions of helicopter noise problems in popular and scientific articles, it is often assumed that the sound pressure levels within the aircraft are the actual pressure level values that impinge on the ears of the personnel who operate the aircraft. It is assumed that the ambient sound pressure levels are the same as the effective acoustical environment of the crewmen. The effective acoustical environment is defined as the actual acoustic energy that is received by the hearing system.

Measuring the effective acoustic environment of helicopter crewmen is a complex process. The purpose of this paper is to discuss the differences between the ambient acoustic level environment of the aircraft and the actual acoustic levels that affect the aircraft crewmen's ears.

HUMAN AUDITORY SYSTEM EFFECTS

The human ear is divided into three sections: the external, middle, and inner ear. The inner ear contains a complex system of membranes, nerves, and hair cells that may be damaged by noise. The amount of noise-induced hearing loss is determined by the effective acoustic environment or the actual energy transmitted into the inner ear.

The middle ear is a pathway to the inner ear and is equipped with certain protective mechanisms that affect the acoustic input. It contains two muscles that limit the input to the inner ear.

The external canal is shaped as an irregular tube. There are various forms and sizes. The variations of sizes and shapes may produce various amounts of protection, especially in the high frequencies. Unpredictable limiting characteristics of the middle ear plus the variations of sizes and shapes of the external ear canal make it difficult to measure the actual acoustic stimuli traveling through the system to the inner ear.

HEARING PROTECTOR AND VOICE COMMUNICATIONS SYSTEMS EFFECTS

The human auditory system just discussed is not the only source of variables that may affect the actual sound transmitted to the ear. Hearing protective devices, earplugs, headsets, and helmets contribute to the transformation of the acoustic environment to sound spectrum characteristics and sound pressure levels that may be vastly different from the values obtained using free field measurements in the cockpit. In general, all types of hearing protectors, both insert and circumaural, attenuate high frequencies much more efficiently than they attenuate low frequencies.

Let us take, for example, the case of a typical pilot flying an Army CH-47 helicopter wearing the standard SPH-4 helmet. One would expect that the change of sound characteristics beneath the helmet when fitted on the head of the aircrewman would be the original sound spectrum on the outside of the helmet minus the attenuation characteristics of the helmet. If the pilot were flying with no voice communication system or warning signals activated, the resultant spectrum at the external ear would be approximately the values as determined by this method. One must remember that the helmet earcups are sealed tightly over the ears of the crewmen and contain earphones that generate a sound source beneath the helmet. One normally does not associate very high sound pressure levels with an earphone. Coupled to small volumes such as the canal of the human ear, earphones are capable of generating up to 120 dB sound pressure level. Our investigations of sound sources from communication systems, warning signals and navigation signals, have revealed that a very significantly high sound pressure level may be transmitted from the earphone. These levels are much greater than the ambient noise that is transmitted through the helmet.

Another source of noise that may enter in the total effective acoustic environment is the distortion created by the design of voice communications electronic systems. It is well-known that military voice communication systems are designed with distortion. Some military specifications require only 70% intelligibility and specify certain various amounts of peak clipping which yield harmful distortion harmonics. The effects of peak clipping have been thoroughly discussed in some of my previous presentations to this group. Peak clipping may cause a decrement of intelligibility and also creates unnecessary harmonics that add to the total excessive energy that is transmitted to the ears and thereby the contributor to hearing loss. Added to these harmonics, often we have found inverter power-line noise that yields very high acoustic signals through the earphones and therefore is a significant source of acoustic hazard.

TRANSDUCER CHARACTERISTICS EFFECTS

Another aspect of the problem that one should note is the characteristics of transducers. Ideally, microphones and earphones should have flat response within the audio range. If either the microphone or the earphones have peaks, the crewmen may set gains of voice communications and other signals emitted through the earphones that are unnecessarily high level. By some evaluations the M-87 microphone has been considered one of the best military type noise cancelling microphones available. The response characteristics contain a very large peak in the 4000 Hz range. So when one receives messages transmitted through this microphone, there is an unnecessarily high emphasis of the 4000 Hz range. With our present-day knowledge of hearing loss causes, it is well established that this is the most vulnerable portion of the audio spectrum for hearing damage. If this microphone were used in low ambient noise conditions and if the reception were in quiet environments, there would probably be no significant amounts of hearing loss. However, in its application in high noise environments where gain settings are very high, the net result is that the ear is subjected to large quantities of energy which, for long periods of time, may cause significant hearing loss for some personnel.

Earphones should also have flat response. If they produce peak response, one would expect the same potential hearing damaging spectra in high level noise for much the same reason that peak microphones cause problems. The recent trend to change to lighter earphones should be watched carefully to avoid regression of headphone response. Some of the small earphones may produce high distortion when driven at the levels required in the military noise environment.

With the excess energy caused by variables of transducer response plus the many other signals such as voice communication messages, warning signals, navigation signals, and special instrumentation, there are significantly high acoustic levels generated beneath the helmet earcups.

SPECIAL PROBLEMS OF LOW FREQUENCY NOISE

One other aspect of the helicopter noise problem that may affect the effective acoustic environment of the crewmen is extremely low rotary blade passing frequency which is usually below the octave bands traditionally given in the analyses of survey data. In this region of the audio spectrum, measurement is seldom made of the aircraft noise spectra. The attenuation characteristics of the hearing protectors that are also worn in helicopters are not usually reported. The questions arise: Are these low frequencies passing through the helmets? Do they cause high frequency harmonic distribution that contributes to the total noise in the effective acoustic environment?

Our laboratory is presently engaged in the investigation of the effects of low frequencies on animal ears. We have found significant temporary threshold shift in the high frequencies when the animals were exposed to long periods of low frequency band centered at 63 Hz.

CONCLUDING REMARKS

In summary, the purpose of our presentation is to call attention to the fact that the ambient sound pressure level measurements often made in helicopter cockpits with sound level meters will not yield essential information about the noise characteristics that truly affect the helicopter crewmen. We should be aware of the difference between these levels and the actual effective acoustic environment that must be determined by other means. We have shown how the ambient acoustics level transmitted through the helmets is transformed by the attenuation characteristics of the helmet or other hearing protective devices that the crewmen may be wearing. In addition to these transformations, there are added signals caused by the design of microphones, earphones, hearing protective devices, and electronic systems. In a word, the actual acoustic energy at the eardrums of the crewmen is usually totally different from the acoustic environment measured around the various positions inside the aircraft. We have also discussed the variables of the middle ear that limit and modify the acoustic spectrum that is produced at the eardrum. All of these variables and unknowns make it very difficult to assess the real energy that reaches the inner ear, the locale of hearing damage. We have methods by which we measure the output of earphones and the magnitudes of various warnings and navigation signals necessary in the operation of helicopters.

Precise narrow band measurements are necessary, and in addition, standard real-ear attenuation characteristics of helmets and hearing protective devices must be accomplished. A better estimate of the total acoustic input to the crewmen is made by the insertion of a tiny microphone in the ear with small wires that will not affect the attenuation characteristics of the helmets. Also, we have developed a portable cement chamber that is very useful in estimating the output of earphones as used in the helicopter operations.

It is recommended that future helicopters voice communication systems, auditory warning systems, and other special instrumentation with auditory signals be designed with consideration for the total systems output so as to minimize the acoustic hazards that presently exist. This approach is necessary for realizing the most efficient operation of the crewmen. The evaluation of this low frequency problem can be done only after sufficient research has been accomplished. The recent findings about the significance of low frequency noise spectra cast doubt about the present universal application of dBA for reporting helicopter noise measurements. It is also recommended that as more sophisticated instrumentation is obtained for the measurement of helicopter noise, more attention be given to the extremely low frequency of the rotary blade.