

Noise Protection

Pilots are exposed to varying levels of noise during their careers. While exposure to this noise is inherent to the profession, the negative effects of noise can be prevented.

- Noise has adverse effects such as:
 - o hearing loss
 - o increased stress
 - o reduced vigilance
 - o possible performance degradation
- Noise measurement should be performed if there is a suspicion that the 8-hour average noise levels (LEX, 8h) could exceed 80dB
- Hearing protection devices must be used if the 8-hour average noise level exceeds 85dB
- If the average noise levels exceed 80 dB, pilots should be provided with and use noise protection devices
- Pilots should remember to use noise protection during the walk around and also during leisure time when needed

ANATOMY & PHYSIOLOGY

The human ear can be divided into three different parts: the outer ear, the middle ear and the inner ear (Figure 1.).

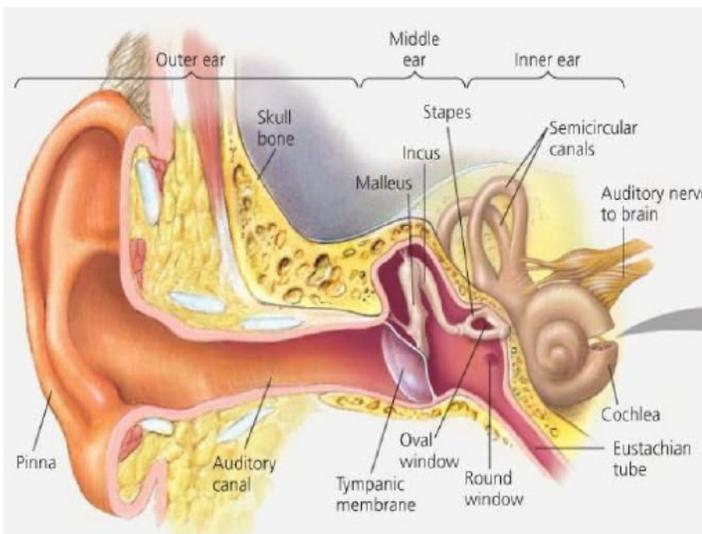


Figure 1, Anatomy of an Ear

The outer ear consists of the ear lobe and external ear canal. Its function is to conduct sound waves into the middle ear.

The middle ear consists of tympanic membrane and the ossicles, incus, malleus and the stapes. In the middle ear, sound waves are amplified and conducted to the inner ear.

The inner ear includes the cochlea, which is shaped like a snail shell. Inside the cochlea there is the organ of hearing known as the membranous labyrinth or cochlear duct. It is filled with liquid called endolymph and is surrounded with another liquid, perilymph. In the cochlear duct, there is a specialized structure called organ of Corti, where up to 30 000 hair cells are located. The hair cells transduce vibration into nerve impulses.

The sound is conducted to the cochlea via the oval window. Vibration of the foot plate of the stapes vibrates the perilymph in the bony cochlea. This in turn vibrates the hair cells in the organ of Corti (Figure 2.). The frequency of the sound dictates in which location (close to the oval window or close to the tip of the cochlea) the hair cells vibrate, whereas the amplitude which the hair cells vibrate is sensed as the volume of the sound.

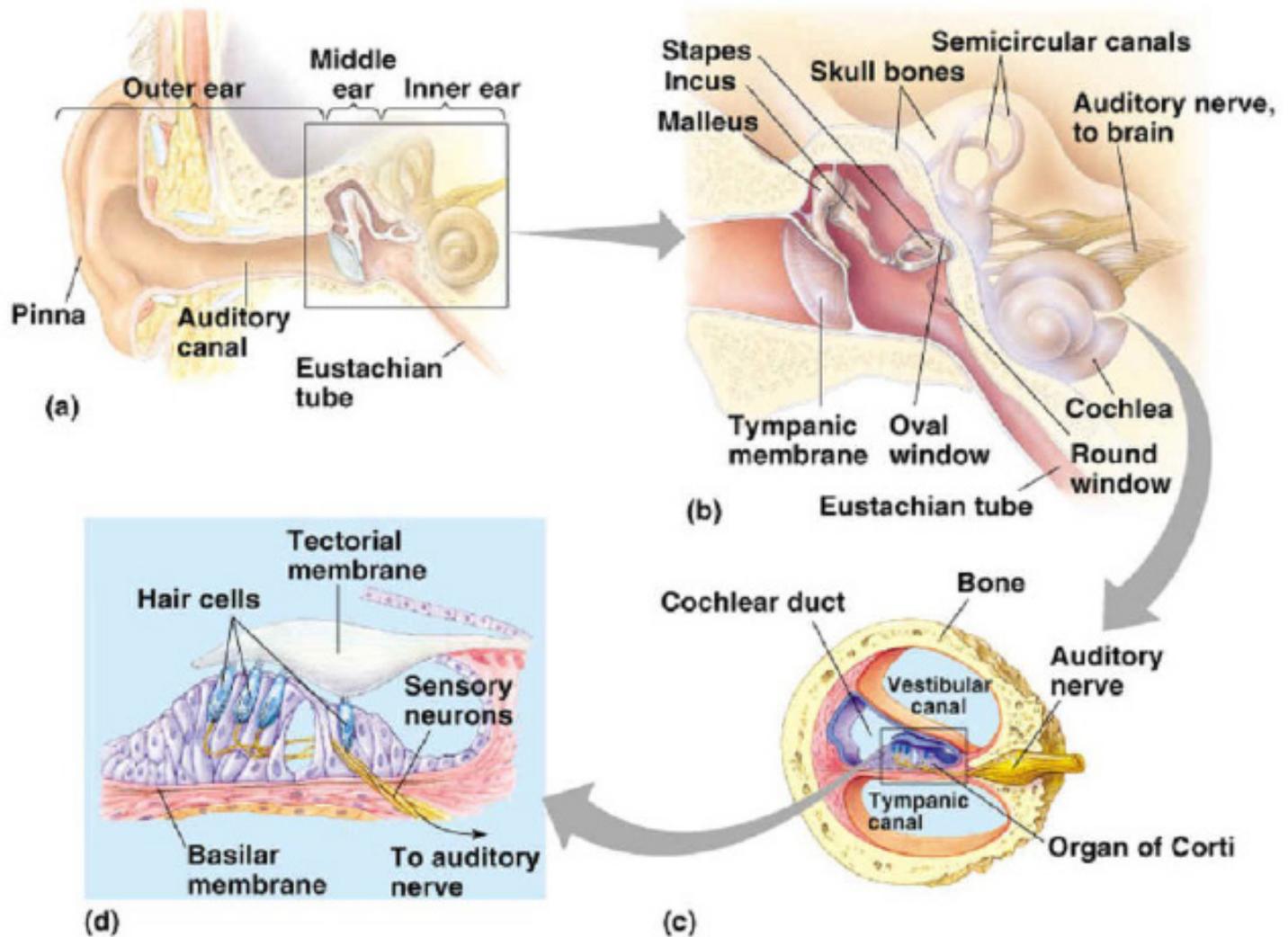


Figure 2, *The Physiology of Hearing*

PERCEPTION OF SOUND

The hearing range for the human ear is between approximately 20 Hz and 20 000 Hz. Speech frequency is a between approximately 500 Hz and 3000 Hz.

Decibel (dB) is the unit used to measure sound pressure levels. Notably, the scale is logarithmic; if the sound pressure level is increased by a factor of 10, it corresponds to a 10 dB change in the level. This means that even a small increase in decibels represents a significant increase in the pressure level. Table 2 shows examples of different noise levels.

A-weighted decibels are often used in noise protection. This is an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted scale, the decibel values of sounds at low frequencies are reduced as the human ear is less sensitive to the low frequencies.

DECIBEL EXPOSURE TIMES

For every 3 dBAs over 85dBA, the permissible exposure time before possible damage can occur is cut in half.

Continuous dB	Permissible Exposure Time
85 dB	8 hours
88 dB	4 hours
91 dB	2 hours
94 dB	1 hour
97 dB	30 minutes
100 dB	15 minutes
103 dB	7,5 minutes
106 dB	3,75 minutes (<4 min)
109 dB	1,875minutes (<2 min)
112 dB	0.9375 minutes (~1min)
115dB	0,46875 minutes (~30 sec)

Table 1

EFFECTS OF NOISE

Noise Induced Hearing Loss (NIHL), is one of the most significant effects of noise.

High noise levels on long flights may cause discomfort, fatigue, sleeplessness, irritation and stress.

Though overall causes of performance degradation remain unclear and complex, performance degradation resulting from noise has been reported with reasonable consistency in a number of task situations. The efficiency of vigilance tasks was degraded in noise environments of approximately 100 dB. High frequency noise produces more harmful effects on performance. Sudden and unexpected changes in noise levels may also cause disturbances. Higher noise levels resulted in higher levels of error.

In a NASA summary describing the effects of noise on performance, it was observed that even an exposure to 75 dB is enough to degrade performance; 85 dB causes fatigue; 90 dB causes vigilance decrement, altered thought process, interference with mental work and performance degradation of multiple choice serial reaction tasks. (NASA Johnson Space Center. Man-system integration standard, NASA STD-3000, Volume I, Part A, 1995.)

HEARING LOSS

Hearing loss is the result of sound signals not reaching the brain.

There are three types of hearing loss, depending on where the problem lies:

- **Sensorineural hearing loss** - caused by damage to hair cells inside the inner ear or damage to the auditory nerve.
- **Conductive hearing loss** - when sounds are unable to pass from the outer ear to the inner ear.
- **Mixed hearing loss** - refers to a combination of conductive and sensorineural hearing loss.

Conductive Hearing Loss

The most common reason for this type of hearing loss is the presence of fluid in the middle ear resulting in decreased movement of the tympanic membrane. The fluid may be the result of an ear infection, barotitis or aerotitis (an inflammation of the middle ear caused by changes in atmospheric pressure), or allergies.

Other reasons for conductive hearing loss are perforated eardrum, impacted earwax, infection in the ear canal, foreign body in the ear canal or otosclerosis.

Sensorineural Hearing Loss

Noise Induced Hearing Loss (NIHL) is one of the most common reasons for sensorineural hearing loss. The threshold for NIHL is particular to the individual. Some people may be more prone to NIHL than others. The most important thing is the sound pressure; if the noise is loud enough, it will cause hearing loss.

The function of the hair cells in the cochlea is reduced or the cells die because of the noise. These hair cells do not grow again. Also, the exposure time worsens the damage. The effect of noise is cumulative, i.e. wherever the noise exposure takes place (work/leisure) it adds to the risk of noise induced hearing loss.

Presbycusis (age related hearing loss) is a progressive and irreversible bilateral symmetrical age related sensorineural hearing loss resulting from degeneration of the cochlea or associated structures of the inner ear or auditory nerves. The hearing loss is most marked at higher frequencies.

Genetics, viral infections (e.g. mumps or rubella), Meniere's disease, tumors or trauma can also cause sensorineural hearing loss.

OCCUPATIONAL EXPOSURE LIMITS

Nearly all countries have occupational exposure limits for workplace noise, and these limits should also be applied to aviation. Quite often the limit is 85 or 90 dB(A) for an 8-hour-shift with a peak level of maximum 140 dB. However, long term repeated exposure to noise between 75 to 85 dBs may be a risk to some people. The EU published its noise directive in 2003 and, until international exposure standards can be developed, it is recommended that these protection methods and limits should be followed:

(a) exposure limit values: $LEX,8h = 87$ dB(A) and $p_{peak} = 200$ Pa (140 dB (C) in relation to 20 μ Pa) respectively;

(b) upper exposure action values: $LEX,8h = 85$ dB(A) and $p_{peak} = 140$ Pa (140 dB (C) in relation to 20 μ Pa) respectively;

(c) lower exposure action values: $LEX,8h = 80$ dB(A) and $p_{peak} = 112$ Pa (140 dB (C) in relation to 20 μ Pa) respectively.

This means that the 8 hour daily occupational exposure of 87 dB(A) shall never be exceeded. If the upper exposure action level (85 dB(A)) is achieved, the employer must ensure that the employee is using personal hearing protection. If the lower exposure action values are met or exceeded, the employer must provide employees with personal hearing protection. Audiometric testing must also be available for employees in order to detect possible hearing loss as early as possible to preserve hearing function.

IFALPA has published a position paper, [Cockpit Noise Level](#), calling for international standards for maximum noise levels in the cockpit.

NOISE MEASUREMENTS

Noise from the engines, the turbulent boundary over the airframe and the pressurization systems and environmental control systems all contribute to the interior acoustic environment.

Noise measurements should be done if there is any suspicion of noise levels exceeding 80dB. The measurements should last from when an employee signs in for duty until the end of the duty period. This way, the average for the entire duty period can be measured. It should be noted that as noise exposure levels are based upon 8 hour averages, the measured spot values should only be used to indicate max peak values and the average exposure for an 8 hour period must be determined. This could mean that if a working day is shorter than 8 hours, the noise levels can be higher, but the average 8 hour levels cannot be exceeded. On the other hand, if the working day is longer than 8 hours, the noise levels have to be lower than the average 8 hour limits.

There is not much data on proper noise measurements in older aircraft. However, the noise levels in older A320s, A330s and A340s have been shown to be 78-80 dBs according to the measurements of one operator.

NOISE PROTECTION

Most importantly, noise levels should be reduced, but as this is often impossible to do in an aircraft, noise protection devices should be provided if the 80 dB 8 hour limit is exceeded.

Active noise reduction headsets are the best choice for noise protection. However, there are some limitations in the installation; the aircraft must be equipped with hot microphone and the headsets need a power supply. In addition, during long flights it may not be convenient to use headsets at all times.

Earplugs cast to the shape of the users' ear can be used with proper filters, i.e. reducing noise 7 to 15 dBs. However, a pilot must pass the required audiogram for medical certification while wearing these earplugs.

During the walk around pilots should be provided with and should use proper aviation hearing protection.

Finally, pilots must also remember to use noise protection in any noisy environment during their leisure time.

Table 2, Different Noise Levels

Average decibel level (dB)	Decibel Effect	Source
0		Softest sound that can be heard
10	Barely audible	Normal breathing
20		Ticking watch, whisper
30	1/16th as loud as 70 dB	Soft whisper
40	1/8th as loud as 70 dB	Refrigerator hum, library
60	Half as loud as 70 dB	Normal conversation, air conditioner
70	Annoying	Washing machine, passenger car at 100 km/h at 9 meters (77 dB)
80–85	2 times as loud as 70 dB	City traffic (inside the car), propeller plane flyover at 1000 ft. (88 dB);
90	4 times as loud as 70 dB. Likely damage in 8 hour exposure.	Gas-powered lawnmowers and leaf blowers, motorcycle at 25 ft. (90 dB)
95	Damage to hearing possible after 1 hour of exposure	Motorcycle, Boeing 737 or DC-9 aircraft at one nautical mile before landing (97 dB)
100	8 times as loud as 70 dB. Serious damage possible in 8 hour exposure. Hearing loss possible after 15 minutes	Approaching subway train, car horn at 16 feet (5 meters), Jet take-off (at 305 meters), jet flyover at 1000 feet (103 dB);
105	Hearing loss possible after 5 minutes	The maximum set level for personal listening devices, very loud radio, stereos, music at home
110	Average human pain threshold. 16 times as loud as 70 dB. Hearing loss possible in less than 2 minutes	Steel mill, auto horn at 1 meter. Turbo-fan aircraft at takeoff power at 200 ft. (118 dB).; live rock music (108 - 114 dB).
120	Painful. 32 times as loud as 70 dB. Hearing loss possible in less than 1 minute	Standing near sirens, chain saw. Oxygen torch (121 dB).
140–150	Pain and even ear injury, eardrum rupture at 150 dB	Jet take-off (at 25 meters), firecrackers, firearm shots

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