Chapter 7

AEROSPACE SYSTEM NOISE

Most persons associated with the operation of military aerospace systems undergo hazardous noise exposures at one time or another. Air Force-wide adoption of turbojet, turboprop, and turbofan-powered aircraft has necessitated special attention to the hazardous noise environment of men working on and near aircraft on the ground, and to the use of land (*i.e.*, hospitals, residences) adjacent to airfields. The operation of missiles and the coming of manned space systems have added other noise environments of concern. Despite the fact that aerospace crew members still are exposed to high-intensity noise levels, it is the ground maintenance and control personnel who are subjected to the most hazardous noise exposure in terms of sound pressure level, duration or both.

The Flight Surgeon must familiarize himself with the noise conditions prevalent in the operations of his particular installation, and he must maintain a constant program of prophylaxis if he is to prevent ill effects among his men. AFR 160–3 provides for the:

a. Indoctrination of personnel on the undesirable effects of noise.

b. Designation and surveillance of hazardous noise areas.

c. Issuance of personal protective devices and instructions on their care and use.

d. Reduction of exposure of personnel to intense noise in work areas.

e. Monitoring of audiometry.

THE EFFECTS OF NOISE ON MAN

Noise, in itself, is of little importance unless it adversely affects a receiver—a man, a structure, or the like. The effects of noise on man fall into three categories:

a. Noise that may be a source of annoyance and irritability.

b. Noise that may interfere with voice communication and other types of auditory signals.

c. Noise that may be of sufficient intensity and duration to have a potential temporary or permanent damaging effect on the hearing of an individual.

Generally, with an increase in noise intensity, there are five thresholds of interference involving human functions which should be considered. These are discussed below in the order of increasing intensity:

(1) *Interference With the Threshold of Hearing.* This occurs at very low noise levels as the threshold of hearing is the lowest level at which a sound can be detected.

(2) *Interference With Rest and Sleep.* This may occur on an air base or in adjacent communities. At equal intensity levels, low frequency noise creates less subjective interference than mid- and high-frequency noise. A continuous noise is less irritating than an intermittent noise. Subjective tolerance is also a factor in that persons accustomed to the presence of a noise are less adversely influenced than those unfamiliar with its presence. AFM 86–5 presents a procedure for estimating exposure to engine noise from ground and flight operations of military and civilian jet and propeller aircraft, and for relating the estimated exposure to the expected response of on and off-base residential communities.

(3) *Interference with Auditory Communciation.* The degree of this interference is dependent upon the relative frequencies and strengths of the primary signal and the noise. There are several thresholds for communication, depending upon the quality of

the information required for effective operation.

(4) *Threshold of Hearing Damage Risk.* This refers to noises which can produce a hearing loss after varying periods of exposure. Although permanent hearing loss may not result, temporary threshold shift and tinnitus are likely. The Damage Risk Criterion graph (figure 7–1) shows the best estimate of threshold hazardous sound pressure levels in each of the eight frequency bands between 37.5 and 9,600 cycles per second (cps) for continuous wide-band noise. If these sound pressure levels are exceeded continuously for an 8-hour day, 5 days a week, during a 25-year working lifetime, they will give rise to a risk of permanently impaired hearing for an unprotected ear. However, these levels can be exceeded with comparative safety for noise exposures of shorter duration, or when ear protection is used to reduce the effective exposure.

(5) *Threshold of Aural Pain.* Since pain is considered a sign of physiological damage, the noise level in the ear canal should never exceed this threshold, no matter how short the exposure period. A person's exposure to noise above this level may result in nonauditory effects such as disorientation, nausea, and vomiting, even if the ear canal is protected.

Noise-Induced Hearing Loss

The susceptibility to noise-induced hearing damage varies among people. Some appear to have *tough* ears and can tolerate higher noise levels better than those with *tender* ears. At present, there is no way of identifying tender ears prior to the individual's exposure to noise. It is known that noise can be harmful or detrimental to the hearing of man even though it is not painful to the ear. In fact, there are no pain fibers within the inner ear to warn of impending injury. Therefore, if the damage risk criterion is exceeded, ear protection should be worn. The damage risk criterion represents a conservative standard and, if not exceeded continuously, should prove to be safe for the majority of individuals who are routinely exposed to noise.

Description of Hearing Loss

When the muscles of the middle ear, whose function it is to attenuate high-intensity noise, and the sensory cells and nerve fibers of the inner ear become fatigued, the inner ear may be damaged. In cases of extreme impact noise or blast, the tympanic membrane is ruptured and the ossicles may be dislocated. The degree of damage to any individual ear is dependent upon the intensity, duration, and type of stimulation. The differences is susceptibility and in capacity to recover are very great among individuals. Some ears will be damaged temporarily by exposure to noise levels as low as 90 db for short periods; others will withstand intensities of 120 db for relatively long periods. Also, some persons will recover from a given degree of loss suffered from noise exposure in a few minutes while others will require a full day or longer.

Severe depressions in auditory acuity can be suffered without danger of permanent impairment if sufficient time is allowed for recovery before the next exposure. Such hearing losses are termed *temporary* threshold shifts. Persons who require a longer recovery process, and who work in occupations that generate noise continuously, may not be afforded sufficient time for complete recovery between exposures. This results in a daily accumulation of hearing loss. Unless

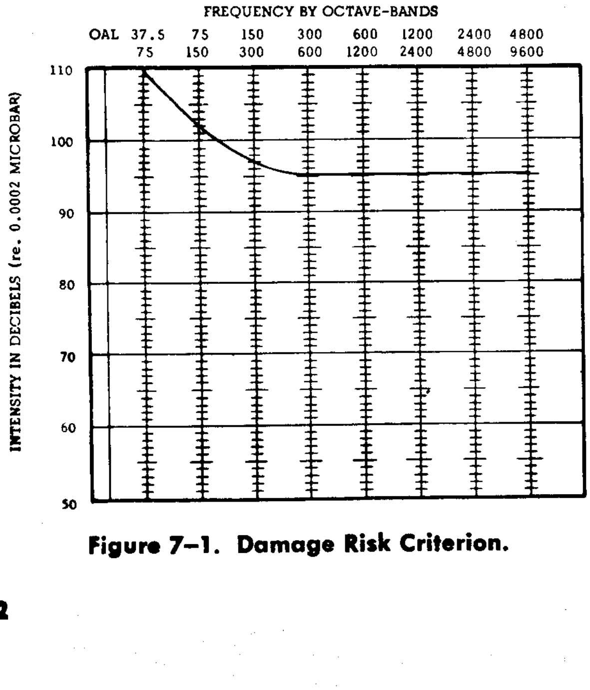

Figure 7–1. Damage Risk Criterion.

they are removed from the job or are equipped with adequate ear protection, their ears do not recover appreciably even with longer time allowances. Their hearing losses may then be termed *permanent.*

Although the temporary deafness suffered may involve the lower and middle frequency ranges, the permanent impairments more often center around the frequency of 4,000 cps. The low point of impairments most commonly recognized is from 3,000 to 6,000 cps. A typical progression is one in which the damage is first confined to a narrow frequency band. With further exposure, the impairment spreads to the surrounding frequency bands, and the initial low point goes lower. The losses are perceptive in character. (Conduction loss is superimposed when the middle ear is also injured.) Those in whom the loss is centered about 4,000 cps may suffer quite extensive impairment in the high frequencies before hearing in the speech range is affected. Figure 7-2 depicts progressive audiograms showing a typical regression of hearing acuity resulting from prolonged exposure to severely hazardous noise.

Incidence of Noise-Induced Hearing Loss

In assessing the effects of noise on the auditory acuity of a group of people, it should be remembered that, among the so-called normal population, there are many

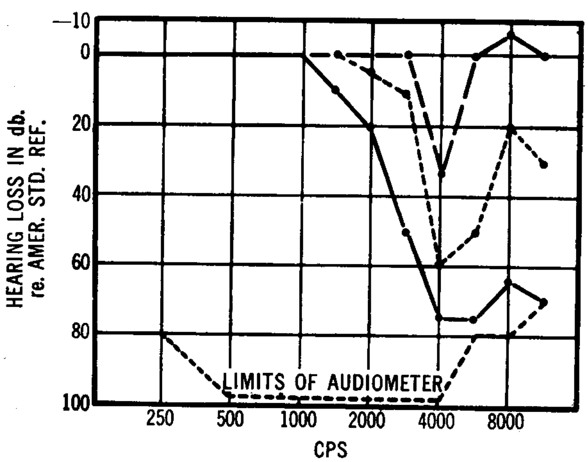

Figure 7-2. Typical Regression of Hearing Acuity Resulting From Prolonged Exposure to Hazardous Noise.

cases of high-tone perceptive hearing loss which cannot be attributed to noise. Approximately 20% of normal young men exhibit an impairment of some degree in the frequencies above 2,000 cps. Furthermore, the average person gradually loses acuity for the high frequencies with age. By computing the percentage of such losses among men working in noisy occupations and comparing it with that among the general population, it has been demonstrated that the proportion of such impairments is higher with longer exposure to more intense noise. On the other hand, in even the noisiest areas, there have been persons who have retained perfect hearing acuity.

There are many occupations in the Air Force today which of necessity involve potentially hazardous noise exposures. The degree of hazard is dependent upon the sound pressure level and frequency composition of the noise, the duration of the noise exposures and the intervening "quiet" periods, and upon the susceptibility of the individual ears. The occupations range from flight crew through the various ground maintenance areas, to shop, armament, and missile activities. Although adequate preventive measures have been developed for each occupation, noise-induced hearing losses continue to show up among some members of all occupations.

It is also imperative to recognize the potential hazard that noise represents to persons in housing areas in proximity to the noise source.

Tinnitus

The temporary deafness incurred by noise is frequently accompanied by a feeling of "fullness" and a ringing, buzzing or roaring sound (tinnitus) in the ears. Such sounds will subside for most persons within a few minutes, but will continue with others over a period of many hours. A few people perceive one of these types of noise almost constantly. Although there are many factors which can and do cause tinnitus, those cases which follow exposure to noise are thought to be indicative of a direct irritation of the nerve and/or the sensory cells by the noise. Many persons who have permanent impairments in the middle or high frequency range experience fairly constant tinnitus. People with normal hearing acuity rarely suffer from tinnitus except immediately after noise exposures.

Effect of Noise on Speech Perception

In the past, it was thought that the temporary depression in acuity resulting from noise exposures would affect perception for speech during such exposures. The assumption was that a man who displayed very definite speech impairment under quiet circumstances following a long flight would, likewise, have experienced difficulty in perceiving signals over his radio during the latter portion of his flight. It was demonstrated, however, that such was not the case with most men. Although there is definite impairment for signals of low intensity, there may be little or no impairment of ability to perceive signals of high intensity. Hearing acuity is "recruited" as sound pressure level of the signal rises. Because of the high signal intensities required in flight by normal ears for adequate perception of signals, the acuity of ears which have been fatigued is therefore adequate. The situation is similar for people employed on the ground in areas where noise is intense. This phenomenon prevails for many, although not for all persons demonstrating permanent perceptive lesions.

Nonauditory Effects

Among the general effects of noise, the most universal is a feeling of excessive fatigue at the end of exposures which is out of proportion to the fatigue that would be expected from similar work under quieter circumstances. Both fliers and ground maintenance men have noted this effect to be greater at higher noise levels. With respect to the fliers, it appears likely that a portion of the fatigue can be attributed to the necessity for paying strict attention to the radio signals, especially during instrument flight. Although the signals usually do not add to the total noise, the signal-to-noise ratio (difference in intensity between signal and ambient noise) is very small when compared with that in normal ground communication. There is, then, a psychological strain involved in the listening. As for the ground maintenance men, the noise alone appears to be responsible, the noise of jets being relatively more fatiguing than that of piston engines.

There is, frequently, an increase in irritability connected with generalized fatigue. This effect has been noted by men working on jet aircraft. If proper ear protection and ear protector-communication devices are worn, the fatigue factor can be decreased significantly.

There are great differences among people with respect to the degree of nonauditory effects developed. This degree varies from time to time in the same person, depending upon his general physical and emotional condition. Little correlation has been found between auditory acuity and nonauditory responses, but emotional stability appears to be a significant factor here. There is a very definite correlation with the spectrum of a noise. Low-pitched noise is far less disturbing to most individuals than the equally intense sound of medium pitch. Very high-pitched noises are annoying to most persons at any level. Narrow-band or pure-tone components magnify the annoyance for all frequency ranges.

In some instances, complaints of nonauditory response are so vague as to suggest malingering. The person cannot put his finger on any one symptom; he just does not like the noise. In other cases, specific symptoms are described. There is acute pain in the ears if no protection is worn. Regardless of ear protection, there is a feeling of overall pressure or blast. The nasal cavities, chest and abdomen are felt to vibrate in response to the sound. Vestibular reactions are sometimes evoked; unsteadiness and occasional nausea and vomiting occur. Weakness in the knees has been noted in some cases, and visual disturbances have been observed. All of the latter symptoms disappear with cessation of the noise.

Clinical Experience

Considerable data concerning the effects of noise on man has been obtained during the past few years. As mentioned previously, excessive fatigue and somatic symptoms occur infrequently among persons using adequate ear protection. When these symptoms do occur, they are almost invariably associated with the assignment of a new type of aircraft or engine at the base. There appears to be little, if any, consistent relationship between the noise intensity and the reporting of these symptoms. After a new aircraft or engine has been operating on a base for several months and experience is gained in its operation, the reports of excessive fatigue and other somatic complaints seemingly disappear. For this reason, it is suspected that, often, symptoms may be more psychological than physiological in nature.

Effect on Work Output

Among those who are able to adapt to and protect their ears from noise, there is apparently no change in work output, either qualitatively or quantitatively. It is not possible to assess the precise effect on work of those who continue to object to noise. The difficulty of concentration and the desire for the noise to cease are thought to combine so that work is performed hurriedly and with less attention to accuracy by these persons. The increase in fatigue and in general irritability must also be assumed to affect performance of duties.

Influence of Ultrasonics

During early experimentation on jet and rocket engines, observation of the symptoms outlined above led many to believe that there might be very intense ultrasonic frequencies (those above 20,000 cps) included in the acoustic energy which were responsible for the effects. A number of investigations were carried out which resulted in the following determination: *There is no reason to fear damage from ultrasonic energy generated by jet and rocket engines* for the following reasons:

a. The ultrasonic frequencies present in the vibration spectrum generated by jet engines are far less intense than those within the sonic range. They seldom exceed 120 db at 20,000 cps and fall off in intensity rapidly with increase in frequency. The noise spectra of the newer and more powerful engines tend to include progressively less energy above the sonic range as they include more in the very low frequencies.

b. Small fur-bearing animals can be killed by exposure to ultrasound in the range of 150 db, but *not* by the lower intensities of ultrasound present in jet noise spectra.

c. These small furred animals absorb a fairly high proportion of ultrasonic energy while absorption of high-frequency energy by human skin is relatively very poor. The small animals are not able to dissipate the heat generated in absorption while the human organism has an efficient system for regulating heat. Therefore, even 150 db of ultrasound would have little serious effect on a human.

d. Experiments using pure tones of low frequency and bands of noise covering *only* the sonic range have shown that somatic and mental symptoms, identical to those experienced upon exposure to jet noise, can be aroused by very high intensities of sonic energy. The problem is one of high intensity rather than high frequency.

e. Personal ear protectors attenuate ultrasound very effectively.

Air Force personnel who work on jet or rocket aircraft continue to be plagued by occasional rumors to the effect that all personnel will suffer various dire consequences following exposure to "supersonics." (The commercial airlines experienced similar rumors during the early days of the jetliner.) The Flight Surgeon should keep the above points in mind and be prepared to ward off serious morale situations.

NOISE IN FLIGHT

The types of noise generated at the ear level of crew and passengers during flight are varied. The following are significant contributors to internal noise:

a. Basic power plants such as reciprocal, turbojet, turbofan and turboprop.

b. Rotating propellers and rotors.

c. Aerodynamic friction and boundary-layer disturbances.

d. Airflow and airducting from air-conditioning and ram air systems.

e. Secondary auxiliary power units that are located inside or attached to the main fuselage.

f. Communication system noise such as electrical static, background noise, and extraneous secondary signal noise.

Reciprocating Engine-Powered Aircraft

A fixed-wing, reciprocal engine-powered aircraft generates intense low frequency-type noise. The primary noise emanates from the rotating propeller tips and is greatest in the plane of the propeller. It is characteristically low frequency and increases in magnitude as the RPM increases. The fundamental frequency of propeller-type noise is usually below 300 cps and is rich in higher harmonics. The noise generated by the engine exhausts is higher in frequency, but usually less intense. Figure 7–3 shows the noise spectrum in the propeller plane of a C–119C aircraft during various phases of operation.

The noise generated by the propellers during rotation is dependent upon several factors, namely, the number of blades, shape of the blade and blade tips, chord size, propeller diameter, blade pitch, and RPM. During flight, internal positions nearest the prop plane are usually the stations where the most intense noise is experienced. The audible spectrum produced within the crew compartment of single-engine aircraft is usually a mixture of propeller, exhaust, and structurally induced noise. The noise produced at various station positions in multiengine aircraft varies with the location of the propeller plane in relation to the general over-all design of the aircraft. Dual-engine aircraft are usually designed in such a manner that the propeller plane is closer to the pilot compartment than is the propeller plane of four or more engine-aircraft where the wing is set back at a greater distance.

Noise from the exhaust of large reciprocating engines may be quite intense. The contribution of the exhaust to the total noise

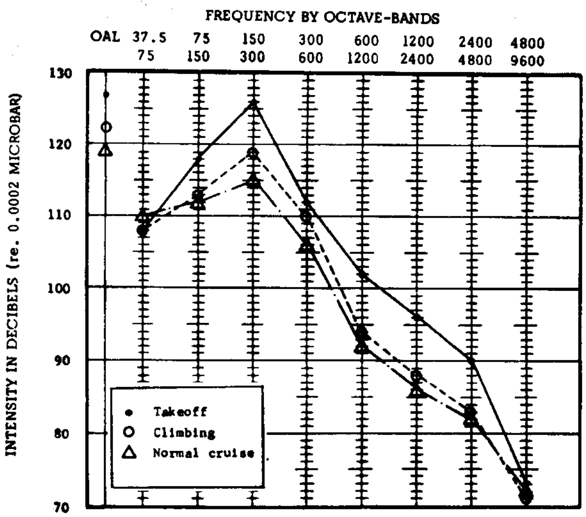

Figure 7–3. Internal Noise at Propeller Plane of C–119C.

exposure varies with the location of the observer in relation to the exhaust ports. If the exhausts are positioned so that the noise emitted from them is not blocked by the wing or other structures, it will be more intense at crew stations, both laterally and aft of the exhaust port openings.

Aerodynamic friction is usually not a significant contributor to internal noise because indicated airspeeds are relatively low, but the passage of air over seals at doors, windows, and hatches can produce a significant increase in the mid and higher frequency noise at crew or passenger stations near them.

Turbojet and Turbofan-Powered Aircraft

Noise experienced at crew stations within a turbojet or turbofan-powered aircraft originates from two principal sources: engines and aerodynamic friction. During ground runup, taxi, and takeoff, the engines are the primary contributors; as airspeed increases, the presence of aerodynamic noise becomes more dominant. When aircraft engines are installed internally or semi-externally in the main fuselage, engine noise may be propagated by direct structural vibration.

In turbojet and turbofan aircraft, aerodynamic noise increases as the airspeed increases, and at high speeds, it is considerably more noticeable than the engine noise. The noise spectrum measured in the rear seat of a T–38A, as shown in Figure 7–4, illustrates the influence of increased airspeed on aerodynamic noise. This noise increases progressively in the frequency bands above 150 cps.

Noise within bomber, cargo, and tanker-type jet aircraft varies with station positions. Aerodynamic noise is predominant in areas forward of the wing, especially in the cockpit. Station positions aft of the wing

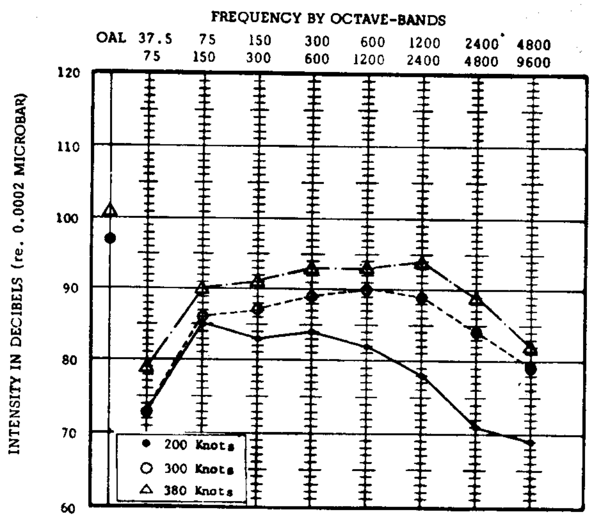

Figure 7–4. Noise at Second Station of T–38A (25,000 Feet Altitude, 90% RPM).

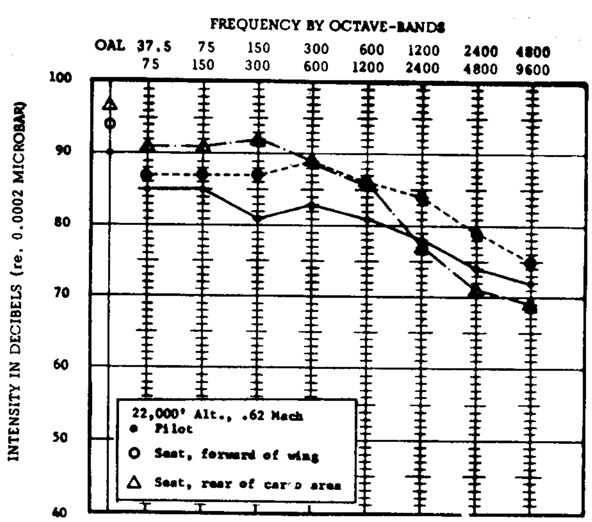

Figure 7–5. C–135A Internal Noise at Normal Rated Cruise Power.

usually contain the most intense noise radiated by the engine exhausts. Compared to propeller-driven aircraft, relatively little acoustically induced structural vibration contributes to the total noise level. Figure 7–5 illustrates noise levels at different positions in a C–135A flying at maximum continuous cruise power.

From the viewpoint of noise, the introduction of turbofan versions of basic turbojet engines offers an advantage. There is significantly less noise from the exhaust for the same or greater thrust rating. The turbofan-type engine is presently used in fighter, bomber, cargo-transport, and cargo-tanker aircraft, including the F–111, A–7, B–52H, C–135B, C–141A, and KC–135B. Figure 7–6 shows a comparison of the noise generated at comparable crew stations in a C–135A (turbojet) and a C–135B (turbofan). As can be seen, the high frequency whine of neither engine is outstanding. This is primarily due to the good attenuation of high frequency noise by the fuselage.

Many high performance turbojet and turbofan-powered aircraft employ air or dive brakes. These brakes, when deployed, may significantly increase the level of internal noise. Figure 7–7 illustrates the change in noise within the passenger compartment of a T–39A when the air brakes are extended.

Turbojet and turbofan engines do not require a runup prior to takeoff as do propeller engines. Therefore, intense noise generated at ground level with high power settings is present only during actual takeoff.

Turboprop-Powered Aircraft

The noise levels in turboprop-powered aircraft are not unlike the levels and spectrum of conventional reciprocating engine-aircraft. Characteristic of the noise within the aircraft is the low frequency energy emanating from the rotating propeller tips. Figure 7–8 shows an octave band spectrum level curve for the C–130B aircraft for two flight conditions inside the flight compartment. The octave band levels for other turboprop aircraft vary somewhat, but the general shape of the noise curves are similar.

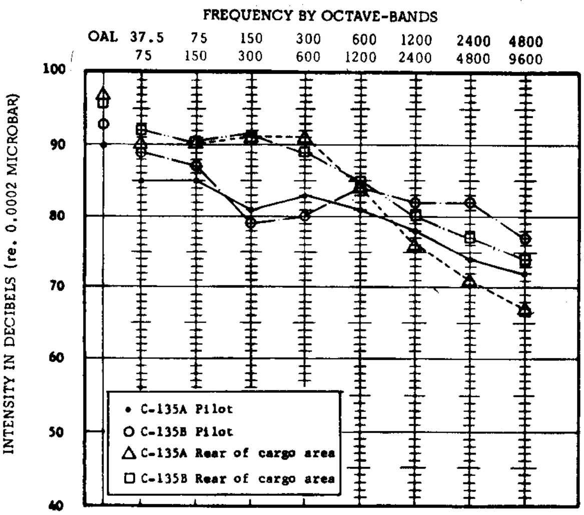

Figure 7–6. Noise Comparisons in C–135A and C–135B at Comparable Crew Stations, Normal Rated Cruise Power.

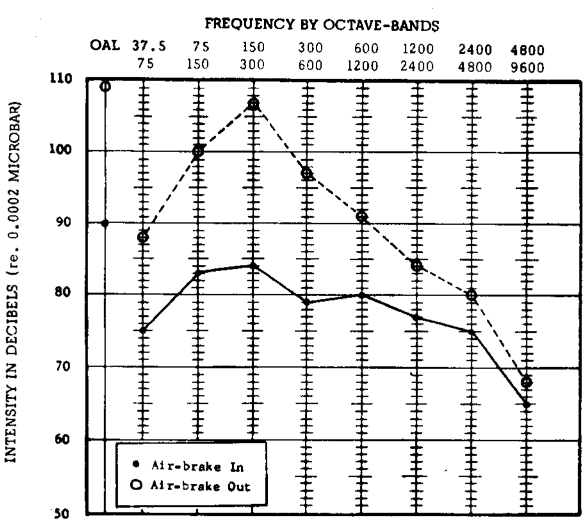

Figure 7–7. T–39A Dive Brake Noise.

Internal Auxiliary Power Units

Many cargo and tanker-type aircraft use an AC, DC, or a combination AC-DC auxiliary power unit which is located within the main fuselage or in a semi-external pod. These units usually are powered by a reciprocal or gas turbine engine, with the exception of the C–133, and operate only during ground checkout, loading and unloading, and just prior to landing. Figure 7–9 shows some noise measurements made near these units while they were operating. If these units are to be kept in operation for any length of time, the flight crew working around them should be advised to wear ear protection.

Helicopter Noise

Many rotary wing aircraft create considerable noise and vibration. Sources of this noise and vibration are the power plant, transmission, exhaust, and rotors. Noise produced by the impacting and shearing motion of the gears within the transmission and

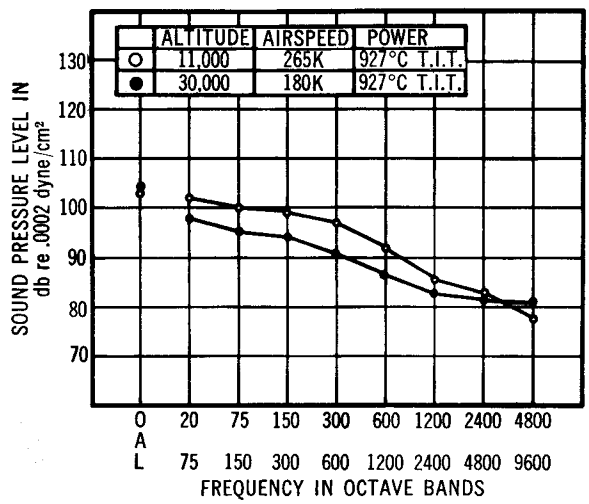

Figure 7–8. C–130B Flight Compartment Noise Levels in Flight.

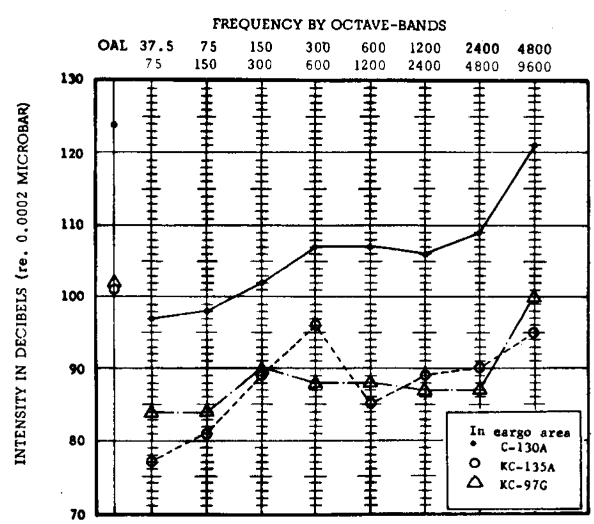

Figure 7–9. Measurements at Operator Position of Internal Auxiliary Power Units.

gear boxes exists on almost all military-type helicopters. Reciprocating engines, especially large ones, produce intense exhaust noise below 400 cps. Little exhaust noise is associated with helicopters powered by jet engines, but in some instances, objectionable high frequency noise may be produced by the compressor stages of the engine. The rotors are responsible primarily for low frequency noise which increases with the speed of rotation. Structural vibration and resonance may also raise the internal noise level. Figure 7–10 illustrates the noise measured at the pilot position in three types of helicopters.

NOISE DURING GROUND OPERATIONS

Ground maintenance and other ground crew personnel are exposed to the most intense noise associated with aircraft operations. This is especially true of engine maintenance personnel. The following sections discuss the major sources of this noise.

Ground Power Units

Many types of ground power units are used by maintenance and ground crew personnel. Some of the more important types include:

a. AC, DC, or AC–DC auxiliary electrical power units.

b. Gas turbines which provide highly compressed air for starting reaction-type engines.

c. Air-conditioning and heating units.

In many instances, the ground crew personnel may be exposed to hazardous noise from these ground power units. Personnel working around such equipment should be encouraged to wear proper ear protection.

Reciprocating Engine-Powered Aircraft

Reciprocating engine noise is a discontinuous noise having a low fundamental frequency and a gradual falling off of energy at higher frequencies. As illustrated earlier, crews flying reciprocating engine aircraft receive little exposure to high frequency noise because of this feature and the attenuating effect of the fuselage. However, considerable high frequency noise is present in the spectrum reaching ground personnel since they are outside the aircraft. Figure 7–11 shows the noise levels measured at various angular positions at a distance of 200 feet on the left side of a C–124A aircraft during a ground runup of engines one and two at takeoff power, with engines three and four at idle power. The most intense noise was found 80 through 120 degrees from the nose of the aircraft.

Turbojet and Turbofan-Powered Aircraft

The noise of jet engines operating on the ground is continuous and of a high intensity level throughout the audible frequency range. Noise levels of 110 to 120 db are very common even at relatively low power settings, both at the locations where men work on jet aircraft and over a fairly wide area surrounding the aircraft. Toward the rear of the engines at high power settings, the noise often exceeds 130 db.

Turbojet and turbofan engines have certain characteristics which are seemingly common to any reaction-type engine. Some of these characteristics are as follows:

a. Of the total power generated by a reaction-type engine, only a small portion is in the form of acoustic energy.

b. The most intense acoustic energy is propagated at an angle of about 10 to 45 degrees to the front of the engine and about 15 to 35 degrees to the rear of the engine.

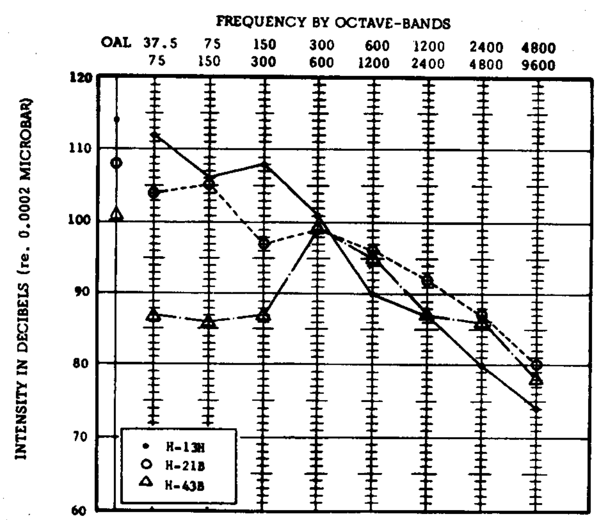

Figure 7–10. Measurements at Pilot Positions in Three Types of Helicopters at Normal Cruise.

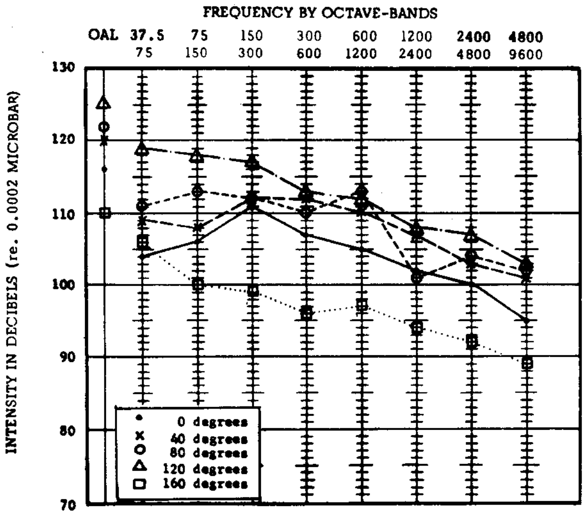

Figure 7–11. C–124 Ground Runup Noise at a Distance of 200 Feet, With Engines One and Two at Takeoff Power, and Engines Three and Four at Idle Power.

Very great differences in noise level are found at locations only a few feet apart.

c. At high power settings (military power and augmented power), the most intense acoustic energy is distributed near the exhaust plane.

d. The greater the thrust of an engine, the lower will be the frequency range containing the most intense acoustic energy.

This shift in maximum acoustic energy with increased thrust can be seen in figures 7–12 and 7–13. Figure 7–12 shows the noise spectrum of a J–57 engine at approximately 10,200 pounds of thrust while figure 7–13 illustrates the noise spectrum of a TF–33 engine operating at about 17,000 pounds of thrust. A comparison of the two illustrates the difference in level of exhaust noise generated by turbojet and turbofan engines.

One point of note with regard to maintenance of the jet engine and that of the reciprocating engine is that it is often necessary to work on the jet engine while it is operating, but this is seldom necessary or possible in the case of the reciprocating engine. One of the more common maintenance jobs around turbojet engines is the fuel flow adjustment, which is accomplished while the engine is operating at various power settings. Noise levels encountered by personnel performing this operation are shown in figure 7–14. It is readily apparent from this graph that mechanics exposed to these noise levels should wear combination protection of *plugs and muffs.*

Turboprop-Powered Aircraft

The turboprop engine may produce intense noise exposures for ground crew personnel since the propellers rotate at high RPM regardless of the phase of ground runup. Figure 7–15 shows the noise environment generated at maintenance positions near the propeller plane of a C–133A operating at 80% of normal rated power.

The C–130, C–133, and C–141 cargo aircraft have gas turbine auxiliary power units installed in the left-hand gear pods. These units may operate for long periods while the aircraft is on the ground. Figure 7–16 shows that the noise produced is rich in intense high frequency components near the intakes of the auxiliary power units; however, the levels are less severe at the loading ramp where most personnel must be.

PROTECTION AGAINST NOISE

There are three approaches to the problem of protecting personnel against noise: a. The reduction of noise at its source; b. the reduc-

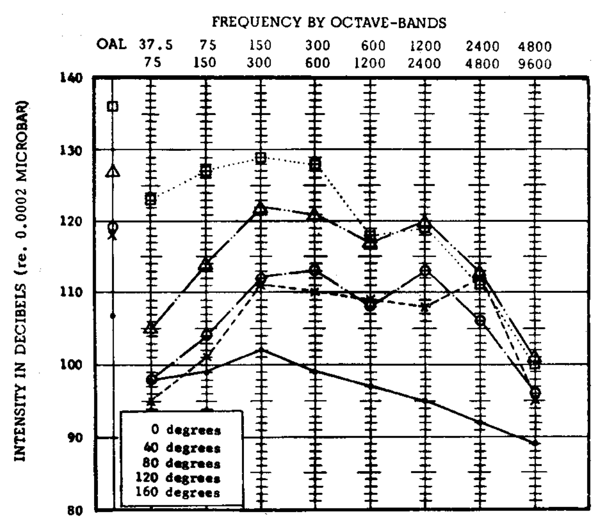

Figure 7–12. Turbojet Engine Noise at 100 Feet, Military Power.

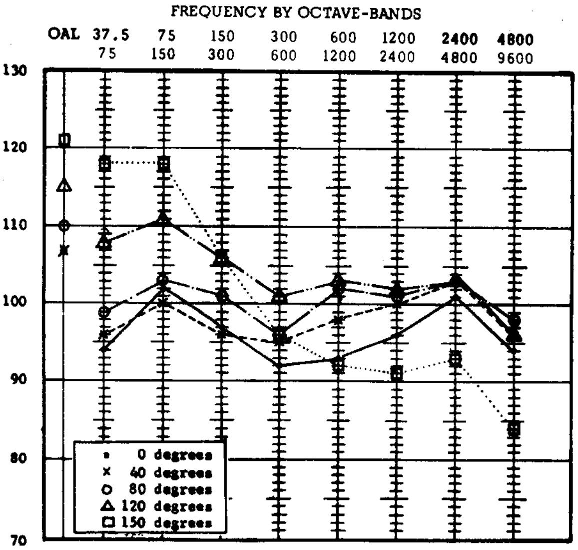

Figure 7–13. Turbofan Engine Noise at 150 Feet, Maximum Takeoff Power.

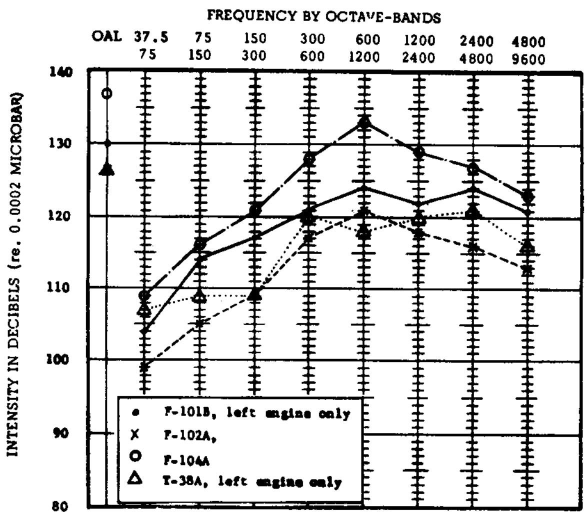

Figure 7–14. Engine Trim Noise Exposures, Military Power.

tion of exposure durations; and c. the provision of personal protective measures. With reference to the first two, the Flight Surgeon can and should keep himself informed of the noise situation on his base by frequent inspections of the flightline area. He can often make recommendations for moving aircraft farther from hangars and placing them in such a way that the worst noise is aimed away from inhabited areas during engine runups. In some cases, he may be able to initiate changes in procedure which will result in fewer individuals being required to stay in the immediate vicinity of aircraft during runups, and in lessening of total exposure time. The primary responsibility for attempts to reduce noise, however, lies with the aircraft designers and engineers, the architects who design new facilities for Air Force bases, and those who develop maintenance procedures. The Medical Service has

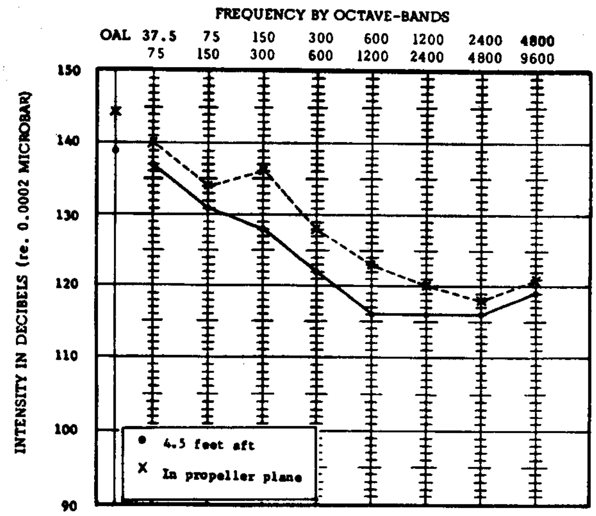

Figure 7–15. C–133A External Propeller Noise, 3140 HP, 80% of Normal Rated Power.

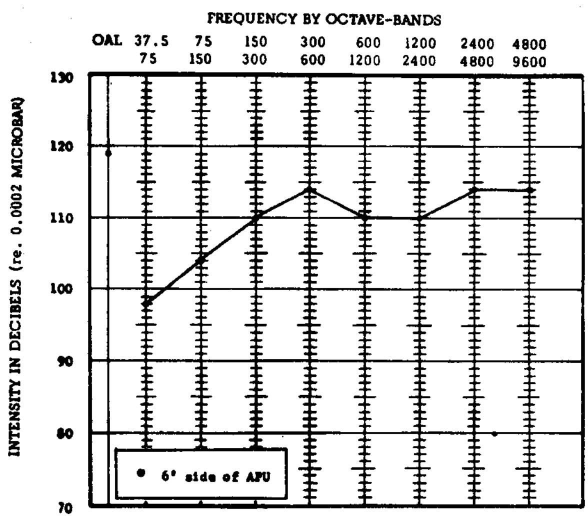

Figure 7–16. Ground Crew Exposures Near Side of C–133A Aircraft Auxiliary Power Unit.

372-8-A EARMUFF

V-51R EAR PLUG

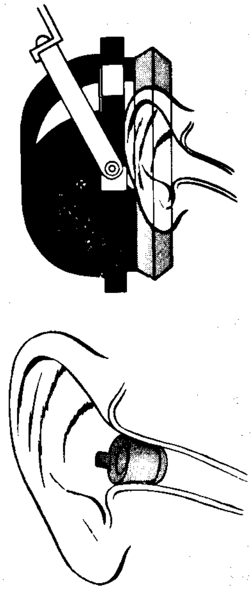

Figure 7-17. Air Force Standard Stock-Listed Items of Ear Protection.

responsibility for advising civil engineers regarding noise reduction and protection characteristics in new buildings and base designs. On the other hand, the Flight Surgeon is wholly responsbile for providing personal protective measures to persons who must work in high noise levels. Protective measures are discussed as follows:

Types of Protection

Ear defenders available are of two general types: those inserted into the ear canal (earplugs), and those worn over the ear (headsets, helmets, and earmuffs). The current Air Force issue earplug is molded in a standard design known as the V-51R. It is made of vinylite and comes in five sizes. Standard Air Force earmuffs may be one of several designs. Figure 7-17 shows the standard earplug and one version of earmuff. The muffs are also available with earphones and a noise-cancelling microphone mounted in a noise shield. These communication muffs are primarily for use by ground crew personnel during engine runup and checkout operations.

Standard aircraft headsets and cushions are not specifically designed for use as ear protectors, however, they provide some degree of noise attenuation. Such headsets provide good attenuation in the higher frequency ranges, but very little in the lower ranges. Therefore, the items expressly developed for hearing protection (the V-51R earplug and the various earmuffs) are always to be preferred when effective attenuation of noise is of paramount concern.

Protection Provided

All types of defenders block out or attenuate noise of high frequency more effectively than noise of low frequency. There is a fairly regular increase in efficiency of the defenders with rise in frequency. The V-51R may attenuate as much as 20 or 25 db in the low frequencies and 35 db or more in the high frequencies (see figure 7-18). The exact amount of protection afforded by a specific defender will vary among persons being governed principally by how good a fit is obtained. It will vary for any one person at different times, depending upon how carefully he has inserted the defender. Muffs now available to Air Force personnel are as effective as well-fitted earplugs. They provide a convenient means of increasing the attenuation of dangerously high noise levels when they are worn in addition to insert plugs.

There is a definite limitation on the degree of protection which can be afforded by defenders of the insert or headset type. This limitation is imposed by the fact that airborne sound, when it becomes sufficiently intense, initiates vibrations of the skull which, in turn, are carried to the cochlea through the bone; thus, they bypass the outer and middle ears. The threshold for such transmission is high compared to that for air conduction of sound, but it is well below the levels which are commonly encountered during aircraft operations. Although, theoretically, a perfect earplug might attenuate noise as much as 60 db, such a plug would not guarantee safety from hearing loss at noise levels of 140 db or higher since a very appreciable portion of the sound energy at these levels would reach the cochlea by bone.

Precautions in the Use of Personal Ear Protectors

For an insert-type earplug to be most effective, it must make an airtight seal of the

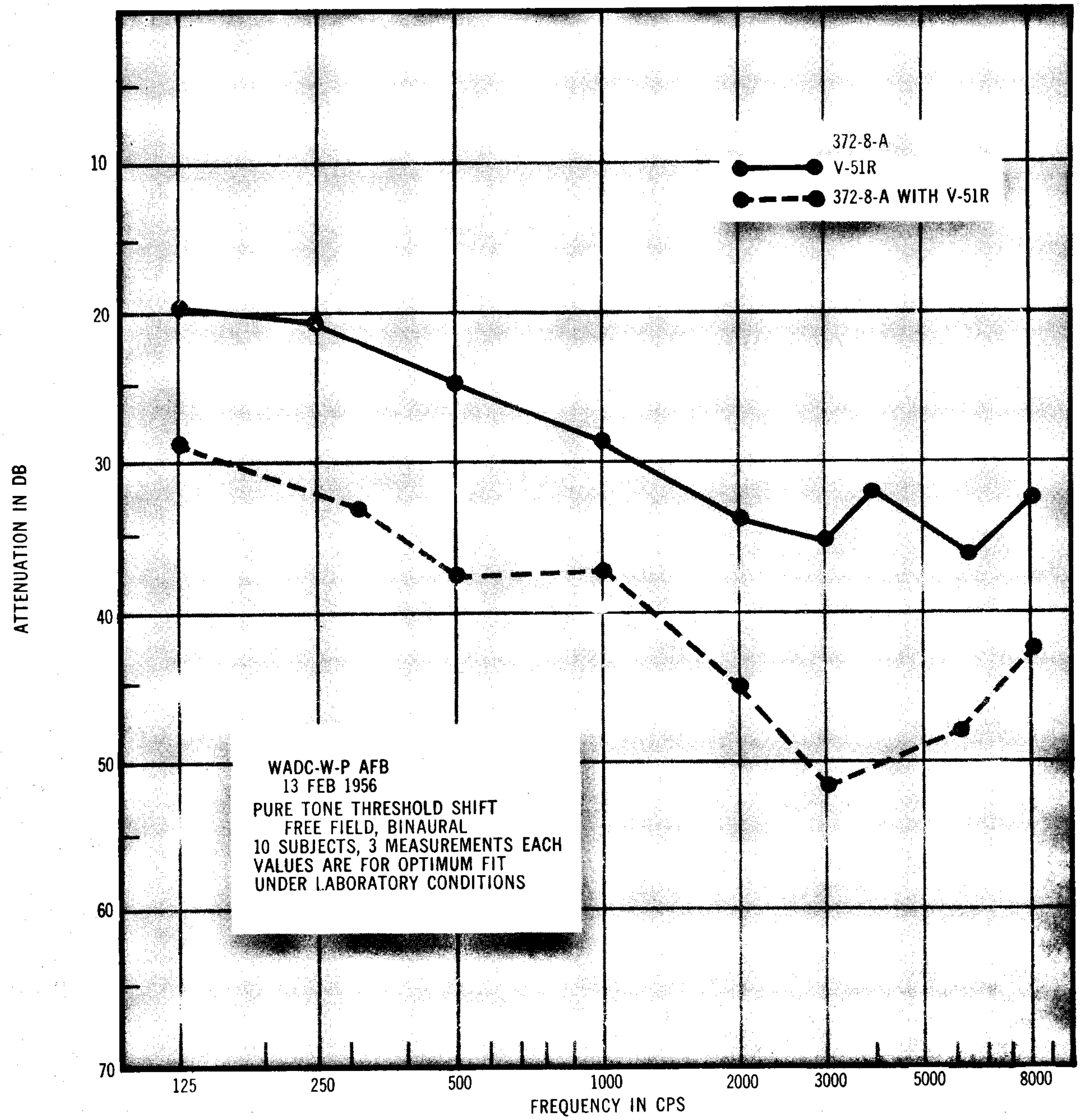

Figure 7–18. Attenuation Characteristics of Standard Ear Protection Devices.

external ear canal. The following factors should be remembered when earplugs are to be fitted and used:

a. The earplug must fit tightly if it is to offer the maximum allowable attenuation. People who are not accustomed to earplugs often complain that the properly fitted earplug is "too tight," but after wearing it routinely for about two weeks they find that it is comfortable. This is probably due to the fact that they have become accustomed to the feeling of tightness or pressure.

b. Personnel fitting earplugs should always fit each ear separately. In many instances, people have different-sized ear canals.

c. Earplugs should be kept clean and dry.

d. When earplugs become brittle, they should be replaced and a new fitting made. Matching the previous earplug size is not to be assumed as adequate.

Use of Defenders in Flight

Insert-earplugs are particularly effective under flight conditions. They serve to attenuate the ambient noise in the cockpit to a greater degree than that accomplished by the headset alone. They further act to improve the clarity of the radio signals. Defenders attenuate proportionately more of the static coming over the radio than they do of the speech signals. Therefore, they allow a signal which is less distorted and one which stands out better over the noise background. If desired, the volume control can be turned up to permit a louder signal.

There is an operational limitation, however, which makes it mandatory that any insert-defender other than dry cotton be used with caution under flight conditions, and that only dry cotton be worn under a close-fitting helmet. If a defender worn in the outer canal seals perfectly, there will be an airtight pocket in the canal between it and the tympanic membrane. On ascent, the air in this pocket will expand and tend to equalize with the ambient pressure by pushing the plug out a bit and escaping around it. If the wearer then tightens the seal of the defender, he will again have an airtight pocket. A negative pressure, however, will exist between the plug and the tympanum on descent. The plug will tend to be pushed in, and discomfort or true vascular damage to the soft tissue of the canal may result.

The term *aerotitis externa* is used to describe this condition. Experience has shown that such pathology occurs very rarely. Yet, flight personnel should be warned to watch for it, and to remove the defenders before or during descent if any discomfort is aroused. *Under no circumstances should imperforate ear defenders be worn under protective flight helmets and full or partial pressure helmets.*

In the past, it was recommended that a tiny perforation be made in the defender to allow for pressure equalization. Several commercial companies have manufactured plugs which embody a perforation or a valve. Nevertheless, dependence upon such defenders is not recommended as the effectiveness of the perforations or valves is voided by the entrance of even the tiniest speck of dirt or cerumen.

Use of Defenders During Ground Operations

Ear defenders should be made readily available to all persons whose duties carry them near or on the flightline. Included in this group are the crews assigned to particular aircraft; the alert crews who service transient aircraft; the men who carry on repair work in the hangar and remove and reinstall equipment in the aircraft while other maintenance is going on (radio and radar men among others); and the fuel truck and tow-tug drivers. Often overlooked in the distribution of defenders are the firemen and air policemen who, for hours at a time, are stationed as guards at various points on the flightline. Noise levels often exceed 100 db in and near the hangars. Other on-base areas—such as firing ranges, air-conditioning plants, and ground power, carpenter, and welding shops—should not be neglected.

The defenders should be worn by all men in the immediate vicinity of an operating aircraft, even though the engines are only idling. Men working both inside and outside the aircraft are included, and especially the men who maintain outside contact with the pilots or engineers by intercom. The defenders should be worn by all within a wide area when engines are run to higher than idle power levels. The specific distances within which defenders should be worn will vary with the type of aircraft and its position with respect to the individual. No aircraft (jet, propeller or helicopter) is excluded here.

As a general rule, both ear plugs and muffs or plugs and noise-excluding headsets should be provided when noise levels are in excess of 135 db, and especially when they exceed 140 db. The exposure duration and frequency of noise levels will affect these values. (See AFR 160-3.) Such intensities are found in work positions around the B-47, B-52, B-58 and the "Century Series" fighters, and especially near the tailpipe of any aircraft equipped with afterburners when the latter are in operation. Every effort should be made to minimize the duration of such exposures, and to allow an extended time period between such exposures for any one person.

Both flight and ground personnel who learn to wear ear defenders regularly find the annoyance formerly created by noise to be lessened or eliminated entirely. Speech is understood more easily. Temporary deafness, "fullness" of the ears, tinnitus, and diplacusis following exposures are minimized.

Men who once experienced excessive fatigue and irritability after working on or near jet engines all day, find themselves in relatively good physical and mental condition following such duties when they have protected their ears. Those who have suffered nausea, equilibrial disturbances and other unusual symptoms may not do so when defenders are worn.

A few persons will be found who, even with the best of current defenders, continue to experience ill effects from noise. The Flight Surgeon must be continually on the alert to screen out and reassign the exceptionally susceptible men.

Indoctrination on the Need for and Use of Defenders

Although the need for and the effectiveness of ear defenders had been recognized in scientific circles for many years, it was not until jet aircraft were in fairly widespread operation that the idea of ear protection was generally accepted by men working in excessive noise. There remain numerous entire groups and many people within other groups who are not aware nor convinced of the facts in the preceding pages.

Various reasons for this situation are evident. The most pronounced is ignorance on the part of supervisors and workers alike, of the need for and value of defenders. Inadequate knowledge of airmen on how to handle defenders, poor fitting of those who have them, and unreliable supply channels also are contributing factors.

The Flight Surgeon must assess the situation on his base and initiate a vigorous program of indoctrination designed to correct whatever phases may be faulty. His program will succeed more rapidly if he concentrates his initial efforts on the older and generally respected men. When the line chiefs and crew chiefs are convinced, it is an easy matter to persuade others to follow suit, including both airmen and officers. Many will then ask for defenders.

Fitting ear defenders in the noise environment is an excellent method of demonstrating both the decreased annoyance and the adequacy of speech perception while wearing the defenders.

Approximately 98% of ears can be fitted adequately with one of the five sizes of V-51R design earplug. It is essential that each ear of a person be fitted separately as the two often require different sizes. There are a few people whose outer ear canals are either too small or too large for this type of earplug; a few others have peculiar configurations of the outer ear which defy

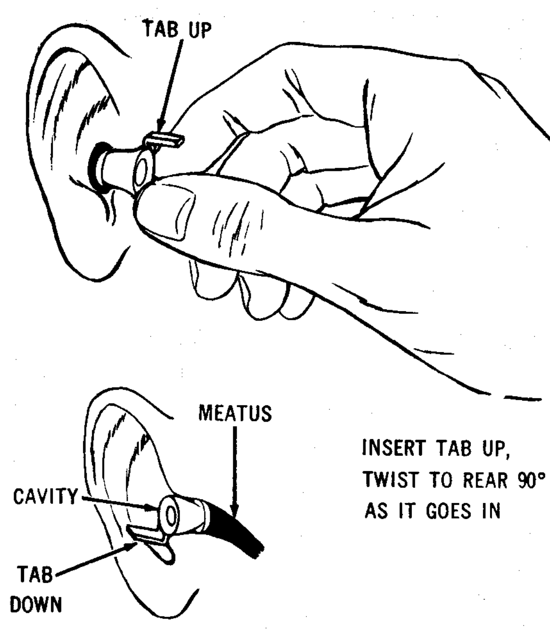

Figure 7-19. Proper Method of Inserting V-51R Defender.

proper fit. Other procurable plugs should be tried for such persons. Men suffering from external otitis can use only dry cotton and headsets or muffs until the infection is cured.

Figure 7-19 shows the proper method of inserting a V-51R defender. The pinna is drawn upward, outward, and forward with one hand, as it is prior to the introduction of a speculum. The tab of the defender is grasped between the thumb and forefinger of the opposite hand in such a manner that the tip of the forefinger covers the central cavity of the plug. The plug is then introduced into the external meatus and moved inward with a twisting motion until the outer rim rests snugly against the auricle. The tab is directed superiorly as insertion begins but is rotated 90° posteriorly during the procedure. When the plug is properly seated, the tab should be positioned to the rear of the head.

As other and more effective defenders are developed and made available, the Flight Surgeon must make certain that those responsible for these fittings are trained in the proper use of each style. With experience, each fitter will learn to recognize when a proper fit is achieved. He will often find that a defender which is actually too small will be judged as too large by the wearer. A small plug enters sufficiently far to come in contact with the more sensitive portion of the canal and, therefore, is perceived as "too big." A proper fit is one in which the plug is large enough to seal the canal thoroughly, yet not so large as to create true discomfort or pain. The person soon will become accustomed to the feel of the defender, even though he may not like it at first.

To insure effective utilization of the defenders, it is essential that each man be shown how to insert the plugs, how to remove them, and how to care for them. Mechanics' hands are frequently covered with grease, fuel, and other contaminating agents. Further, many men's fingers are large, blunt, and have only very short nails. Also, the external meatus is so far forward under the tragus in some persons as to make proper seating and removal of defenders particularly difficult. In many of the latter cases, the insertion can be aided by having the man reach over his head with the opposite hand and pull the pinna up, forward, and out, as is done by the fitter. Each man must practice in order to develop his own technique of handling the tiny plugs so that he can manage insertion and removal quickly.

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