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FOREWORD

This report was prepared in the Veterinary Sciences Division under task No. 775311, according to program direction initiated by Headquarters, Strategic Air Command, to support health and effectiveness of military sentry dogs. The work was accomplished between May 1968 and March 1969. The paper was submitted for publication on 1 May 1969.

The professional assistance of the Dental Sciences Division, and the cooperative support of the Otolaryngology Branch, Clinical Sciences Division, are gratefully acknowledged. Appreciation is also extended to the Veterinary Services, Dental Services, and Security Police of Barksdale and Carswell Air Force Bases of the Strategic Air Command, and to the Sentry Dog Center, Lackland Air Force Base, Air Training Command, for their effective accomplishments in early tests and final field evaluation.

The animals involved in this study were maintained in accordance with the "Guide for Laboratory Animal Facilities and Care" as published by the National Academy of Sciences–National Research Council.

This report has been reviewed and is approved.

JOSEPH M. QUASHNOCK
Colonel, USAF, MC
Commander

ABSTRACT

Concern for hearing impairment of Air Force personnel as a result of turbojet noise led Air Force veterinarians to postulate that similar impairment may occur among Air Force sentry dogs. It was the purpose of this project to develop and test canine ear defenders and to evaluate the feasibility of using them in Air Force dogs.

Three basic types of ear defenders were developed: universal earplugs, molded earplugs, and external earmuffs. Variations to these basic types were also developed and tested. Eighteen dogs were used to evaluate the ear defenders under conditions ranging from acoustical chamber to flight-line runup of operational aircraft. Exhaust noise levels, as recorded, ranged to 128 dB at all frequencies (20 Hz to 20 kHz) and intake noise levels ranged to 115 dB at all frequencies.

None of the dogs showed any apprehension to, or discomfort from, the noise without earplugs, although one dog gave evidence of somatic damage from the 128 dB noise level. It was, therefore, impossible to establish an end point for testing the protective devices. Earplugs were rejected as a means of protection because only 1 of the 18 dogs would tolerate them. Earmuffs were also rejected because the position of the canine ears precluded adequate application of the muffs. Recommendation was made to rotate and selectively station dogs found apprehensive of noise.

EVALUATION OF CANINE EAR DEFENDERS

I. INTRODUCTION

For nearly two decades the United States Air Force has been acutely concerned with noise and its effect on aircrews. The *Flight Surgeon's Manual* (5) discusses the subject in considerable detail. With the advent of the turbojet, concern for the aural health of ground crews has surpassed that for flight crews. The problems encountered by flight-line personnel who are frequently subjected to noise levels in the magnitude of 125 to 140 dB for brief periods while trimming an engine, or to daily levels of noise in excess of 90 dB during normal operations, have been well documented. Persistent auditory embarrassment, day-in and day-out, without proper protection or recovery periods, will inevitably lead to hearing impairment. Frequent, but not continuous, embarrassment to the hearing mechanism can result in annoyance and irritability, loss of proper rest, interference with speech, or, under extreme circumstances, in physical pain and somatic injury.

In more recent years, Air Force investigators have discussed the related problem of canine hearing loss and sought ways to alleviate or protect against it. It was postulated that many of the same problems experienced by military personnel from turbojet noise were being encountered by sentry dogs. The purpose of this project was to develop and evaluate ear defenders for military dogs.

II. BASIC CONSIDERATIONS

Jet aircraft noise

Jet aircraft noise can be divided into two types—intake noise and exhaust noise. Noise which occurs within a 45-degree arc of the intake is of lesser intensity, but has a greater portion of the high frequencies than does exhaust noise. The intake noise is sirenlike in character. Exhaust noise is characterized as a smooth, intense roar. Although it has a higher intensity at all frequencies, exhaust noise has a relatively greater composition of the low frequencies.

Hearing loss in humans

Hearing losses in man may be negligible, temporary, or permanent. Situations in which an individual sustains a minor impairment for a period of minutes or hours, only, are classified as "no hearing loss." Those impairments resulting in a partial hearing loss for several days are considered "temporary" losses. Those impairments, usually a result of continuous or frequent embarrassment, which result in unregainable hearing losses are termed "permanent" losses. In man, the majority of hearing impairments or losses occur in a specific frequency range of approximately 4 kHz.

The cause of hearing loss is a factor of both the intensity and duration of noise. The Air Force has established damage risk criteria which require the use of ear defenders whenever personnel are subjected to noise levels above 95 dB. Although individuals can develop a subjective tolerance to this noise and adapt to working under conditions of intense noise, physical phenomena such as tinnitus (buzzing in ears), or psychologic phenomena of fatigue or irritability, frequently occur. Specific consideration has been given to the ultrasonic noise problem; i.e., those sounds above 20 kHz frequency. It has been concluded that ultrasonics present no major threat to hearing since the intensity of sounds above 20 kHz drops off rapidly as the frequency increases.

Protective devices for humans

The ear defenders developed for human use are of two types: the insertable plug (usually the universal type, but occasionally molded), and the external earmuff. Personnel exposed to more than 95 dB are required to wear ear defenders. At above 135 dB both types of ear defenders are required. No person should ever be exposed to noise levels in excess of 150 dB, the point of somatic injury. Ear defenders have proved to be indispensable equipment for airmen required to work under abnormal noise conditions. Fatigue and irritability, as well as most hearing losses, can be prevented. Some individuals will never accommodate to noise situations regardless of protection.

Hearing loss in animals

Despite the extensive research conducted in human audiology, a review of current literature reveals a relative dearth of information on canine hearing. Pavlov was among the first to condition dogs to respond to auditory stimuli. He concluded that dogs could hear tones to 100 kHz (4). We may question whether Pavlov had equipment sophisticated enough to produce a pure tone in this frequency, however. Current findings would place the upper end of the canine hearing spectrum at 40 kHz (6).

Others have conducted stress experiments and have shown that rats, mice, and guinea pigs can adapt to noise levels of 132 to 140 dB at 2 to 40 kHz (2). Sound in the magnitude of 149 to 153 dB for 2 to 4 minutes caused histopathologic changes in the middle-ear mechanism, but these tended to resolve with time (3). Frequent auditory embarrassment over a period of weeks resulted in a decreased defense response as judged by adrenal depletion in mice and guinea pigs (1).

It appears, therefore, that while noise will stress an animal, he can adapt to the situation, and that, although he may suffer some cellular-level damage from short-term auditory embarrassment, such damage will resolve itself. Since dogs probably have twice the frequency range of hearing that man does, certain phenomena beyond man's hearing range may occur in dogs. It is unlikely, however, that any consistent phenomenon occurs since the majority of dogs appear to have no apprehension about turbojet noise. The review of literature revealed no reports of noise studies in this spectrum with dogs.

III. DEVELOPMENT AND TESTING

Three categories of devices were developed and tested in dogs: universal earplugs, molded earplugs, and external earmuffs.

Universal earplugs

The initial principle for the universal earplug was an air-filled rubber plug. Two such types were tested—one, developed by this investigator; the other, an over-sized human earplug, obtained commercially. The basic problem encountered with this design was that the plug lacked sufficient "body" to be insertable. The situation is analogous to inserting a balloon into a bottle; fluid dynamics (Pascal's law) requires the downward pressure to be exerted in all directions, not in the one desired direction only. Two improved models were then developed—one made with foam rubber inserts; another of a putty-like substance. Although these plugs had more "body," they, also, could not be inserted. It became evident that nothing flexible could be inserted in this manner. An overall complication encountered with this category of plugs—an overwhelming factor in discontinuing work on this line—is the fact that the canine ear, and even more specifically, the ear of the German Shepherd, is not remotely universal in size or shape. The rugae of the ear canal are variable in setting as well as magnitude. Imprints made of the cross-sections of the ear canals of three German Shepherds showed a wide diversity in size and shape (fig. 1). It was apparent that no universal plug could be adapted to the German Shepherd ear.

Molded earplugs

Two approaches to molded earplugs were tried. One involved using a dental rubber-base impression material and molding the plug in the ear directly. Of the various brands and consistencies used, Federal Stock Catalog (FS) No. 6527-764-2262 resulted in the most well-formed plugs. The procedure included cleaning the ear, inserting a cotton ball just beyond the near right angle to prevent deep filling, and infusing the liquid rubber-base mixture. A small loop of nylon string was implanted into the material. After approximately 10 minutes the material had hardened, the plug was removed with the string, and the edges were trimmed as necessary to remove useless tags of material. This procedure was performed with the animal under heavy sedation, and the resulting cast was the actual earplug. The alternate approach was to mold the original with a permanent-impression plastic, FS No. 6520-551-7050, in the same manner. This procedure would enable a dental laboratory to mold replacement plugs as necessary, and would preclude repeated sedation of the dog whenever new plugs were needed. The resulting earplug was a firm, spongy, rubber mass, correct in every detail to the specific anatomy of the ear in which it was to be used (fig. 2).

FIGURE 1

Cross-sectional views of molded earplugs taken just above the near right angle show the great variation in size and shape of ear canals.

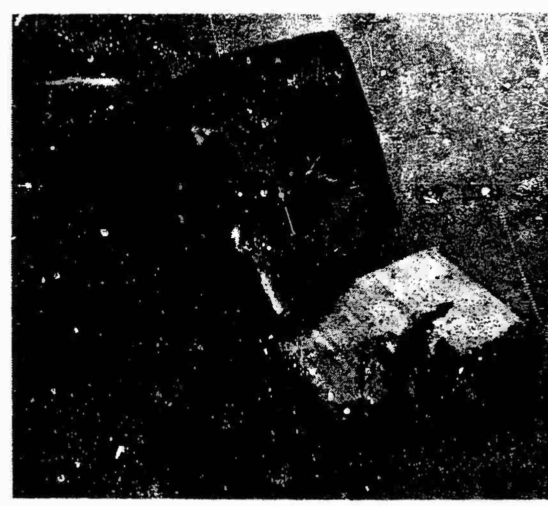

FIGURE 2

The permanent plaster mold (cutaway) and the dental rubber-base molded earplugs.

External earmuffs

An external earmuff was obtained by making an alginate mold of the periauricular area of the shaved head of a sedated dog. From the alginate impression, a permanent stone mold (fig. 3) was made (FS No. 6520-557-7015). The permanent mold was altered by building up conical domes above the contoured base to allow sufficient room for the external pinna. From this mold a Fiberglas hull could be duplicated, which, in turn, was lined with closed-cell foam rubber. The muffs were attached by a harness of Velcro strips. Although the dogs accepted the earmuffs much better than the plugs, certain drawbacks became evident. The first was that the contour of the German Shepherd's head is not universal and would, therefore, require individual moldings. Second, it was nearly impossible to achieve an airtight seal without shaving the dog's head. The degree of seal attained is proportional to the noise protection afforded. Third, the canine ear is essentially directed upward, and, whereas the human muff can be held in place by opposing spring action against the head, the canine muff must be held downward by a counter pressure such as a "chin strap." In order to attain a sufficient seal, an objectionable amount of pressure is created on the

FIGURE 3

The stone casts of the periauricular area from which the earmuffs were molded.

FIGURE 4

The earmuffs created undue pressure on the larynx and were difficult to fit.

larynx and trachea of the dog (fig. 4). In addition to these shortcomings the muff was bulkier for the handler to use than was the plug.

Testing

To determine the efficacy of the noise protection devices and their acceptability by the dogs, a testing program was begun. Initial tests were conducted in the USAFSAM acoustical chamber using a noise spectrum of up to 120 dB and maximum of 20 kHz frequency to simulate jet engine noise. Since the results were inconclusive, it was deemed advisable to perform further testing on the flight line with actual aircraft runups.

Five retrained sentry dogs with experienced handlers and an F-100 were used to conduct the first flight-line tests. The test was a total failure. All 5 dogs walked as close to the aircraft as ground rules permitted (25 ft.) without the slightest apprehension. Overall noise level was 112 dB.

A second attempt was made to test the earplugs with 5 different retrained dogs and handlers, and an F-102 harnessed to a noise suppressor. With this aircraft so situated, 100% power could be obtained without an actual takeoff. High-frequency intake noise (115 dB) again caused no apprehension in any of the dogs (table I). The dogs were then directed toward the open door of the noise chamber where an overall noise level of 128 dB was recorded with afterburner. The 5 dogs showed no apprehension to the noise whatsoever. One handler directed his dog to place its head in the open chamber, a distance of approximately 10 ft. from the exhaust of the aircraft. The dog did so without hesitancy, but when the animal returned to a safe distance it was noted that his gingivae were hemorrhaging slightly. Coincidentally, an observer at a safe distance from the craft became ill from sonic vibration. The only other noteworthy observation was that the dogs would lay their ears back as they approached the noise in an apparently successful attempt to diminish the noise levels.

Because of the failure to reach an end point (a level of noise at which the dogs would show some sign of discomfort or apprehension so that the protective devices could be applied and a protection level could be determined), the

TABLE I

Noise-level survey of F-102

Frequency (Hz)	52% Power intake noise at 25 ft. (dB)	70% Power exhaust noise at 35 ft. (dB)	70% Power intake noise at 25 ft. (dB)	100% After-burner exhaust noise*
16,000	65	48	73	—
8000	98	65	96	—
4000	94	68	98	—
2000	94	76	96	—
1000	92	71	94	—
500	88	77	86	—
250	82	81	84	—
125	83	88	91	—
63	83	86	85	—
31.5	78	82	83	—
All frequencies (20-20,000)	98	93	103	128

*Because of the extremely short period of time the afterburner was used, individual sound levels could not be measured. In the all-frequency range (20 to 20,000 Hz), intake noise level during afterburner use was 115 dB.

tests were moved to Carswell AFB, Tex., for an actual field study.

The 5 dogs selected ranged in age from 2 to 5 years. The rubber earplugs were molded for each dog.

The first phase of the field study which followed began in December 1968 and consisted of an adaptability study in which the dogs used the earplugs daily on regular patrols. After 30 days, 1 dog still refused to accept the earplugs, 2 dogs would not move with them in place, and 2 dogs would perform very inattentively for several minutes and then proceed to shake them out. After 60 days, 3 dogs refused to wear the earplugs more than 10 to 30 minutes and performed very poorly during that time. One dog accepted the earplugs and, in the opinion of the handler, performed normally although he constantly kept his ears down while the plugs were in place (fig. 5). The handler and the fifth dog were reassigned during the testing period; therefore, data on that animal are not complete.

Only 1 transient case of *otitis externa* was reported during these 60 days. This is in contrast to moderate cases of *otitis externa* in 2 dogs used in a pilot study at the USAFSAM vivarium. These dogs were living in a warm and humid environment, while the dogs at Carswell AFB were experiencing the cool, dry North Texas winter. It is postulated, and supported by the earlier evidence at USAFSAM, that any form of insertable earplug would greatly increase outer ear canal infections, especially in the hot, humid areas of Southeast Asia.

In the second phase, noise tolerance tests were conducted using the 4 remaining dogs and

FIGURE 5

The typical inattentive posture of the ear is demonstrated by a dog with the insertable earplug.

a J-57 engine on an unmuffled test stand. Overall noise levels (20 Hz to 20 kHz) of 114 to 117 dB were recorded (table II). As before, none of the dogs indicated apprehension to the noise without plugs; therefore, no testing of the plugs could be made. A final attempt to reach an end point for testing purposes was made using the 4 dogs and a KC-135 flight-line runup. Except for the fact that the dogs laid their ears back, they gave no signs of apprehension at noise levels in the range of 104 to 114 dB (table III).

IV. DISCUSSION

Based on the data compiled on 18 dogs under various testing programs, we find that acute reactions to intense noise are not as prevalent as had been considered. While individual variations are found to the tolerance of noise—as, for example, pet dogs that howl at the noonday siren—these appear to be exceptions rather than the rule. Of the 18 dogs, not one indicated discomfort or apprehension to noise levels ranging to 128 dB. A survey (7) of noise levels at 17 SAC bases indicated that noise levels above 128 dB generally do not exist and levels above 120 dB are very infrequent. Therefore, very few dogs should exhibit audiophobia under field conditions. The type of engine used in these tests is the same type used in many, if not a majority, of the aircraft currently protected with sentry dogs.

Older, more experienced dogs appear to tolerate noise better than younger dogs. It would seem feasible to station these older dogs on patrols where higher noise levels would most likely occur. From our experience, danger to the physical well-being of the animal and the handler would precede any noise reaction on the part of the dog. The ability of a dog to collapse and redirect his external pinnae apparently is a great asset in protecting him against higher sound levels.

The canine, or more specifically the German Shepherd, will not readily tolerate any object in the ear, whether it be an earplug, parasite, foreign body, or inspissated cerumen. This conclusion, along with preliminary data on

TABLE II

Noise-level survey of J-57 engine runup

Frequency (Hz)	Noise levels in dB
9600 to 4800	103
4800 to 2400	107
2400 to 1200	[illegible]
1200 to 600	103
600 to 300	104
300 to 150	106
150 to 75	108
75 to 375	104
All frequencies (20 to 20,000)	114

TABLE III

Overall noise-level survey of KC-135 flight-line runup

Noise level	Placement
104 to 114 dB	30 degrees and 20 ft. from exhaust
104 to 114 dB	90 degrees and 20 ft. from exhaust
104 to 109 dB	30 degrees from engine intake

otitis externa related to the use of earplugs, suggests that the earplug approach be discontinued. Although the earplugs were tolerated by one dog on routine patrol, the general reaction on the part of all the other dogs studied was one of inattention with a conscious concern about the objects in their ears.

We have found no evidence that frequent auditory embarrassment by jet aircraft engines will diminish the sentry capability of a dog. While certain concepts in human audiology may be applicable to sentry dogs, we have found no feasible method for testing this theory. Reports reaching the Lackland Sentry Dog Clinic indicate that few, if any, sentry dogs are lost because of diminished sentry capabilities. Currently, a large percentage of dog losses are due to battle action. Death in the remaining dogs is attributed to physiologic insufficiencies of old age such as arthritis, renal disease, dermatologic disease, and the like, but not to loss of hearing. One report was received of a 7-year-old dog that was reassigned to the Air Force from an Army NIKE site and considered clinically deaf; however, by all standards utilized on regular patrols, the dog was still considered an excellent sentry dog. Considering that the average life expectancy of a sentry dog not killed in action is 8 to 9 years, it is questionable that the high noise levels to which they are subjected for 6 to 8 years should be a matter of Air Force concern.

V. CONCLUSIONS

While certain data relating to human audiology can be logically extrapolated to apply to canines, there is insufficient evidence that the Armed Forces are losing dogs because of hearing impairment. The results of this project would indicate, on the contrary, that most dogs accept or acclimate to noisy situations whereas few, if any, dogs will tolerate ear defenders.

Sentry dog posts and patrols currently subjected to frequent, intense noise levels (greater than 125 dB) should be moved farther from the source of noise for the physical well-being of the handler and the dog. Those individual dogs which are intolerant of the high frequency or high intensity noise on a certain patrol should be reassigned to a more suitable patrol until they have matured and become more acclimated to noise. Since current evidence indicates that temporary hearing impairments will resolve with rest periods between noise episodes, dogs should be rotated from high noise patrols to areas of less noise on a routine basis.

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13. ABSTRACT

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