A CLINICAL SURVEY INTO THE EFFECTS OF TURBO-JET ENGINE NOISE ON SERVICE PERSONNEL : SOME PRELIMINARY REMARKS

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THE jet engine and the approach of transonic flight, by their emphasis on the possibilities of ill-effects from ultrasonic vibrations, have stimulated enquiry into the physiological effects of vibrations as a whole.

Ultrasonic vibrations and frequencies develop in aircraft from two sources. Firstly, the engine turbine and compressor are likely sources of ultra-sound in addition to the gas in the jet itself. Secondly, the disturbance produced by the aircraft in the medium through which it travels, is a source of aerodynamic noise, the peak frequency of which has risen as aircraft speeds have increased. With further increases of speed a larger proportion of ultrasonic frequencies are likely to occur. As aircraft speed increases the sound level will increase in volume as well as frequency, and eventually very high intensities may develop. Thus it appears that operational aircraft of the future are likely to provide higher energy levels in the upper audible and ultrasonic ranges as their speeds increase, even if little engine noise is present.

A gas turbine unit consists of three essential components : (1) a rotary air compressor at the front, (2) a series of combustion chambers into which kerosene is sprayed and burnt continuously, and (3) a turbine revolving with the compressor on a common shaft. From the rear of the turbine, heated air emerges from a nozzle as a high velocity jet say 1,800 feet per second or 1,227 m.p.h.

The effects of vibration on the human body depend on both the frequency and the intensity of the vibrations. Frequencies to the region of 2,000 cycles per second (c.p.s.) produce sensations of " vibration " if they act on the sensory nerve endings of the skin and deeper tissues. The ear will respond to frequencies of 32 to 20,000 c.p.s. These frequencies are called " sonic " because they are appreciated as sound by the human ear. Frequencies above 20,000 c.p.s. known as " ultrasonic "†

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† " Ultrasonic " refers to *sound* beyond the sonic range ; " supersonic " is employed in reference to *speeds* greater than that of sound.

do not act upon the ear in such a way as to produce the sensation of sound. We have no reliable apparatus as yet with which to record the presence of ultrasonic frequencies, or to analyse the radiation in terms of frequency and intensity. In the ultrasonic field very little is known of the effects on the body. In the realm of physics work has been done in liquids, but less is known of their range, propagation and transmission in air. What effect ultrasonic frequencies have on the ear is not known, nor is there any evidence that sensory nerves are capable of interpreting to the sensorium the presence of ultrasonic radiations. Their biological effects seem to be related to enormous alternating local accelerations which are produced in the tissues, and to the local heating effects arising from the absorption of energy in dampening the vibrations. Sonic vibrations however, particularly of high intensity cause not only a state of fatigue and consequent inability to concentrate, but also damage to the cochlea from which permanent deafness may result.

The publicity given to certain apparent results of exposure to gas turbine engines raised the additional problem of the effect on the morale of service personnel engaged in this work. The possibility of organic effects also had to be considered.

This paper presents the results of a survey on a number of Royal Air Force personnel employed in various capacities on gas turbine engine aircraft. No claim is made to a controlled investigation ; on the contrary, it is merely a clinical survey. No statistical approach was made either to the group of men submitted, or to the conduct of the investigation. However, within its limits the survey gives some indication of what is to be expected from exposure to gas turbine engine noise under service conditions, and will perhaps form a useful basis for future work.

Scope of the Investigation

At the outset 120 men were selected for follow-up. Owing to various difficulties a start was made with 97 men, who were under observation for a period of one year. Loss from demobilization, posting abroad, and the like, caused this number to fall to 80 by the conclusion of the survey. The investigation was conducted at the Central Medical Establishment, R.A.F. where personnel attended at approximately three-monthly intervals over a period of one year (1947-1948).

After completion of the follow-up, we secured for one visit the attendance of 14 subjects from the 120 originally selected. Their record of jet aeroplane work, symptoms, and findings were in keeping with the results obtained from those followed for the year. Data concerning these extra 14 is omitted (except for the electroencephalographic findings) as inclusion would only confuse the compilation of results. Such a course was decided upon owing to the absence of any marked effects.

The personnel under review were selected from R.A.F. Stations

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equipped in whole or in part with jet aircraft. They consisted of 20 pilots and 77 ground crew (made up mainly of fitters and flight mechanics).

The aircraft were of two types, namely Meteors and Vampires producing slightly different noise intensities. The results did not show any difference in effect between these two. Nor was differentiation made between employment on the various modifications of these engines.

The average time spent by the 97 subjects on jet aircraft prior to commencement of the survey was 5·5 months. On completion of the investigation this had risen to 15·5 months.

The average time flown in jet aircraft by pilots up to the end of the survey was 89 hours; most fell within the range of 60-80 hours. In some cases, pilots flew other types as well as jet aircraft during the survey period.

With the aim of ascertaining the presence and aetiology of both objective and subjective features, enquiry was conducted into (*a*) previous history in relation to personal and family background, prior occupation, and noise exposure (e.g. test bench work and musketry); (*b*) conditions and duration of work on jet aircraft, including nature of employment and amount of exposure to jet engine noise; (the subject on each visit gave an estimate of the time of exposure, rather unscientific and inaccurate it is true, but we had no other means of determining it); (*c*) their symptoms; (*d*) examination of C.N.S. and E.N.T. and special tests such as electroencephalography and audiometry. We felt the foregoing data would provide an adequate background, as well as sufficient information about jet noise exposure, for an opinion to be formed.

Although superficially, it appeared that a group of 100 service personnel would be well-nigh ideal for the purpose of a survey, it soon became apparent that this was not so. The duration of exposure varied, for reasons such as a fluctuating number of jet aircraft, weather conditions, courses of instruction and temporary changes in nature of employment. The discovery of engine defects increased the exposure to noise of the mechanics concerned by a considerable amount. A further difficulty was in defining any set distance from the source of the noise, there being a great tendency for a subject to include in his estimate of exposure, noise heard up to several hundred yards distance. We overcame this by taking 5 yards as the criterion for assessing exposure. To estimate too, an average daily exposure is not easy, when the limits for each day vary considerably.

In order to amplify our knowledge of working conditions, visits were paid to the two R.A.F. Stations from which the majority of the subjects came. We were able to observe at first hand the normal working routine, and it accorded us a better understanding of the varied descriptions we received during the interviews.

Findings

1. Noise Exposure

As previously noted noise exposure was extremely variable. The time of exposure of a pilot within five yards of a jet aircraft running up, apart from actual flying, was insignificant. Similarly with ground crews, exposure varied from minutes per week to hours per day. At most, it can be said that the majority appeared to have been exposed for under one hour a day within five yards of the aircraft running up. In any case, it should be pointed out that personnel are discouraged from being within this distance on such occasions. The approximate exposure ascertained by direct questioning produced the figures included in the accompanying table.

Table 1

Time of Exposure in Hours per Day	No. of Subjects
Less than ½ hour	16
½-1 hour	23
1-2 hours	21
Greater than 2 hours	13

We noted that those who worked in hangars often commented that the noise experienced there, as a result of jets running up outside, was more unpleasant than exposure to a similar noise in the open ; this is probably due to a build up of standing waves.

2. Ear Protection

Use of protection for the ears of ground crews was not popular, mainly because of difficulty in conversation. Thus, 1 used cotton wool when the engine was running at high speeds ; 5 had employed ear plugs sporadically during their careers. The remainder used their fingers to block their ears when the noise was of too great an intensity to be borne without discomfort. All the pilots in contrast wore helmets when flying.

3. Symptomatology

The symptoms presented are listed in the accompanying table. The chief point which is demonstrated by a more detailed analysis of these figures is their mildness and lack of continuity. Thus instances of regular complaints visit by visit were entirely lacking; in fact continuity of symptom over two consecutive occasions was infrequent.

TABLE II

VISIT	DISCOMFORT	DEAFNESS	TINNITUS
I	7	5	10
II	12	5	10
III	28	12	9
IV	18	6	4

The complaint of " discomfort " refers to discomfort appreciated in the ears during actual running of the engines at high revolutions per minute (r.p.m.), but was never present to any marked degree. The other symptoms (see Table II) were effects felt after running up. They are manifest only at high r.p.m., and varied up to a maximum of some ten minutes duration. Other infrequent symptoms noted were: (*a*) General discomfort—once on the first visit; twice on the second visit; and once on the fourth visit. (*b*) Slight unsteadiness—thrice on the first visit; once on the second visit; and thrice on the third visit. (*c*) Decreased sense of concentration—occurred only once, during the fourth visit.

4. EXAMINATION AND SPECIAL TESTS

(i) *Clinical* examination of Ear, Nose and Throat revealed no detectable changes.

(ii) *Nervous system.* A full examination of the nervous system was not undertaken, but examination of tendon reflexes of the lower limbs, external ocular movements and pupillary reflexes, and tests of cerebellar co-ordination, were the objects of attention. Enquiry was conducted along these lines to seek evidence of any clinically detectable changes in the nervous system. Apart from two congenital defects of the external ocular movements, no abnormalities were detected, and no change of any significance was observed during the period that the examination was conducted.

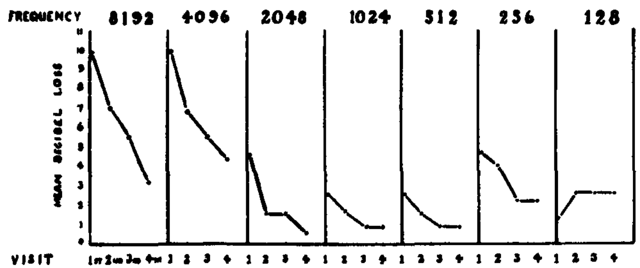
(iii) *Pure Tone Audiometry.* The audiogram obtained on the first visit of the survey formed the reference level for comparison throughout the year, as no audiograms prior to the survey had been made. Subjects showing a loss on the first visit of 20 db. and over in either ear, which was repeated on a second occasion, were investigated in an attempt to

QUARTERLY AUDIOMETER TESTS 1947 – 1948

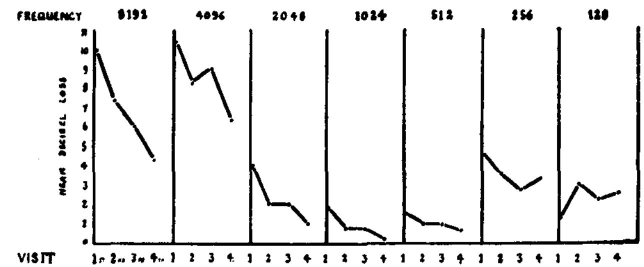
ALL CLASSIFICATIONS

NUMBERS ON EACH VISIT – 1st – 97; 2nd – 94; 3rd – 91; 4th – 80

MEAN DECIBEL LOSS



RIGHT EAR

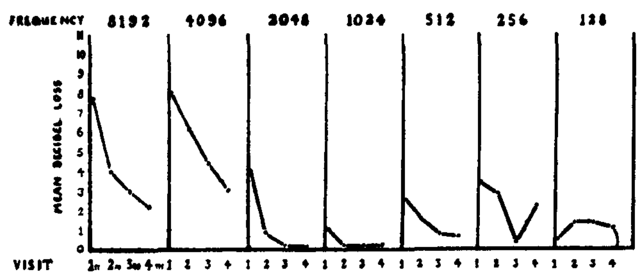


LEFT EAR

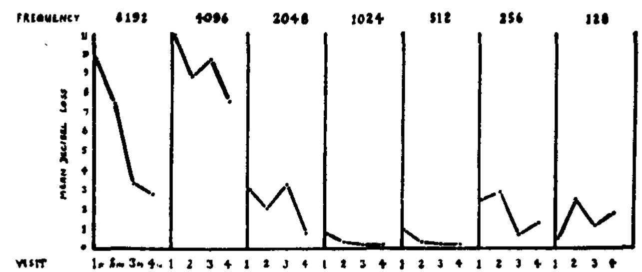
PILOTS ONLY (METEORS AND VAMPIRES)

NUMBERS ON EACH VISIT – 1st – 20; 2nd – 20; 3rd – 18; 4th – 16

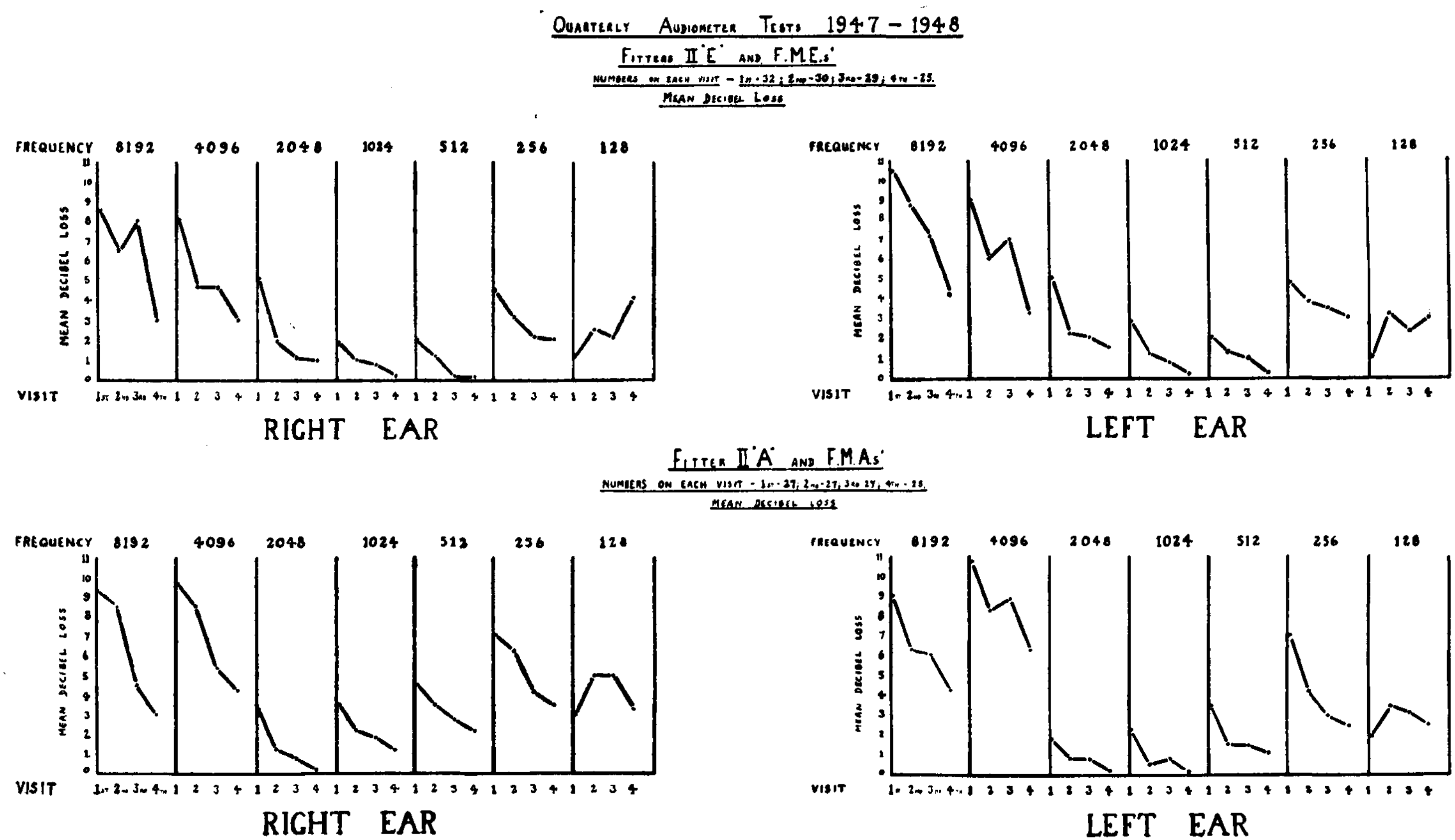
MEAN DECIBEL LOSS



RIGHT EAR



LEFT EAR



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determine the reason for the loss. We were unable to ascribe a definite cause to any of these cases. The group was composed of (*a*) 22 cases with a high tone loss, i.e., a loss of 20 db. or over in either ear at 8192 or 4096 c.p.s. (in two instances there was associated loss at lower frequencies). All these losses were initially mild, and followed over the year there was no instance of significant deterioration. The majority actually showed improvement. (*b*) 3 cases showed a general loss over the whole frequency range; all three improved during the year of survey. In total figures over the year, 9 of these 25 cases with an initial loss remained in *statu quo*, whilst 16 improved in some degree.

Taking the 100 subjects over the year, 17 showed a loss: these consisted of: 14 with a deterioration of 10 db. (in one ear in 10 cases and in both ears in 4); 2 with a deterioration of 15 db. in one ear, and 1 with a deterioration of 20 db. in one ear. Such losses are minimal, and since the majority occurred in the 128 and 256 frequencies, we feel justified in regarding them as within the limits of experimental error. The findings are shown as " mean db. loss " in the graphs. (Appended.)

We made the following deductions from these results: (*a*) That they show a progressive decrease in the average decibel loss at each examination, except for the 128 frequency—this is linked with the fluctuations of this particular frequency. Such improvement may have been due in part to a practice effect.

(*b*) The average loss was greatest at the 8192 and 4096 frequencies and least in the middle ranges.

(*c*) Separate graphs for all pilots, fitters, and flight mechanics were prepared, to determine whether there was any difference according to trade. The numbers in these sub-groups were very small, but the graphs show the same pattern for each frequency, for each ear, and are all very similar to that for the group as a whole.

(iv) *Electroencephalography.* Recognizing the possibility of changes occurring in the cerebrum undetectable by clinical examination, electroencephalography was undertaken (using a 6-channel recorder). It was carried out during the last six months of the survey on 100 subjects (see page 277) a few being lost through non-attendance and the like.

Dr. Denis Williams of the National Hospital, Queen Square, analysed the results for us. We extend to him our grateful thanks for his invaluable help and advice. His report was as follows:

> " The records are perfectly normal at rest and after over-breathing in 92 cases. They were thought to be abnormal in 4, while in another 4, although small aberrations were present, the records were considered to be within normal limits. In these latter four cases, the abnormality was symmetrical, episodic and of mild degree. Had I not known the story I would consider all the changes to have been constitutional and inborn. There was nothing to suggest any local

lesions, or any acquired brain disorder. For your guidance, a similar investigation on 100 aircrew under training in 1941 showed that five out of 100 had abnormality by the same standard, and the abnormality was of the same kind. You may therefore take it that intense noise has had no significant effect upon the cerebral electrical activity of any of these 100 men."

Conclusions

The absence of a control group employed on reciprocating engines is a limiting factor in the interpretation of the results. The aim was not so much statistical accuracy as clinical evaluation. Several valuable data have been observed:

(i) Of symptoms, the triad, of discomfort in the ear during running up, the minor degrees of deafness and tinnitus after running up, were the most prominent. There were occasional complaints of such subjective disturbances as dizziness and unsteadiness, usually noted when the subject stood near the air intake, or at least to the fore of the aircraft; such were in almost all cases unsustained and isolated experiences. The main features of the symptoms were their infrequency, absence of severity and short duration. We cannot help feeling that such effects are but little in excess of those experienced with piston engines under the same conditions.

(ii) The results of clinical examination were negative. From this the deduction that gross changes were not produced can be made; beyond this we can only surmise.

(iii) Hearing acuity, as determined by audiometry showed that on the whole there was no deterioration during the year. The absence of both a control group of persons not exposed to noise, and of audiograms of the subjects under survey prior to their exposure to jet noise, prevent sweeping dogmatism. We can only say that this noise exposure appears to have been without harmful effect.

(iv) No adverse effect on the morale of those under review was detected during the survey, despite the fact that they were aware of the published accounts in the popular press of so-called "Supersonic Sickness".

The survey reveals no significant effects produced as a result of work on gas turbine engines under present service conditions during the limited time in which personnel have been so employed. Where they are exposed to greater intensities of this type of noise, such as running "ram jet" engines on the test bench, the possibility of effects has as yet to be excluded. We feel that this investigation is a stimulus to further research on these problems, including observations for longer periods. Deafness or other manifestations may take a much greater time interval to reveal themselves and yet be apparent before such changes develop in workers on reciprocating engines.

The damaging effect of any frequency whether sonic or ultrasonic depends on its intensity and the proximity of an individual to the frequency source. Due to the greater degree of absorption of ultrasonic waves in air, compared with sonic waves, the danger area of the ultrasonic source will probably be much smaller. The absorption of energy in air increases rapidly as the frequency rises. Thus for example, a frequency of 10,000 c.p.s. will fall in intensity to one-third the original over a distance of 500 yards; a frequency of 50,000 c.p.s. would fall similarly in intensity over only 20 yards.

Not only must the problem of ultrasonics receive attention, but high intensity low frequency noise must also be regarded as a very likely source of detrimental effects.

We wish to record our thanks to the Director-General of Medical Services, R.A.F. for permission to publish these results.