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11 December 2017

Dear [redacted],

Thank you for your email of 24 October in which you requested the following information:

"I would like to be furnished with any studies, including results, carried out by the Ministry of Defence, DSTL and ROWETU, covering hearing loss sustained by military helicopter aircrews both on operations and in the UK, and the preventative measures taken by the MOD."

Following my letter of 17 November in which I confirmed the Ministry of Defence holds some information in scope of your request, I have undertaken a public interest test and concluded that the balance lay in releasing the information. Please, therefore, find attached the following documents:

A - Wildcat AH Mk1 and Lynx AH Mk9A – Noise and Vibration Assessment – QINETIQ dated 3 March 17;
B - A survey of hearing loss in army aircrew – Occup. Med Vol 46, 53-58, 1996;
C - Hearing Protection in British Army Lynx and Apache Aircrew and Appendices – Abstract for Aerospace Medical Association Annual Scientific Meeting (not dated);
D - Hearing Protection in JHC Aircraft – CI J5003 dated 10 Jan 17.

Information relating to noise vibration in document A has either been removed or redacted as being out of scope of the request. For clarity, pages 27 to 31, 34 and 47-68 of the report have been removed in their entirety as being out of scope. Other information has been redacted as being exempt from release under section 40 of the Freedom of Information Act – personal information. This is an absolute exemption and there is no requirement to consider the public interest in making a decision to withhold the information.

With regard to preventative measures, aircrew are provided with flying helmets worn with in-ear communication devices; a new In Ear Control Device is in the process of being introduced (VAMP 31), which is a custom moulded silicone plug to be worn under the flying helmet muff; all aircrew undertake an annual audiometry to detect any hearing loss; there is also a five-yearly aviation medical refresher training, which covers health effects of noise exposure and how pilots are protected (i.e. Personal Protection Equipment (PPE)). It also highlights their personal responsibilities under the Control of Noise at Work Regulations, which covers areas such as looking after PPE, reporting of any defects and protect themselves against non-occupational noise exposure.

If you have any queries regarding the content of this letter, please contact this office in the first instance. Following this, if you wish to complain about the handling of your request, or the content of this response, you can request an independent internal review by contacting the Information

Rights Compliance team, Ground Floor, MOD Main Building, Whitehall, SW1A 2HB (e-mail CIO-FOI-IR@mod.uk). Please note that any request for an internal review should be made within 40 working days of the date of this response.

If you remain dissatisfied following an internal review, you may raise your complaint directly to the Information Commissioner under the provisions of Section 50 of the Freedom of Information Act. Please note that the Information Commissioner will not normally investigate your case until the MOD internal review process has been completed. The Information Commissioner can be contacted at: Information Commissioner's Office, Wycliffe House, Water Lane, Wilmslow, Cheshire, SK9 5AF. Further details of the role and powers of the Information Commissioner can be found on the Commissioner's website at https://ico.org.uk/.

Yours sincerely,

Disclosure and Litigation Leader

A

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~~QinetiQ Proprietary~~

Wildcat AH Mk1 and Lynx AH Mk9A - Noise and Vibration Assessment

[redacted]
QINETIQ/17/00576
QINETIQ/MS/AD/CR1700516/1.0
03 March 2017

72 pages

ATEC
Air Warfare Centre & QinetiQ in partnership

Produced by QinetiQ in collaboration with the Air Warfare Centre

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Administration Page

Customer Information	
Customer reference number	HL00966
Project title	Comprehensive Noise and Vibration Assessment – Impulse, Continuous and Environmental
Customer Organisation	Lynx-Wildcat Project Team, DE&S, MOD
Customer contact	[redacted]
Contract number	HELSS/0009
Milestone number	4
Date due	10 March 2017

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Additional Release Conditions

None

Release Authority	
Name	[redacted]
Post	Associate Project Manager – Wildcat & Lynx
Signature	[redacted]

Record of changes

Issue	Date	Detail of changes
1.0	03/03/2017	Initial issue

Executive Summary

The Lynx-Wildcat Project Team tasked the Aircraft Test and Evaluation Centre to conduct a comprehensive noise and vibration assessment of the Wildcat AH Mk1 and a comprehensive noise assessment of the Lynx AH Mk9A. The overall tasking required the assessment of aircrew exposure to the impulsive noise encountered during gun firing, the continuous noise and vibration encountered during flight, ground crew exposure to continuous noise during ground activities and the environmental noise impact of operating the two helicopter types within a local area. The impulse noise and environmental noise assessments have been reported separately. The focus of the work reported here is the assessment of aircrew exposure to noise and vibration and ground crew noise exposure during ground activities.

In terms of crew noise exposure, the use of an ear insert device (such as the Communications Ear Plug (CEP) or VAMP 27) with a flight helmet significantly reduces noise levels at the ear and consequently increases the daily 'allowable' exposure durations. However, the suitability of a particular hearing protection system will depend on how many flight hours per day the aircrew are expected to attain. On Wildcat AH Mk1 the use of any flight helmet, listed within the aircraft Release To Service, with a CEP or VAMP 27 device will result in 'allowable' exposure durations of greater than 8 hours at all crew positions, when assessed against the Exposure Limit Value (ELV) of UK legislation. Due to the higher ambient noise levels on Lynx AH Mk9A a reduced selection of hearing protection (Mk4A/4+CEP, Mk4B/4L+CEP and Mk4B/4L+VAMP 27) would have to be worn to allow flight durations over 8 hours at all crew positions.

Likewise, when firing the General Purpose Machine Gun or M3M Heavy Machine Guns, the suitability of a particular hearing protection system will depend on the duration of flight required and the number of rounds per day that are expected to be fired. Generally, on both aircraft types, keeping the cockpit windows closed reduces the ambient noise levels in the cockpit when gun firing and therefore, with respect to the pilots, allows for a greater number of rounds to be fired per day. Use of the CEP or VAMP 27 devices with a flight helmet reduces noise levels at the ear and therefore also allows for a greater number of rounds to be fired per day.

With the Peltor Optime III ear defenders and the Esterline JetGard headsets worn during the trial, ground crew noise exposure should not exceed current UK noise legislation if the issued hearing protection (or a device with similar attenuation characteristics) is worn, and worn correctly for the duration of the exposure.

[redacted]

This review has shown that aircrew noise exposure in the Wildcat AH Mk1 and Lynx AH Mk9A is a function of the flight duration and gun firing requirement. This study has provided an indication of the hearing protection suitable to meet the range of sorties likely to be conducted in these particular platforms and to maintain compliance with the legislative noise exposure criteria. [redacted]

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1 Introduction

1.1 The Aircraft Test and Evaluation Centre

1.1.1 QinetiQ and the Air Warfare Centre conduct military aircraft test and evaluation activities under the MOD-QinetiQ Long Term Partnering Agreement (LTPA). This element of the LTPA, which includes the approved framework for operating UK military-registered aircraft and the Government aerodrome at Boscombe Down, is referred to as the Aircraft Test and Evaluation Centre (ATEC).

1.2 Background

1.2.1 The Joint Helicopter Command (JHC) has a requirement to understand aircrew noise and vibration exposure, and ground crew noise exposure, whilst operating the Wildcat AH Mk1 and Lynx AH Mk9A platforms. Consequently, the Lynx-Wildcat Project Team (LWPT) has tasked ATEC to assess aircrew exposure to the impulsive noise encountered during gun firing and the continuous noise and vibration encountered during flight. There is also a requirement to assess ground crew exposure to continuous noise during ground activities and to understand the impact of the environmental noise of these two platforms within a local area.

1.2.2 The measurement of aircrew noise exposure during gun firing was conducted separately by the Institute of Sound and Vibration Research (ISVR) at Southampton University and is documented within a separate report [1]. Relevant data from that report has been used to support the assessment reported here, where required.

1.2.3 The Lynx AH Mk9A Environmental noise assessment has also been documented in a separate QinetiQ report [2].

1.2.4 The focus of this report is the assessment of the continuous noise and vibration encountered by aircrew during flight, the ground crew exposure to continuous noise during ground activities and an analysis of the impact gunfire has on aircrew exposure.

1.3 Customer Requirements

1.3.1 From the detail within the Tasking Form [3], the customer requirements for the continuous noise and vibration assessment are summarised below:

1. Gather the continuous noise experienced by aircrew and passengers during normal flight operation on the Wildcat AH Mk1 and Lynx AH Mk9A and assess crew and passenger noise exposure when wearing the hearing protection systems documented in the aircraft Release To Service (RTS) documentation [4, 5]. Also to be included was an assessment of noise exposure during firing of the General Purpose Machine Gun (GPMG) and M3M Heavy Machine Guns (HMG)s;

2. Provide a means of assessing new Personal Protective Equipment (PPE) against the ambient noise levels measured on each platform thereby negating the requirement for further flight trials;

3. [redacted]

4. Conduct an assessment of ground crew exposure to continuous noise during ground activities;

5. To develop a representative flight sortie profile (see Appendix A) to include some or all of the following:

   - General Flying Practice;
   - Low Level Navigation;
   - Load Lifting;
   - Lynx AH Mk9A Configuration post Afghanistan;
   - Any others yet to be identified;
   - Ground running (internal [aircrew] and external [ground crew]).

1.4 Aircraft Build Standard

1.4.1 Standard squadron aircraft were utilised as part of this assessment; the aircraft build standard being defined in Section 6 'Air System Configuration' of the RTS documentation of the Wildcat AH Mk1 [4] and Lynx AH Mk9A [5].

1.5 Trial Information

1.5.1 All Wildcat AH Mk1 trial sorties were flown from Royal Naval Air Station (RNAS) Yeovilton using Rotary Wing Test and Evaluation (RWTES) aircrew. Lynx AH Mk9A trial sorties were flown from Army Air Corp (AAC) Middle Wallop and Royal Air Force (RAF) Odiham, again using RWTES aircrew. Trials aircraft and dates flown are shown in Table 1-1. A dedicated Under Slung Load (USL) sortie was also flown on Wildcat AH Mk1 on the same day as sortie 4.

Wildcat AH Mk1			Lynx AH Mk9A		
Sortie	**Aircraft**	**Date flown**	**Sortie**	**Aircraft**	**Date flown**
1	ZZ525	11 Oct 2016	1	ZE376	10 Nov 2016
2	ZZ383	13 Oct 2016	2	ZG885	21 Nov 2016
3	ZZ384	07 Nov 2016	3	ZG921	22 Nov 2016
4	ZZ389	24 Nov 2016			
5	ZZ403	30 Nov 2016			

Table 1-1: Trials aircraft and date flown

1.6 Evaluation Strategy

1.6.1 To provide a statistically robust set of measurements, trial sorties were flown on five different Wildcat AH Mk1 aircraft. However, measurements were only made on three different Lynx AH Mk9A aircraft both due to the availability of the aircraft for trials work and the smaller fleet size. By consulting with the Wildcat AH Mk1 Statement of Operating Intent (SOI) [6] and the Lynx AH Mk9A Statement of Operating Intent and Usage (SOIU) [7] RWTES aircrew provided advice on typical mission profiles and specific test points relating to noise and vibration. From those discussions the flight conditions documented in Appendix A were flown.

1.7 Assumptions and Exclusions

- The assessment is bounded to those sorties that are flown during peacetime and training activities.
- It is assumed that all the trials aircraft flown are representative of the Wildcat AH Mk1 and Lynx AH Mk9A fleets respectively, particularly as they were drawn from current squadron assets.
- Noise attenuation data for the two passenger helmets, Passenger Helmet Mk15 and Helicopter Passenger Helmet (RN) Type HGU 25P, could not be sourced by the LWPT and hence no assessment could be conducted for these helmets. Consequently, data for the passenger helmets has been excluded.
- Aircraft Release Recommendations (ARRs) are excluded from this assessment, although pertinent findings are included within the conclusions.
- Assessment of the communications system has been excluded.
- Assessment of audio warnings has been excluded.
- Full details of the impulsive noise assessment are excluded from this report and instead are documented in a separate ISVR report [1].

1.8 Reported Findings

1.8.1 The following chapters in this report describe the measurements made (Section 2), a summary of legislation (Section 3), the common aspects of the noise assessment methodology (Section 4) against which the noise analysis has been conducted (Sections 5 and 6), and the vibration analysis conducted (Section 7). Summarising comments are also presented (Section 8).

2 Measurements

2.1 Noise Measurements

2.1.1 Ambient noise measurements were collected using a hand held noise recording system at the three measurement positions shown in Figure 2-1 for all stable flight conditions (Appendix A) and at position 2 for transient conditions. During the USL sortie measurements were also conducted at position 4 (door). All measurements were conducted on the centreline of the aircraft. Note that Figure 2-1 also shows the seats, bordered in yellow, used for the vibration measurements.

AC FWD	Pilot Seat	Seat 1D Facing Aft	4	Seat 1B Facing Fwd	Seat 3C Facing Fwd	AC AFT
	1	2	Seat 1G Facing Aft, 1E Facing Fwd	Seat 1F Prohibited 3	Seat 3B Facing Fwd	
	Co-Pilot Seat	Seat 1C Facing Aft		Seat 1A Facing Fwd	Seat 3A Facing Fwd	

Figure 2-1: Ambient noise and whole-body vibration measurement positions

2.1.2 It should be noted that Figure 2-1 details the measurement positions on the Wildcat AH Mk1; measurements on the Lynx AH Mk9A were taken at identical positions with the exception of position 4 which was not used as the USL profile was only flown on Wildcat AH Mk1.

2.1.3 As well as using a hand-held recording system to measure ambient noise levels, the four crew members also wore man-mounted recording systems to simultaneously record ambient noise and noise levels inside the helmet earshell. This enabled the capture of transient flight conditions as required. A second hand-held recording system was used to measure ambient noise at the ground maintainer positions, whilst the QinetiQ Noise Subject Matter Expert (SME) also wore a pair of noise dosemeters that simultaneously measured noise levels at the ear and the corresponding ambient noise levels.

2.1.4 The noise measurement equipment is described in more detail and was fitted in accordance with the noise equipment fitment notes [8, 9, 10 and 11].

2.2 Vibration Measurements

2.2.1 [redacted]

Figure 2-2; [redacted]

2.2.2

2.2.3

2.2.4

2.2.5

[redacted]

2.2.6 [redacted]

2.2.7 [redacted]

2.2.8 [redacted]

3 Summary of Legislation

3.1 The Control of Noise at Work Regulations (CNAWR)

3.1.1 The UK CNAWR [16] includes a number of exposure action and limit values as detailed below:

a. Lower Exposure Action Value (LEAV) – hearing protection to be made available:

- a daily or weekly personal noise exposure of 80dB(A);
- a peak sound pressure of 135dB(C).

b. Upper Exposure Action Value (UEAV) – hearing protection must be worn:

- a daily or weekly personal noise exposure of 85dB(A);
- a peak sound pressure of 137dB(C).

c. Exposure Limit Value (ELV) – legally enforceable limit with hearing protection:

- a daily or weekly personal noise exposure of 87dB(A);
- a peak sound pressure of 140dB(C).

3.1.2 The CNAWR allows for the calculation of noise exposure either daily or over a working week. This is only applicable where the noise exposure varies markedly from day to day.

3.1.3 Both the LEAV and the UEAV relate to ambient noise levels at the ear (i.e. without hearing protection being worn) and provide levels at which various actions should be taken to minimise noise exposure and hearing damage risk. If hearing protection is worn then the ELV is applicable. It is illegal to expose anyone to levels above the ELV. It is measured at the ear, taking hearing protection into account, and if the hearing protector also allows for the presentation of speech and non-speech communications direct to the ear then these signals add to the noise dose and must be included in the noise exposure calculation.

3.1.4 The dB(A) levels (80, 85 and 87) quoted within the LEAV, UEAV and ELV all relate to 'continuous' (i.e. non-impulsive) noise and are those that are typically assessed against. The dB(C) levels are for impulsive noise exposure such as that received during gun firing.

3.2 Vibration Standards

3.2.1

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3.3.3 and a daily
'esponsive'

[redacted]

4 Noise Assessment Methodology

4.1 Overview

4.1.1 The methodology for the assessment of ambient noise levels and crew noise exposure was consistent across both aircraft platforms and is therefore described separately in this section rather than repeated within sections 5 and 6.

4.2 Internal Ambient Noise

4.2.1 Ambient noise data was collected using a hand-held noise recorder at the locations shown in Figure 2-1. Although this recording system allowed data collection for the majority of the required flight conditions, a number of the crew also wore man-mounted noise recording systems to capture ambient noise at their particular crew position. This was useful for monitoring conditions of a particularly transient nature where it was not possible to move between locations with the hand-held recorder.

4.2.2 Analysis of the noise recordings was conducted using a Bruel & Kjaer (B&K) type 2143 frequency analyser resulting in a series of one-third octave and octave band ambient noise spectra for each flight condition. These spectra enabled an investigation as to how noise levels vary between the five different Wildcat AH Mk1 and three different Lynx AH Mk9A aircraft across the flight conditions flown. However, the primary use of the ambient noise spectra was as the first stage in enabling the noise levels at the ear to be predicted at each crew position during typical sortie profiles. This is described below and reported fully in sections 5 and 6.

4.3 Crew Noise Exposure – Continuous Noise

4.3.1 Calculation of the crew noise exposure has been conducted in line with the CNAWR [16] and aligned to the proposed MOD-wide noise measurement protocol being prepared by the RAF Centre of Aviation Medicine (RAF CAM) and QinetiQ in response to an initiative by the MOD Air Capability noise steering/policy group [20]. These detail that firstly the Assumed Protection Value (APV) of the hearing protection device (in this case calculated as the mean attenuation minus one standard deviation), is subtracted from the ambient noise spectra to provide a prediction of the noise level at the ear. This is conducted using octave band data from 63Hz to 8kHz. In line with the Health and Safety Executives (HSE) guidance, 4dB is then added to the overall noise at ear level to account for 'real world' fitting of the hearing protection. Finally a communications contribution figure is added to the overall noise at ear level to account for the increase in noise level at the ear due to speech and non-speech signals presented directly to the ear over the radios and intercom system. In this case, a mean communications dose figure of 9.8dB(A) has been used for both platforms, this figure being obtained from previous assessments of communications noise on Lynx AH Mk7 and AH Mk9 flown during similar profiles [21].

4.3.2 The addition of 4dB is recommended by the HSE to account for the fact that, in industry, employees may not be provided with advice on how to fit their hearing protection or have the fit checked by someone qualified to do so. Consequently, there may be a large variation in fit of the hearing protection worn which would lead to a large variation in the attenuation performance provided. It is debateable as to whether adding 4dB is required when considering military aircrew noise exposure as the fit of their hearing protection, particularly flight helmets, is overseen by qualified safety equipment maintainers and rechecked at regular periods of time. Hence, the fit of aircrew hearing protection is more tightly controlled. However, in order to adhere to the CNAWRs, 4dB has been added to the predicted noise at ear levels calculated within this report.

4.3.3 By consulting the Wildcat AH Mk1 SOI [6] and Lynx AH Mk9A SOIU [7] the primary sortie profiles flown by the aircraft were identified, as detailed in Table 4-1 below. Each sortie profile contains a list of constituent flight conditions and the durations they are flown during that sortie. Consequently, by using the ambient noise spectra obtained for the relevant flight conditions identified within the sortie profiles, a single sortie spectrum could be constructed for each profile. This was done by calculating the Equivalent Continuous Noise Level for each octave band based on the data for each constituent flight condition and was obtained for each crew position and sortie profile of interest and these are shown in Appendix B. It should be noted that the sortie profiles documented within the Wildcat AH Mk1 SOI [6] did not contain any period of ground running; as this condition was routinely observed during the trial sorties a short phase of ground running was included during the construction of the sortie spectra.

Wildcat AH Mk1	**Lynx AH Mk9A**
WT-02: ISTAR 2 (ML)	A1a: Trooping
WT-06: Command Support & C2 (ML)	A3a: General Flight Practice
WT-07: Troop & Freight (LL)	A10a: Air Test
WT-09: Escort	A12a: Convoy Escort, Eagle VCP & Tactical Pairs Troop Insertion
WT-11: Under Slung Loads	
WT-15: Training & General Handling	

Table 4-1: Most commonly flown sortie profiles as determined by the SOIU

4.3.4 For the purposes of this assessment the APV attenuation spectrum of each hearing protection system was then subtracted from the calculated sortie spectrum. This resulted in a predicted noise level at the ear for each sortie profile, crew position and hearing protection system.

4.3.5 During this assessment predictions of noise levels at the ear have been obtained for the aircrew hearing protection systems (flight helmet, Communication Earplug (CEP) and VAMP 27 earplug) contained within the Wildcat AH Mk1 and Lynx AH Mk9A RTS documentation [4, 5] and these are listed in Table 4-2.

Mk4A helmet	Mk10R-RW helmet
Mk4A helmet + CEP	Mk10R-RW helmet + CEP
Mk4B/4L helmet	Mk10R-RW helmet + VAMP 27
Mk4B/4L helmet + CEP	ALPHA 928 helmet
Mk4B/4L helmet + VAMP 27	ALPHA 928 + CEP

Table 4-2: Aircrew hearing protection systems assessed

4.3.6 All noise attenuation performance data was provided by the LWPT with the APVs being listed in Appendix C. It should be noted that the noise attenuation data provided for the Mk10R-RW was actually for the Mk10R flight helmet. The differences between the Mk10R and Mk10R-RW flight helmets are documented within DAP-108F-0215-123 [22], and are embodied as modification number HM133. The changes relate to the introduction of a Rigid Visor Cover (RVC) and adaptors to permit use of legacy Night Vision Goggles (NVGs) with the Mk10R. As well as the RVC, the modification includes introduction of counterbalance weights for use with NVGs, use of wicking material instead of leather on crown and brow pads, and small changes to the visor mechanism. It was judged that these differences would not alter the noise attenuation performance of the flight helmet and therefore the Mk10R noise attenuation data has been taken to be representative of the Mk10R-RW.

4.3.7 It should be noted that it was not possible to conduct an assessment of the two passenger helmets worn on the Wildcat AH Mk1 and Lynx AH Mk9A as noise attenuation data for these could not be sourced by the LWPT.

4.3.8 Once the overall sortie noise level at the ear (sortie noise dose) had been predicted the 'allowable' exposure durations were calculated. This calculation was conducted for both the ELV of the CNAWR [87dB(A) for an eight hour working day] as this is the legally enforceable level when hearing protection is provided and worn, and to the UEAV of the CNAWR [85dB(A) for an eight hour working day] as it is acknowledged that the MOD aspires to meet this level; the UEAV is not, however, a legally enforceable limit.

4.4 Crew Noise Exposure – Firing of the GPMG and M3M HMGs

4.4.1 Noise levels during firing of the GPMG and M3M HMGs were measured during a ground fire trial conducted on a Wildcat AH Mk1 and fully documented within the ISVR report [1]. Of interest in this report are the 'points per 100 rounds' figures that show how many 'Noise Exposure Points' firing the weapons relates to with reference to the advice contained within the CNAWRs [16]. The CNAWRs contain a 'Noise Exposure Ready-Reckoner' [23] that provides a method for calculating the total noise exposure due to different types of work activity, particularly where they cannot be summed easily by other means. This is particularly relevant when trying to combine the noise exposure due to continuous noise and impulse noise and is also the method requested by the LWPT.

4.4.2 In the noise exposure points scheme the ELV is 160 points and the UEAV is 100 points. Effectively, exposure to noise at each crew position for a given duration of flight time will result in a number of noise exposure points (for example 90 points for a particular sortie). By subtracting this number of points from the ELV or UEAV points (e.g. 160-90 for the ELV) an indication can be obtained of how many noise exposure points remain to be used that day before the ELV is exceeded. In this example there would be 70 points remaining and, for the purposes of this assessment, these could then be used to account for the additional noise exposure received during gun firing. Therefore, by dividing the 70 remaining points by the 'points per 100 rounds' figure presented in the ISVR report [1] the number of rounds that can be fired during that particular duration of sortie can be calculated.

4.4.3 For this assessment an Air Live Firing (ALF) serial sortie profile was created based on information supplied by the LWPT and JHC [24]. This was done to create a nominal sortie profile (listed in Appendix B) representative of that flown during training when firing the HMGs and consisted of ground running (5 mins), take-off (1 min), hover (5 mins), climb (2 mins), forward flight at 60KIAS (7 mins) and 80KIAS (7 mins), descent (2 mins) and landing (1 min). It was indicated that ALF serials typically take 20-30 minutes flight time, of which the actual firing segment is 5 to 10 minutes, and each ALF requires up to 400 rounds of ammunition. Therefore, for the purposes of this assessment it was assumed that each ALF took 30 minutes. Typically four to eight ALFs could take place during one day and it is possibly that some of the crew would participate in all of these; consequently, calculations have been based on eight ALFs (i.e. covering four hours flight time) per day to give an indication of how many rounds can be fired per day before the ELV and UEAV of the CNAWRs are exceeded.

4.4.4 It is understood that, independently and separate to the assessment reported here, a live firing exercise is being conducted by the AAC during late February / early March 2017. During that exercise JHC are intending to collect information relating to the number of ALFs flown per day, the flight time per day and the number of rounds fired per day. This information may lead to JHC gaining a more detailed understanding of crew noise exposure during firing of the GPMG and M3M.

4.5 External Ambient Noise and Ground Crew Noise Exposure

4.5.1 To determine ground crew noise exposure the QinetiQ Noise SME operated a hand held noise recording system and shadowed the ground crew during see-off and see-in activities. Analysis of the recordings resulted in a number of one-third octave and octave band noise spectra for typical ground crew locations. The QinetiQ Noise SME also wore noise dosemeters that logged ambient noise and noise level at the ear against time.

5 Wildcat AH Mk1 Noise Assessment

5.1 Internal Ambient Noise

5.1.1 The ambient noise spectra for each individual flight condition were compared to determine the variability across the five aircraft flown. The noise spectra obtained on each aircraft were closely correlated across aircraft conditions, in terms of noise level and spectral shape, with Figure 5-1 being representative of the results, in this case at the forward cabin position for forward flight at 120KIAS. Also shown, in red, is the mean noise spectrum for this condition. It should be noted that the two bands to the right of the plotted spectra show the overall linear sound pressure level (L) and overall A-weighted sound pressure level (A). The A-weighting network is applied to the data to represent the non-linear frequency sensitivity of the human ear and it is the overall A-weighted sound pressure level that is used to determine hearing damage risk within the CNAWRs. Hence, for the ambient data the overall A-weighted sound pressure level also gives the direct noise exposure figure for anyone not wearing hearing protection.

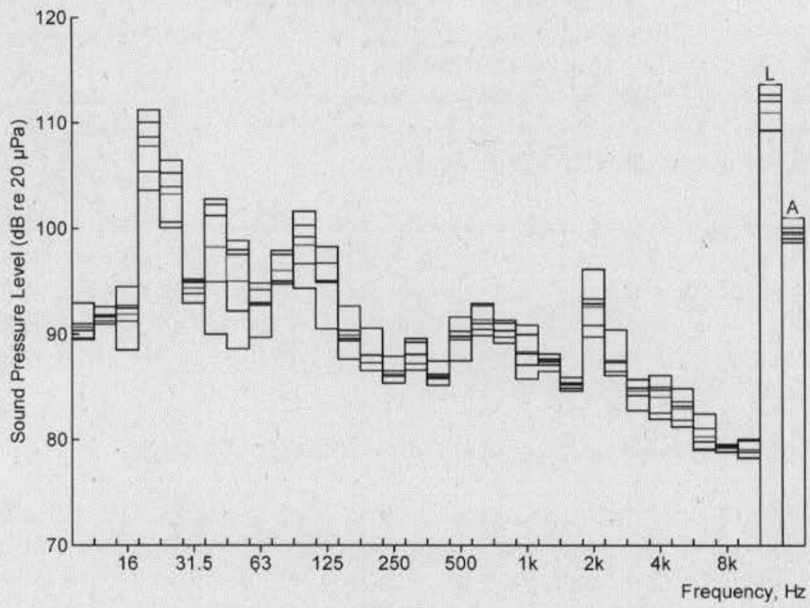

Figure 5-1: Wildcat AH Mk1 ambient noise spectra recorded in the forward cabin during flight at 120KIAS

5.1.2 The highest in-flight ambient noise levels for all three crew positions were experienced during take-off and landing, climb and some of the more transient conditions such as turns. However, these do not necessarily translate into the highest A-weighted 'at ear' noise levels due to the frequencies concerned and the hearing protection attenuation performance at those particular frequencies; indeed, the highest noise levels at the ear often occurred during the descent. It was interesting to note that noise levels during ground running were of a similar level to some of the 'noisier' in flight conditions and, particularly within the rear cabin, may provide a large contribution to overall crew noise exposure if conducted for long periods of time. Also, in general, crew positions in the cabin exhibited higher ambient noise levels than those in the cockpit.

5.1.3 Opening of the cockpit windows during flight increased ambient noise levels within the cockpit by approximately 2dB(A) but had only a slight impact on ambient noise levels within the cabin. Interestingly, in flight, the ambient noise levels with just one cabin door open were generally higher than those with both cabin doors open, although not so pronounced within the rear cabin. During flight, ambient noise levels within the aircraft with the doors open can be up to 10dB higher than with the doors closed although typically this translates to an increase in A-weighted noise levels of around 5-7 dB(A). As stated in the previous paragraph these differences do not necessarily translate directly into differences in the A-weighted 'at ear' noise levels due to the frequencies concerned and the hearing protection attenuation performance at those particular frequencies. An open doors configuration has been considered during the assessment of crew noise exposure during the USL and gun firing sorties.

5.1.4 For each flight condition the individual aircraft spectra were averaged to give a mean noise spectrum that could be used for predicting noise levels at the ear.

5.2 Crew Noise Exposure – Continuous Noise

5.2.1 Predictions of overall sortie noise levels at the ear were calculated for each crew position and each form of hearing protection for each of the six sortie profiles detailed in

Table 4-1. This overall sortie noise level at the ear was then used to calculate the 'allowable' exposure durations to both the ELV and UEAV of the CNAWRs as detailed in section 4. Table 5-1 show the resultant 'allowable' exposure durations when calculated to the ELV. The results for the UEAV calculations are shown in Appendix D.

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the ELV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
WT-02	06:03	24:00	04:48	24:00	24:00	03:43	24:00	23:09	04:17	24:00
WT-06	05:02	24:00	04:05	24:00	24:00	03:14	24:00	19:41	03:38	24:00
WT-07	05:55	24:00	04:42	24:00	24:00	03:43	24:00	22:37	04:11	24:00
WT-09	04:55	24:00	04:00	24:00	24:00	03:10	24:00	19:14	03:33	24:00
WT-11	04:17	24:00	03:24	24:00	24:00	02:34	24:00	15:16	02:57	19:14
WT-15	04:05	24:00	03:19	24:00	24:00	02:45	24:00	16:45	03:01	23:09
Forward cabin										
WT-02	05:47	24:00	04:35	24:00	24:00	03:38	24:00	21:06	04:00	24:00
WT-06	04:48	24:00	03:43	24:00	24:00	02:57	24:00	17:08	03:14	23:09
WT-07	05:47	24:00	04:35	24:00	24:00	03:38	24:00	20:37	04:05	24:00
WT-09	04:35	24:00	03:33	24:00	24:00	02:53	24:00	16:22	03:10	22:37
WT-11	02:45	24:00	02:11	21:36	21:06	01:30	16:00	09:11	01:49	11:34
WT-11 door	01:12	15:16	00:57	10:33	11:18	00:36	06:48	03:49	00:45	04:48
WT-15	04:05	24:00	03:10	24:00	23:41	02:34	24:00	14:55	02:49	20:09
Rear cabin										
WT-02	05:09	24:00	04:17	24:00	24:00	03:38	24:00	20:37	04:00	24:00

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the ELV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
WT-06	04:17	24:00	03:33	24:00	24:00	03:01	24:00	17:32	03:19	22:37
WT-07	05:16	24:00	04:11	24:00	24:00	03:38	24:00	20:09	04:00	24:00
WT-09	04:11	24:00	03:28	24:00	24:00	02:57	24:00	17:08	03:10	22:06
WT-11	02:42	24:00	02:11	17:57	21:06	01:39	14:35	09:37	01:54	11:34
WT-15	03:43	24:00	03:06	24:00	24:00	02:42	24:00	15:16	02:53	19:41

Table 5-1: Wildcat AH Mk1 'allowable' exposure durations calculated to the ELV of the CNAWRs

5.2.2 From Table 5-1 it can be seen that with the exception of sortie code WT-11 (USL) the 'allowable' exposure durations are all greater than 14 hours per day at all crew positions, provided either the CEP or VAMP 27 earplugs are worn. During the USL sortie the 'allowable' exposure times, with an ear insert device worn, are still greater than 9 hours at all positions except for the Aircrewman who is at the open cabin door for large periods of time. By the open cabin door the 'allowable' exposure durations, with an ear insert device worn, reduce to 3 hours 49 minutes for the Mk10R-RW flight helmet with VAMP 27 although are appreciably higher with other flight helmets/earplug combinations.

5.2.3 Without an ear insert device, which may be the case if there is a failure of the earplug system requiring its removal, the 'allowable' exposure durations are greatly reduced but are still a matter of hours for most of the sorties considered. However, for the USL sortie profile the 'allowable' exposure durations reduce to 36 minutes for the Aircrewman by the open cabin door and 1 hour 30 minutes for other crew in the cabin. Again, it is the Mk10R-RW flight helmet with VAMP 27 that provides the least protection.

5.3 Crew Noise Exposure – Firing of the GPMG and M3M HMGs

5.3.1 Using the ALF sortie profile and methodology described in sub-section 4.4, Table 5-2 details the number of rounds that can be fired per day before exceeding the ELV of the CNAWR. The results for the UEAV calculations are shown in Appendix D. It should be noted that Table 5-2 is based on the worst case result for each test condition as shown in the ISVR report [1], the cockpit figures being particularly dependent on the orientation of the weapon with forward azimuth being very much the worst case for the pilots.

Weapon & Condition	'Allowable' rounds fired for each hearing protection system, calculated to the ELV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
GPMG windows open	0	14,700	0	11,667	8,750	0	7,000	4,800	0	5,120
GPMG windows closed	0	49,000	0	35,000	35,000	0	23,333	17,143	0	18,286
M3M windows open	0	8,647	0	6,364	5,000	0	4,000	2,727	0	2,909
M3M windows closed	0	18,375	0	14,000	11,667	0	9,333	6,316	0	6,737
Forward cabin										
GPMG	0	28,800	0	22,500	18,286	0	15,000	10,000	0	10,909
M3M	0	4,364	0	3,214	2,415	0	2,045	1,325	0	1,446
Rear Cabin										
GPMG	0	28,000	0	21,333	19,286	0	14,222	10,000	0	10,909
M3M	0	4,242	0	3,048	2,547	0	1,939	1,325	0	1,446

Table 5-2: Wildcat AH Mk1 - Number of rounds that can be fired per day before exceeding the ELV of the CNAWR (based on flying eight ALFs per day)

5.3.2 Two trends are noticed within Table 5-2. Firstly, the zeros within the table indicate that noise exposure from the flying activity itself, with the flight helmets worn alone, reaches the ELV of the CNAWR (see Table 5-1) and therefore no weapons can be fired during these conditions without exceeding the ELV. Based on the assumption that eight ALFs are flown per day, and these are typically of 30 minutes duration, with cabin doors open, it can be seen that only the wearing of ear insert devices with a flight helmet provides sufficient hearing protection to allow the guns to be fired. Secondly, that for the pilots, keeping the cockpit windows closed during firing greatly increases the number of rounds that can be fired before exceeding the ELV of the CNAWR; this being driven by the forward azimuth conditions.

5.3.3 It should be noted that there is a trade-off between the flight duration and the number of rounds that can be fired. Reducing the flight time per day will increase the number of rounds that can be fired before the ELV of the CNAWR is exceeded.

5.4 External Ambient Noise and Ground Crew Noise Exposure

5.4.1 The worst case noise location for the ground crew was when close to the aircraft with the rotors running where ambient noise levels reached 114dB(A); part of the 'fireman' role.

However, the predicted noise level at the ear for the Peltor Optime III ear defender, that is worn by most military ground crew maintainers, was 82dB(A). This is well below both the ELV and UEAV of the CNAWRs and, indeed, it should be noted that this is the worst case condition which only occurs for a couple of minutes or so per aircraft see-off /see-in cycle. Overall noise levels at the ear for the entire see-off / see-in cycle are much lower and below 74dB(A) for the 'fireman', with noise levels at the ear for the marshaller, stood outside the rotor disk, being lower still.

5.4.2 Analysis of the noise dosemeter results for the JetGard headset were very close to the predictions of noise at ear for the Peltor Optime III ear defender. The highest ambient noise level recorded was 112.7dB(A) with the corresponding noise level at the ear being 83.3dB(A). For the full see-off / see-in cycle noise levels at the ear were in the range 70-74dB(A).

5.4.3 The results indicate that so long as the ground crew wear the hearing protection provided, either the Peltor Optime III ear defenders or Esterline JetGard headset, they will not be exposed to noise levels at the ear that exceed current UK noise legislation.

6 Lynx AH Mk9A Noise Assessment

6.1 Internal Ambient Noise

6.1.1 The ambient noise spectra for each individual flight condition were compared to determine the variability across the three aircraft flown. Figure 6-1 is representative of the results for all flight conditions, in this case at the forward cabin position for forward flight at 120KIAS; the median noise spectrum is shown in red. As only three aircraft were investigated it was not possible to calculate a mean noise spectrum for each flight condition. Consequently, the median noise spectrum calculated by investigation of the overall A-weighted ambient noise level, was taken to be representative of the fleet. As noted in sub-section 5.1 the two bands to the right of the plotted spectra show the overall linear sound pressure level (L) and overall A-weighted sound pressure level (A).

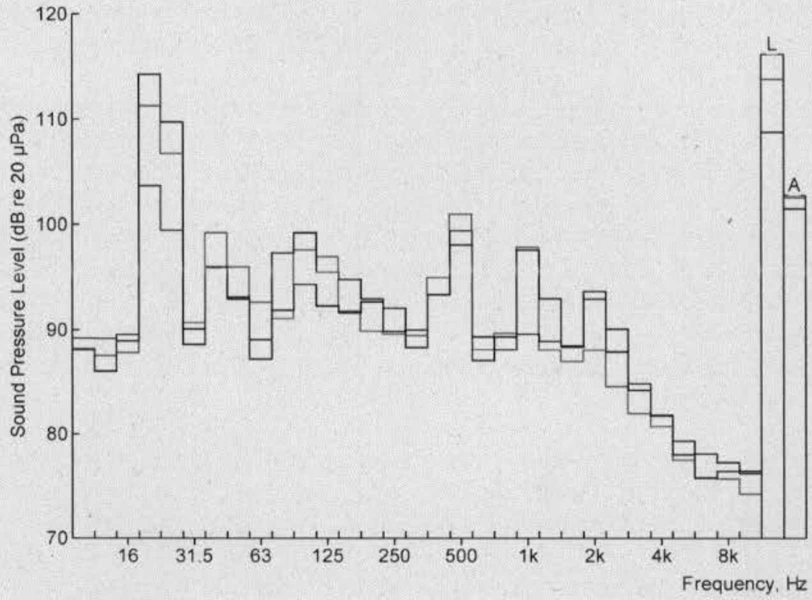

Figure 6-1: Lynx AH Mk9A ambient noise spectra recorded in the forward cabin for flight at 120KIAS

6.1.2 The highest in-flight ambient noise levels for all three crew positions were experienced across a range of conditions although some were transient in nature. Of the 'longer duration' conditions, take-off, transition, climb and the higher forward speeds exhibited the highest ambient noise levels. As for Wildcat AH Mk1, these do not necessarily translate into the highest A-weighted 'at ear' noise levels due to the frequencies concerned and the hearing protection attenuation performance at those particular frequencies. Interestingly, unlike Wildcat AH Mk1, noise levels during ground running were generally quieter than the in-flight conditions. However, like Wildcat AH Mk1, crew positions in the cabin generally exhibited higher ambient noise levels than those in the cockpit.

6.1.3 Opening of the cockpit windows during flight increased ambient noise levels within the cockpit by approximately 2-3dB(A) and by 1-2 dB(A) within the cabin. As for Wildcat AH Mk1, in flight, the ambient noise levels with just one cabin door open were generally higher than those with both cabin doors open although this was not so pronounced within the rear cabin. During flight, ambient noise levels within the aircraft with the doors open can be 7-10dB higher than with the doors closed, although this does not translate to a significant increase in A-weighted noise levels. This is unlike Wildcat AH Mk1 and appears to be due to the higher ambient noise levels at the mid-frequencies on Lynx AH Mk9A. As stated in the previous paragraph these differences do not necessarily translate directly into differences in the A-weighted 'at ear' noise levels due to the frequencies concerned and the hearing protection attenuation performance at those particular frequencies. An open doors configuration has been considered during the assessment of crew noise exposure during gun firing.

6.2 Crew Noise Exposure – Continuous Noise

6.2.1 Predictions of overall sortie noise levels at the ear were calculated for each crew position and each form of hearing protection for each of the four sortie profiles detailed in Table 4-1. This overall sortie noise level at the ear was then used to calculate the 'allowable' exposure durations to both the ELV and UEAV of the CNAWRs as detailed in section 4. Table 6-1 show the resultant 'allowable' exposure durations when calculated to the ELV. The results for the UEAV calculations are shown in Appendix D.

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the ELV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
A1a	02:31	24:00	01:42	17:32	22:37	00:49	09:37	04:48	01:07	06:29
A3a	02:31	24:00	01:39	17:08	24:00	00:46	08:58	04:29	01:04	06:03
A10a	02:24	24:00	01:39	17:32	22:06	00:49	09:24	04:48	01:05	06:29
A12a	02:21	24:00	01:35	16:45	21:36	00:46	08:58	04:35	01:04	06:03
Forward cabin										
A1a	02:21	24:00	01:44	17:08	18:48	00:57	10:18	05:47	01:15	07:17
A3a	02:38	24:00	01:51	18:22	21:36	01:00	10:48	05:47	01:19	07:27

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the ELV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
A10a	02:21	24:00	01:46	17:32	18:48	01:01	11:03	06:03	01:19	07:38
A12a	02:08	24:00	01:35	16:22	17:32	00:53	10:04	05:24	01:10	06:57
Rear cabin										
A1a	01:57	20:09	01:24	13:55	18:48	00:43	07:49	04:17	00:57	05:31
A3a	02:14	21:36	01:35	14:55	21:06	00:47	08:22	04:35	01:04	05:55
A10a	02:02	20:37	01:28	14:15	19:14	00:45	08:11	04:29	01:01	05:47
A12a	02:02	20:37	01:26	14:15	19:14	00:45	08:00	04:29	01:00	05:47

Table 6-1: Lynx AH Mk9A 'allowable' exposure durations calculated to the ELV of the CNAWRs

6.2.2 From Table 6-1 it can be seen that 'allowable' exposure durations with ear insert devices worn are greater than 4 hours across all crew positions and sortie types. The Mk10R-RW worn with VAMP 27s and ALPHA 928 worn with CEPs result in the lowest 'allowable' exposure durations whereas for the other helmet combinations 'allowable' exposure durations are 8 hours or greater, with the exception of the rear cabin during sortie profile A1a (7 hours 49 minutes).

6.2.3 The figures for the Mk10R-RW flight helmet when worn with the VAMP 27 ear inserts is surprising considering the results for the Mk4B/4L flight helmet when fitted with the same ear insert device. A preliminary investigation of the SATRA test results [25] showed that the results of the attenuation testing of the Mk10R-RW with VAMP 27 exhibited both a lower mean attenuation figure and a higher standard deviation, particularly at the low to mid-frequencies. Consequently, the APV figure for this particular hearing protection combination is lower than for similar combinations for the other flight helmets. This was not so important on Wildcat AH Mk1 due to the lower ambient noise levels on the aircraft and the frequency spectrum of the noise environment. However, on Lynx AH Mk9A it has resulted in a significant difference between the flight helmets when worn with the VAMP 27 ear insert device.

6.2.4 Without ear insert devices, which may be the case if there is a failure of the earplug system requiring its removal, the 'allowable' exposure durations are between just 45 minutes and 1 hour for the Mk10R-RW and ALPHA 928 flight helmets. 'Allowable' exposure durations for the Mk4A/4 and Mk4B/4L flight helmets are slightly higher; typically between 1 hour 30 minutes and 2 hours 30 minutes.

6.3 Crew Noise Exposure – Firing of the GPMG and M3M HMGs

6.3.1 Typically four to eight ALFs could take place during one day and it is possibly that many of the crew would participate in all of these; consequently, calculations have been based on eight ALFs (i.e. covering four hours flight time) per day. Using the ALF sortie profile and methodology described in sub-section 4.4, Table 6-2 details the number of rounds that can be fired per day before exceeding the ELV of the CNAWR. The results for the UEAV calculations are shown in Appendix D. It should be noted that Table 6-2 is based on the worst case result as shown in the ISVR report [1], the cockpit figures being particularly dependent on the orientation of the weapon with forward azimuth being very much the worst case for the pilots.

Weapon & Condition	**'Allowable' rounds fired for each hearing protection system, calculated to the ELV of the CNAWRs**									
	4A/4	**4A/4 + CEP**	**4B/4L**	**4B/4L + CEP**	**4B/4L + VAMP 27**	**10R-RW**	**10R-RW + CEP**	**10R-RW + VAMP 27**	**ALPHA 928**	**ALPHA 928 + CEP**
Cockpit										
GPMG windows open	0	14,400	0	11,250	8,750	0	6,000	3,200	0	4,400
GPMG windows closed	0	48,000	0	33,750	35,000	0	20,000	11,429	0	15,714
M3M windows open	0	8,471	0	6,136	5,000	0	3,429	1,818	0	2,500
M3M windows closed	0	18,000	0	13,500	11,667	0	8,000	4,211	0	5,789
Forward cabin										
GPMG	0	27,000	0	21,333	17,143	0	12,222	5,455	0	7,273
M3M	0	4,091	0	3,048	2,264	0	1,667	723	0	964
Rear cabin										
GPMG	0	27,000	0	20,000	18,286	0	10,556	5,455	0	7,273
M3M	0	4,091	0	2,857	2,415	0	1,439	723	0	964

Table 6-2: Lynx AH Mk9A - Number of rounds that can be fired per day before exceeding the ELV of the CNAWR (based on flying eight ALFs per day)

6.3.2 Again, as for Wildcat AH Mk1, two trends are noticed within Table 6-2. Firstly, the zeros within the table indicate that noise exposure from the flying activity itself, with the flight helmets worn alone, reaches the ELV of the CNAWR (see Table 6-1) and therefore no weapons can be fired during these conditions without exceeding the ELV. Based on the assumption that eight ALFs are flown per day, and these are typically of 30 minutes duration, with cabin doors open, it can be seen that only the wearing of ear insert devices with a flight helmet provides sufficient hearing protection to allow the guns to be fired. Secondly, that for the pilots, keeping the cockpit windows closed during firing greatly increases the number of rounds that can be fired before exceeding the ELV of the CNAWR; this being driven by the forward azimuth conditions.

6.3.3 It should be noted that there is a trade-off between the flight duration and the number of rounds that can be fired. Reducing the flight time per day will increase the number of rounds that can be fired before the ELV of the CNAWR is exceeded.

6.4 External Ambient Noise and Ground Crew Noise Exposure

6.4.1 The worst case noise location for the ground crew was when close to the aircraft with the rotors running where ambient noise levels reached just under 113dB(A). However, the predicted noise level at the ear for the Peltor Optime III ear defender, that is worn by most military ground crew maintainers, was 81dB(A). This is well below both the ELV and UEAV of the CNAWRs and, indeed, it should be noted that this is the worst case condition which only occurs for a couple of minutes or so per aircraft see-off /see-in cycle. Overall noise levels at the ear for the entire see-off / see-in cycle are much lower and typically around 70dB(A) for the 'fireman' with levels for the marshaller, stood outside the rotor disk, being lower still.

6.4.2 Analysis of the noise dosemeter results for the Peltor Optime III ear defenders correlated closely with the predicted values. The highest ambient noise level recorded was 113.4dB(A) with the corresponding noise level at the ear being 83.5dB(A).

6.4.3 The results indicate that so long as the ground crew wear the hearing protection provided they will not be exposed to noise levels at the ear that exceed current UK noise legislation.

7 Wildcat AH Mk1 Vibration Assessment

7.1 Overview

7.1.1

7.1.2

7.1.3

7.1.4

8 Summary

8.1 Noise

8.1.1 Ambient noise levels have been measured for a large number of flight conditions typical of those flown within the main sortie profiles documented within the Wildcat AH Mk1 SOI [6] and Lynx AH Mk9A SOIU [7]. The assessment has shown that, on both aircraft types, ambient noise levels were generally higher in the rear cabin, followed by the forward cabin and quieter in the cockpit, although this was not always the case. When comparing ambient noise levels within both aircraft the Lynx AH Mk9A was, typically, noisier in flight than the Wildcat AH Mk1 but quieter during ground running. Indeed during ground running the Wildcat AH Mk1 exhibited similar levels of ambient noise to those observed in flight and has the potential, particularly in the rear cabin, to provide a large contribution to overall crew noise exposure if conducted for long periods of time.

8.1.2 Crew noise exposure has been calculated in line with the CNAWR [16] and in adherence to the proposed MOD-wide noise measurement protocol being prepared by RAF CAM and QinetiQ in response to an initiative by the MOD Air Capability noise steering/policy group [20]. Predictions of noise levels at the ear showed that use of an ear insert device (such as the CEP or VAMP 27) with a flight helmet significantly reduces noise levels at the ear and consequently increases the 'allowable' exposure durations. However, the suitability of a particular hearing protection system will depend on how many flight hours per day the aircrew are expected to attain. As a rough guide, on Wildcat AH Mk1 the use of any flight helmet with a CEP or VAMP 27 device will result in 'allowable' exposure durations of greater than 8 hours at all crew positions. Due to the higher ambient noise levels on Lynx AH Mk9A a reduced selection of hearing protection (Mk4A/4+CEP, Mk4B/4L+CEP and Mk4B/4L+VAMP 27) should be worn to attain 8 hours at all crew positions.

8.1.3 Likewise, when firing the GPMG or M3M HMGs, the suitability of a particular hearing protection system will depend on the duration of flight required and the number of rounds per day that are expected to be fired. Generally, on both aircraft types, keeping the cockpit windows closed reduces the ambient noise levels in the cockpit due to the gun firing and therefore allows for a greater number of rounds to be fired per day. Use of the CEP or VAMP 27 with a flight helmet reduces noise levels at the ear and therefore also allows for a greater number of rounds to be fired per day. However, on both aircraft types there is a trade-off between the flight duration and the number of rounds that can be fired and reducing the flight time per day will increase the number of rounds that can be fired before current UK noise legislation is exceeded.

8.1.4 High ambient noise levels are experienced at the ground maintainer positions during see-off and see-in, particularly when close-in to the aircraft during the engine start checks. However, use of a high performing hearing protector (such as the Peltor Optime III ear defenders or the Esterline JetGard headset) does reduce noise levels at the ear to below the ELV of the CNAWR. Consequently, if hearing protection of this standard is worn, then the 'allowable' exposure duration for ground maintainers would not exceed current UK noise legislation.

8.2 Vibration

8.2.1 [redacted]

8.2.2 [redacted]

8.2.3 [redacted]

8.2.4 [redacted]

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10 List of Abbreviations

AAC	Army Air Corps
AGL	Above Ground Level
ALF	Air Live Firing
AOB	Angle of Bank
APV	Assumed Protection Value
ATEC	Aircraft Test and Evaluation Centre
ARR	Aircraft Release Recommendations
BP	Battle Position
CEP	Communications Ear Plug
CNAWR	Control of Noise at Work Regulations
CVAWR	Control of Vibration at Work Regulations
EAV	Exposure Action Value
ELV	Exposure Limit Value
FFR	Full Flare Recovery
FTE	Flight Test Engineer
GPMG	General Purpose Machine Gun
HOGE	Hover Out of Ground Effect
HMG	Heavy Machine Gun
HSE	Health and Safety Executive
HUMS	Health and Usage Monitoring System
IGE	In Ground Effect (hover)
ISVR	Institute of Sound and Vibration Research
JHC	Joint Helicopter Command
KIAS	Knots Indicated Air Speed
LEAV	Lower Exposure Action Value
LL	Low Level
LTPA	Long Term Partnering Agreement
LWPT	Lynx-Wildcat Project Team
MSC	Minimum Separation Criteria
NB	Not Below
NVG	Night Vision Goggles
PAVD	Physical Agents (Vibration) Directive
PFL	Practice Forced Landing
PPE	Personal Protective Equipment
PSD	Power Spectral Density

RAF	Royal Air Force
RAF CAM	RAF Centre of Aviation Medicine
RHS	Right Hand Side
RMS	Root Mean Square
RNAS	Royal Naval Air Station
RTS	Release To Service
RVC	Rigid Visor Cover
RWTES	Rotary Wing Test and Evaluation Squadron
S&L	Straight and Level
SME	Subject Matter Expert
SOI	Statement of Operating Intent
SOIU	Statement of Operating Intent and Usage
SPC	Sortie Profile Code
UEAV	Upper Exposure Action Value
USL	Under Slung Load
VDV	Vibration Dose Value
WBV	Whole Body Vibration
wRMS	Weighted Root Mean Square

A Flight Conditions

Number	Condition
01	Rotors running
02	Ground taxi into take off
03	IGE hover
04	Normal transition
05	Forward flight S&L 80KIAS
06	Forward flight S&L 80KIAS – cockpit windows open
07	Forward flight S&L 120KIAS – cockpit windows open
08	Forward flight S&L 120KIAS
09	Rate 1 turns, 120KIAS
10	30 degree AOB turns, 80KIAS
11	Forward flight S&L 130KIAS
12	Forward flight S&L - Vmax
13	Climb 120KIAS, 1000fpm
14	Descend 120KIAS, 500fpm
15	Climb 80KIAS, 130% Tq
16	Descend 120KIAS, 1000fpm
17	Autorotation 80KIAS
18	LL flight NB 100' AGL, 30MSC
19	PFL to FFR, NB 30' AGL
20	BP Ops, HOGE into wind
21	HOGE cross-wind
22	HOGE down-wind
23	Bob up / Bob down
24	Quickstop
25	Low speed left 30KIAS
26	Low speed right 30KIAS
27	Low speed rearwards 30KIAS
28	Running take-off
29	Running landing
30	Sim USL – IGE Hover; both doors open [also single USL sortie]
31	Sim USL – Transition [also single USL sortie]
32	Sim USL – 60KIAS S&L [also single USL sortie]
33	Sim USL – Rate 1 turn, 60KIAS [also single USL sortie]
34	Sim USL – Transition to hover [also single USL sortie]
35	S&L 80KIAS – both doors open
36	S&L 120KIAS – both doors open
37	S&L 80KIAS – just RHS door open
38	S&L 120KIAS – just RHS door open
39	Normal approach to hover
40	Spot turns 30 degree per sec
41	Landing from hover

Table A-1: Trial Flight Conditions

B Octave Band Sortie Ambient Noise Spectra

B.1 Overview

B.1.1 Table B-1 and Table B-2 detail the octave band sortie ambient noise spectra used to calculate noise levels at the ear and 'allowable' exposure durations for the six Wildcat AH Mk1 and the four Lynx AH Mk9A sorties described within the report. Also shown are the constructed ALF sorties.

B.2 Wildcat AH Mk1

Sortie type	Octave band centre frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
Cockpit								
WT-02	98.7	96.3	91.0	93.1	90.8	95.6	86.0	82.6
WT-06	99.6	97.6	91.8	93.4	91.6	96.3	86.4	83.3
WT-07	98.2	96.0	91.0	93.0	91.0	96.8	86.3	83.2
WT-09	99.8	97.8	91.9	93.5	91.7	95.9	86.4	83.2
WT-11	99.1	95.3	92.4	95.2	92.6	99.1	86.5	86.0
WT-15	99.9	98.1	92.8	93.9	92.1	97.7	86.6	83.5
ALF	101.4	96.8	92.4	94.5	92.5	97.5	86.9	87.9
Forward Cabin								
WT-02	98.0	97.7	90.7	92.9	92.3	96.3	87.9	83.8
WT-06	98.6	99.1	91.5	93.7	93.1	96.9	88.4	84.3
WT-07	97.5	97.4	90.6	92.8	92.4	97.5	88.0	84.3
WT-09	98.8	99.4	91.7	93.8	93.3	96.4	88.4	84.3
WT-11	100.1	98.1	93.8	98.0	96.1	98.3	88.6	87.7
WT-11 (door)	98.4	98.3	97.8	102.5	99.1	98.9	90.3	92.8
WT-15	98.7	99.7	92.3	94.1	93.6	98.0	88.6	84.6
ALF	101.4	99.4	93.0	95.0	94.2	98.2	88.7	90.0
Rear cabin								
WT-02	102.4	95.5	91.4	92.3	93.0	99.0	90.0	83.6
WT-06	103.6	96.6	92.3	93.0	93.6	99.5	90.1	83.9
WT-07	101.8	95.4	91.2	92.2	93.2	99.8	89.9	84.1
WT-09	103.9	96.8	92.5	93.1	93.6	99.3	90.1	83.8
WT-11	102.5	94.3	93.9	97.1	96.4	102.0	91.1	90.2
WT-15	104.1	97.1	92.8	93.3	94.1	100.6	90.2	84.1
ALF	106.6	96.7	92.3	94.0	95.0	101.1	90.6	90.1

Table B-1: Octave Band Ambient Noise Spectra for Wildcat AH Mk1

B.3 Lynx AH Mk9A

Condition Number	Octave band centre frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
Cockpit								
A1a	98.0	97.7	92.0	102.1	95.6	92.6	83.2	80.9
A3a	98.0	96.3	91.3	102.6	95.4	92.4	83.5	80.6
A10a	97.3	97.3	92.6	102.1	95.9	92.8	84.0	80.7
A12a	98.4	97.5	92.4	102.4	96.0	92.5	83.8	81.1
ALF	99.4	97.5	91.2	99.2	94.5	91.7	85.7	87.0
Forward cabin								
A1a	97.0	98.8	93.4	100.9	97.9	93.3	85.4	81.7
A3a	96.4	98.1	92.2	101.0	97.4	93.3	85.0	80.9
A10a	97.5	98.9	93.6	100.6	97.9	92.9	85.6	81.5
A12a	97.5	99.3	94.1	101.2	97.6	92.8	85.8	82.0
ALF	101.5	100.7	93.3	100.5	96.5	92.9	85.4	90.7
Rear cabin								
A1a	100.1	95.0	93.9	102.5	97.4	97.7	86.8	81.2
A3a	99.0	94.7	92.6	102.3	97.5	96.9	86.5	80.2
A10a	97.9	95.3	93.6	102.2	97.7	97.9	87.0	80.9
A12a	98.9	95.4	93.6	102.3	97.5	97.7	87.0	80.9
ALF	109.6	96.5	93.4	100.7	96.9	94.9	86.2	90.4

Table B-2: Octave Band Ambient Noise Spectra for Lynx AH Mk9A

C Assumed Protection Values for the Aircrew Flight Helmets

C.1 Octave band noise attenuation data was provided by the LWPT and is shown in Table C-1. The data came from two sources – RAF CAM and SATRA – with the RAF CAM data being used as the primary source if two data sets existed for a particular hearing protection system. No data was provided regarding the Mk4A/4 and ALPHA 928 flight helmets worn with the VAMP 27 ear insert device.

Type	Assumed Protection Values, dB								Source
	Frequency, Hz								
	63	125	250	500	1k	2k	4k	8k	
Mk4A/4	18.0	16.0	10.2	23.5	27.6	34.1	43.0	42.2	RAF CAM
Mk4A/4 + CEP	30.1	27.5	26.0	33.0	34.2	39.4	52.9	48.3	RAF CAM
Mk4B/4L	15.6	13.1	10.4	20.9	28.0	31.8	41.0	42.4	RAF CAM
Mk4B/4L + CEP	23.1	22.6	25.3	31.1	33.5	37.2	51.0	47.6	RAF CAM
Mk4B/4L + VAMP 27	25.7	18.6	21.3	35.1	35.0	39.5	51.5	48.2	SATRA
Mk10R-RW	16.4	12.8	10.9	16.6	29.0	33.9	44.2	48.7	RAF CAM
Mk10R-RW + CEP	29.5	27.1	26.5	27.4	31.9	38.1	49.0	48.8	RAF CAM
Mk10R-RW + VAMP 27	20.0	18.5	23.6	24.1	35.4	37.5	53.0	50.1	SATRA
ALPHA 928	16.1	12.4	11.0	18.3	28.1	32.6	42.5	46.4	RAF CAM
ALPHA 928 + CEP	26.1	22.5	24.4	25.6	31.7	38.3	52.4	51.4	RAF CAM

Table C-1: Assumed Protection Values for the hearing protection worn by the aircrew

D Crew Noise Exposure Calculated to the UEAV of the CNAWRs

D.1 Wildcat AH Mk1 – Continuous Noise

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the UEAV of the CNAWRs – Wildcat AH Mk1									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
WT-02	03:49	24:00	03:01	24:00	24:00	02:21	24:00	14:35	02:42	19:14
WT-06	03:10	24:00	02:34	24:00	21:36	02:02	23:41	12:24	02:17	16:45
WT-07	03:43	24:00	02:57	24:00	24:00	02:21	24:00	14:15	02:38	18:48
WT-09	03:06	24:00	02:31	24:00	20:37	02:00	23:09	12:07	02:14	16:45
WT-11	02:42	24:00	02:08	19:41	20:09	01:37	16:22	09:37	01:51	12:24
WT-15	02:34	24:00	02:05	21:36	17:57	01:44	20:09	10:33	01:54	14:35
Forward cabin										
WT-02	03:38	24:00	02:53	24:00	22:37	02:17	24:00	13:17	02:31	17:57
WT-06	03:01	24:00	02:21	22:06	17:57	01:51	20:37	10:48	02:02	14:35
WT-07	03:38	24:00	02:53	24:00	22:06	02:17	23:09	12:59	02:34	17:08
WT-09	02:53	24:00	02:14	22:06	17:08	01:49	20:09	10:18	02:00	14:15
WT-11	01:44	20:09	01:22	13:36	13:18	00:57	10:04	05:47	01:08	07:17
WT-11 door	00:45	09:37	00:36	06:39	07:07	00:22	04:17	02:24	00:28	03:01
WT-15	02:34	24:00	02:00	18:48	14:55	01:37	17:32	09:24	01:46	12:41
Rear cabin										

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the UEAV of the CNAWRs – Wildcat AH Mk1									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
WT-02	03:14	24:00	02:42	22:06	22:06	02:17	21:06	12:59	02:31	16:22
WT-06	02:42	24:00	02:14	18:48	18:22	01:54	17:57	11:03	02:05	14:15
WT-07	03:19	24:00	02:38	20:37	21:36	02:17	19:41	12:41	02:31	15:38
WT-09	02:38	24:00	02:11	19:14	17:57	01:51	17:57	10:48	02:00	13:55
WT-11	01:42	16:45	01:22	11:18	13:17	01:02	09:11	06:03	01:12	07:17
WT-15	02:21	24:00	01:57	16:00	15:38	01:42	15:38	09:37	01:49	12:24

Table D-1: Wildcat AH Mk1 'allowable' exposure durations calculated to the UEAV of the CNAWRs

D.2 Lynx AH Mk9A – Continuous Noise

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the UEAV of the CNAWRs – Lynx AH Mk9A									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
A1a	01:35	16:45	01:04	11:03	14:15	00:31	06:03	03:01	00:42	04:05
A3a	01:35	16:22	01:02	10:48	15:16	00:29	05:39	02:49	00:40	03:49
A10a	01:30	16:22	01:02	11:03	13:55	00:31	05:55	03:01	00:41	04:05
A12a	01:28	15:38	01:00	10:33	13:36	00:29	05:39	02:53	00:40	03:49
Forward cabin										
A1a	01:28	15:38	01:05	10:48	11:50	00:36	06:29	03:38	00:47	04:35
A3a	01:39	16:45	01:10	11:34	13:36	00:37	06:48	03:38	00:49	04:42
A10a	01:28	16:00	01:07	11:03	11:50	00:38	06:57	03:49	00:49	04:48
A12a	01:21	15:16	01:00	10:18	11:03	00:33	06:20	03:24	00:44	04:23
Rear cabin										

Sortie code	'Allowable' exposure durations (hh:mm) for each hearing protection system, calculated to the UEAV of the CNAWRs – Lynx AH Mk9A									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
A1a	01:13	12:41	00:53	08:46	11:50	00:27	04:55	02:42	00:36	03:28
A3a	01:24	13:36	01:00	09:24	13:18	00:30	05:16	02:53	00:40	03:43
A10a	01:17	12:59	00:56	08:58	12:07	00:28	05:09	02:49	00:38	03:38
A12a	01:17	12:59	00:54	08:58	12:07	00:28	05:02	02:49	00:37	03:38

Table D-2: Lynx AH Mk9A 'allowable' exposure durations calculated to the UEAV of the CNAWRs

D.3 Wildcat AH Mk1 – Firing of the GPMG and M3M HMGs

Weapon & Condition	'Allowable' rounds fired for each hearing protection system, calculated to the UEAV of the CNAWRs									
	4A/4	4A/4 + CEP	4B/4L	4B/4L + CEP	4B/4L + VAMP 27	10R-RW	10R-RW + CEP	10R-RW + VAMP 27	ALPHA 928	ALPHA 928 + CEP
Cockpit										
GPMG windows open	0	8,700	0	6,667	5,000	0	4,000	2,400	0	2,720
GPMG windows closed	0	29,000	0	20,000	20,000	0	13,333	8,571	0	9,714
M3M windows open	0	5,118	0	3,636	2,857	0	2,286	1,364	0	1,546
M3M windows closed	0	10,875	0	8,000	6,667	0	5,333	3,158	0	3,579
Forward cabin										
GPMG	0	16,800	0	12,500	9,714	0	8,333	4,545	0	5,455
M3M	0	2,545	0	1,786	1,283	0	1,136	602	0	723
Rear cabin										
GPMG	0	16,000	0	11,333	10,714	0	7,556	4,545	0	5,455
M3M	0	2,424	0	1,619	1,415	0	1,030	602	0	723

Table D-3: Wildcat AH Mk1 - Number of rounds that can be fired per day without exceeding the UEAV of the CNAWR (based on flying eight ALFs per day)

D.4 Lynx AH Mk9A – Firing of the GPMG and M3M HMGs

Weapon & Condition	'Allowable' rounds fired for each hearing protection system, calculated to the UEAV of the CNAWRs									
	4A/4	**4A/4 + CEP**	**4B/4L**	**4B/4L + CEP**	**4B/4L + VAMP 27**	**10R-RW**	**10R-RW + CEP**	**10R-RW + VAMP 27**	**ALPHA 928**	**ALPHA 928 + CEP**
Cockpit										
GPMG windows open	0	8,400	0	6,250	5,000	0	3,000	800	0	2,000
GPMG windows closed	0	28,000	0	18,750	20,000	0	10,000	2,857	0	7,143
M3M windows open	0	4,941	0	3,409	2,857	0	1,714	455	0	1,136
M3M windows closed	0	10,500	0	7,500	6,667	0	4,000	1,053	0	2,632
Forward cabin										
GPMG	0	15,000	0	11,333	8,571	0	5,556	0	0	1,818
M3M	0	2,273	0	1,619	1,132	0	758	0	0	241
Rear cabin										
GPMG	0	15,000	0	10,000	9,714	0	3,889	0	0	1,818
M3M	0	2,273	0	1,429	1,283	0	530	0	0	241

Table D-4: Lynx AH Mk9A - Number of rounds that can be fired per day without exceeding the UEAV of the CNAWR (based on flying eight ALFs per day)

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Report Documentation Page

Originator's Report Number	QINETIQ/MS/AD/CR1700516/1.0		
Originator's Name and Location	[redacted], Room 103, B813W, MOD Boscombe Down		
Customer Contract Number	HELSS/0009		
Customer Sponsor's Post/Name and Location	[redacted], Lynx-Wildcat Project Team, DE&S, MOD		
Report Protective Marking and any other markings OFFICIAL SENSITIVE QinetiQ Proprietary	Date of issue 03 March 2017	Pagination 72 + Covers	No. of references 25
Report Title Wildcat AH Mk1 and Lynx AH Mk9A - Noise and Vibration Assessment			
Translation / Conference details (if translation give foreign title / if part of conference then give conference particulars) N/A			
Title Protective Marking	OFFICIAL SENSITIVE		
Authors	[redacted]		
Downgrading Statement	N/A		
Secondary Release Limitations	N/A		
Announcement Limitations	N/A		
Keywords / Descriptors	Wildcat AH Mk1, Lynx AH Mk9A, Noise, Vibration		

Abstract

ATEC were tasked by the DE&S Lynx-Wildcat Project Team to conduct a noise and vibration assessment of the Wildcat AH Mk1 and Lynx AH Mk9A aircraft to assess ambient noise levels within and external to the aircraft, air and ground crew noise exposure and whole body vibration data for crew positions in the cockpit and cabin. Data was collected on five Wildcat and three Lynx airframes during October and November 2016, using representative flight conditions. Using the Wildcat AH Mk1 and Lynx AH Mk9A Statements of Operating Intent, aircrew noise exposure, for all hearing protection documented within the RTS, was assessed against the most commonly flown sortie profiles; this also including an assessment of noise exposure when firing the Heavy Machine Guns. Ground crew noise exposure during routine see-off / see-in activities on both aircraft types was assessed whilst aircrew and passenger vibration exposure was also assessed for just the Wildcat AH Mk1. Assessment of noise and vibration exposure was with reference to the CNAWR and CVAWR and tabulated such that daily 'allowable' exposure durations were documented for ease of use by the Lynx-Wildcat Project Team.

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0962-7480/96

A survey of hearing loss in army aircrew

[redacted]

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Military aircrew are exposed to excessive noise at work, with the concurrent risks of acquiring Noise Induced Hearing Loss (NIHL). Past studies have related aircrew NIHL to a variety of factors; however, no clear causal relationship has been shown. The difficulty of establishing NIHL due to flying remains when many other confounders are present, especially age and exposure to firearms noise in the military environment. A cross sectional prevalence study of hearing loss in Army Air Corps aircrew has been undertaken. One hundred and twenty one aircrew who had more than ten years flying experience were studied and the results show that there appears to be a threshold shift in excess of that expected from the ISO levels for otologically normal males of the same age. The hearing threshold shift was found to correlate with the number of years flying and aircrew age, with the number of flying hours being less significant.

Occup. Med. Vol. 46, 53–58, 1996

Received 28 June 1995; accepted in final form 12 September 1995.

INTRODUCTION

Military helicopter aircrew are exposed to continuous noise levels which are recognized to cause hearing damage, the Gazelle AH1 helicopter having a mean cockpit noise level of 102 dB(A) L_{EQ}. The weight penalties from increased sound insulation on the aircraft are such that personal protective equipment (the aircrew helmet) provides the only practical solution.

Radio communications, intercom and auditory warning devices form a significant part of the information needed to fly safely and poor hearing is likely to compromise the flight safety. However acquired flying skills may compensate for hearing loss as demonstrated in one of the few studies to look at the effect of impaired hearing on flight safety.[1] The accident rates were examined for 70 US Army aviators who had impaired hearing below the normally acceptable limit but were still flying following a medical examination and issue of a waiver. No relationship was found between accident rates and impaired hearing in this group. The study concluded that the evaluation appeared sensitive enough to recognize those who were medically safe to continue flying.

The effects of noise exposure at the levels encountered in military aviation have been studied in several countries with a variety of conclusions. In 1983 a study of US Army aviators at Fort Rucker by Peters[2] showed an association between the number of flight hours and an increase in hearing loss. These findings were supported by a later study of 178 helicopter pilots in the US Army by Fitzpatrick[3] which concluded that hearing loss in aviators was a function of their noise exposure, as expressed by the number of flying hours completed. A similar study by Edgington[4] who looked at 200 helicopter aircrew in the Army Air Corps (AAC) had shown a relationship between hearing loss and number of years spent flying. However, Ribak *et al.*[5] produced differing results, studying 777 personnel in the Israeli Air Force. This study demonstrated a strong relationship between age and hearing threshold shift, while flying time and aircraft type were only poorly related. The large number of subjects were, however, from different branches of aviation and their noise exposures varied from transport, fighter and light aircraft as well as helicopters.

The varying conclusions from the aforementioned studies demonstrate the difficulties in trying to determine the primary cause of hearing loss when there are several influencing factors. One confounding factor that needs to be taken into account is the natural effect of presbyacusis. There is also the effect of improved hearing protection provided by modern aircrew helmets, combined with a reduction in the number of hours spent flying due to financial and training con-

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straints, which result in a different noise dose over the years. Advances in audiometry have occurred over the same period, with automatic recording and self-calibrating audiometers in acoustically screened booths replacing manual recording machines. When the effects of exposure to impulsive noise from firing military weapons are added, the final relationship between hearing impairment and military flying becomes even more difficult to verify.

This study was designed to assess the hearing status of AAC aircrew and to determine the prevalence of NIHL. The correlation of any contributing factors such as the hours flown, age or years spent flying were also studied in order to try and confirm or refute some of the findings of the studies discussed above.[1-5]

METHODOLOGY

One of the most recent military studies was by Jones in the Royal Navy.[6] This showed that NIHL did not appear to be a problem for aircrew with less than ten years flying experience. Therefore this study was designed to look at AAC aircrew with 10 years or more noise exposure from flying. A cross sectional prevalence survey of aircrew audiograms was established from the annual medical fitness examinations.

AAC personnel who had more than 10 years flying experience were identified. The criterion for inclusion was the initial military aircrew qualification date either as a Helicopter Pilot, Aircrew Observer or Aircrew Gunner. A number of the Observers and Gunners had subsequently retrained as Pilots but had a total of more than 10 years flying time and were included under the latter category.

The aircrew were contacted by letter with a request to complete and return a Flying Log Summary Sheet, which detailed the number of hours flown each year by aircraft type. By transcribing the details from the annual summary section in the Pilots Flying Log Book for all years since qualification, it was possible to obtain the complete flying history for all personnel in the study.

All applicants for military aircrew training undergo a standard medical examination at the RAF Officer and Aircrew Selection Centre (OASC) which is recorded and held in the individual's medical folder (FMed 4). This includes an Ear, Nose and Throat (ENT) history, examination, tympanography and pure tone audiogram. The candidate should be of 'H1' grade, to be considered fit from the ENT aspect. The relevant grades are given in the Joint Services Publication 346[7] as shown below:

H1 Grade

- Normal ENT Examination
- Pure Tone Audiometric loss up to and including 45 dB in either ear, summated over either 0.5, 1 and 2 kHz or 3, 4 and 6 kHz

H2 Grade

- Normal ENT Examination
- Pure Tone Audiometric loss in either ear of up to and including 84 dB summated over 0.5, 1 and 2 kHz, or 123 dB summated over 3, 4 and 6 kHz

Once aircrew training is complete, all aircrew have to undergo an annual medical examination in order to retain their aircrew status. The audiometry standard required to continue in normal flying duties is H2 grade or better. If the audiometric loss is greater, a medical certificate has to be issued to authorize continued flying.

The most recent audiogram result, date and type of recording were noted, along with any abnormality of the ENT examination or relevant comments at the examination summary. The initial OASC examination records were then examined and the same details noted. In those cases which pre-dated the use of audiograms, the notes were examined and the first available audiogram used.

The information for the study was drawn from the FMed 4s during visits to all the medical centres serving AAC bases. The flying and audiometric data were loaded onto a personal computer programmed with the 'FoxPro for Windows' database (Microsoft Corporation). Data analysis was assisted by using the statistics software package 'SPSS for Windows' (SPSS Inc.).

Flying data was recorded for the number of hours flown annually for each aircraft type and the career total number of flying hours by aircraft type was calculated. The year of qualification, age at qualification and number of years flying were also recorded.

The audiometric data was classified by date, whether a manual or automatic recording, and then for both ears as a threshold shift from zero for the frequencies: 500 Hz, 1, 2, 3, 4 and 6 kHz. The sum of the low frequency threshold shift over 500 Hz, 1 and 2 kHz was calculated, as was the sum of the high frequencies over 3, 4 and 6 kHz.

Table 1. Analysis of the difference between the first and last audiograms

Difference measured	*Mean of the diff.*	*sd*	*SE of the mean*	*t value*	*p value*
Rt: low freq (1st–2nd)	4.61	26.48	1.98	2.33	0.021
Lt: low freq (1st–2nd)	2.74	17.22	1.29	2.13	0.035
Rt: lhighfreq (1st–2nd)	28.80	38.14	2.85	10.10	<0.001
Lt: lhighfreq (1st–2nd)	31.59	31.92	2.39	13.25	<0.001

Degrees of freedom=178

Table 2. Summary of the changes in hearing threshold recorded between first and last audiograms

Grouped frequency ranges	*Median change (dB)*	*Mean change (dB)*	*Greatest 'improvement' from first–last (dB)*	*Greatest loss from first–last (dB)*
Right low frequencies (Sum 0.5, 1 and 2 kHz)	4	4.6	50	199
Left low frequencies (Sum 0.5, 1 and 2 kHz)	5	2.6	45	65
Right high frequencies (Sum 3, 4 and 6 kHz)	20	28.8	30	294
Left high frequencies (Sum 3, 4 and 6 kHz)	29	31.6	51	160

Table 3. Pearsons correlation between hearing threshold, age, flying years and flying hours

	Age		*Years flying*		*Flying time*	
Frequency (Hz)	*Right ear*	*Left ear*	*Right ear*	*Left ear*	*Right ear*	*Left ear*
500	0.267 p=0.003**	0.145 p=0.11	0.261 p=0.004**	0.218 p=0.016*	0.101 p=0.27	0.107 p=0.24
1000	0.320 p<0.001***	0.293 p=0.001**	0.330 p<0.001***	0.340 p<0.001***	0.146 p=0.11	0.011 p=0.90
2000	0.405 p<0.001***	0.438 p<0.001***	0.430 p<0.001***	0.481 p<0.001***	0.157 p=0.086	0.277 p=0.002**
3000	0.496 p<0.001***	0.437 p<0.001***	0.499 p<0.001***	0.499 p<0.001***	0.275 p=0.002**	0.253 p=0.005**
4000	0.466 p<0.001***	0.448 p<0.001***	0.495 p<0.001***	0.450 p<0.001***	0.264 p=0.004**	0.262 p=0.004**
6000	0.305 p=0.001**	0.367 p<0.001***	0.318 p<0.001***	0.331 p<0.001***	0.136 p=0.136	0.099 p=0.276
Low diff. (1st–2nd)	0.199 p=0.029*	0.029 p=0.751	0.229 p=0.011*	0.103 p=0.257	0.066 p=0.474	-0.375 p=0.683
High diff (1st–2nd)	0.217 p=0.017*	0.185 p=0.042*	0.234 p=0.010*	0.176 p=0.053	0.205 p=0.024*	0.105 p=0.252

n = 121; *p<0.05; **p<0.01; ***p<0.001

The absolute hearing threshold shift was calculated from the last audiogram to assess the present hearing status. The flying career threshold shift was calculated as the difference between the first and last audiograms, along with the age at both audiograms. The audiograms from automatic and computer controlled audiometers were adjusted to equate with those for the manual ones, by adding 3 dB to each test frequency in accordance with the recommendations in the International Organization for Standardization (ISO) Publication 6189.[8] In order to facilitate the analysis the results were grouped into 5-year age bands.

It was then possible to examine whether there was a correlation between the hearing threshold shift, with factors such as age, number of years flying and total number of flight hours. The median hearing thresholds for the aircrew were compared to those for normal males using the formulae from ISO 1999.[9] The median hearing threshold shift for each aircrew age group were then compared to the ISO levels in order to assess their hearing level against a standardized datum. As the applicants to fly had been initially examined at their own units prior to applying for aircrew duties and they all fulfilled the medical criteria for army service as detailed in JSP 346, they have been treated as a 'highly-screened' otologically normal population in accordance with ISO 7029.[10]

RESULTS

Flying log data

Two hundred and twenty eight aircrew were sent a request to complete a Flying Log Sheet. Replies were received from 184 personnel (80.7%) of which seven had commenced terminal leave or had been discharged. Four returned forms were incomplete or unclear and had to be excluded, leaving n=173.

The replies analyzed revealed that most of the aircrew had flown up to four different aircraft types, though some had much wider experience with one pilot having flown 32 types of aircraft. The mean total flying time=3,349 hrs (range=896–7,512 hrs, sd=1500 hrs). The mean aircrew age=40 yrs (range=32–55 yrs, sd=5 yrs), and the mean number of years flying=15.6 yrs (range=10–32 yrs, sd=5 yrs).

Audiometry data

Audiometric data was available for 179 aircrew. Twenty-two of the personnel were below the H1 hearing level at the time of their first audiogram: five exceeding the limit in the low frequency (0.5, 1 and 2 kHz), 15 in the high frequency (3, 4 and 6 kHz) and two in both groups.

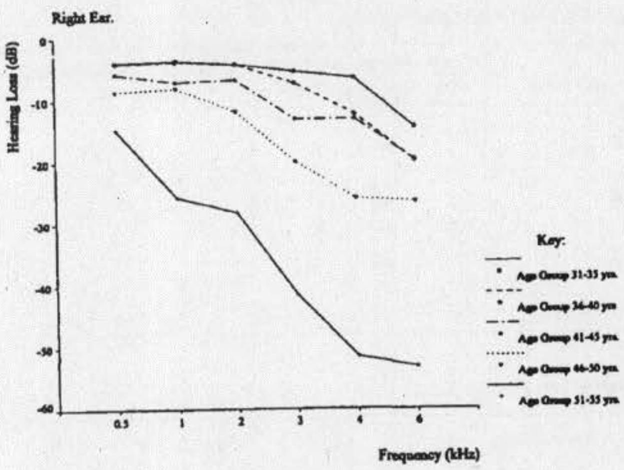

Figure 1. Mean hearing loss for each age group at last audiogram (right ear)

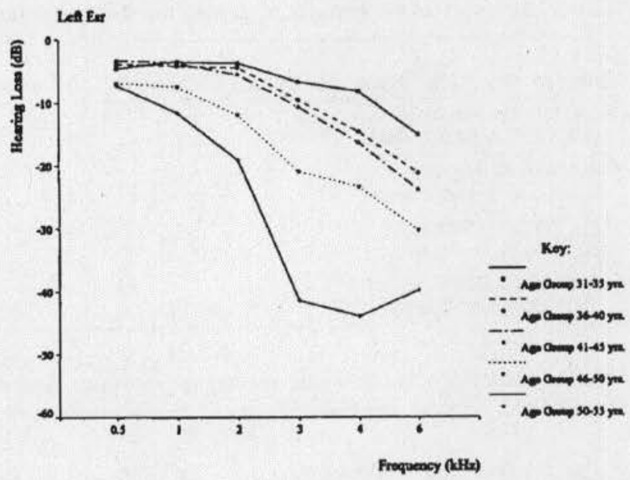

Figure 2. Mean hearing loss for each age group at last audiogram (left ear)

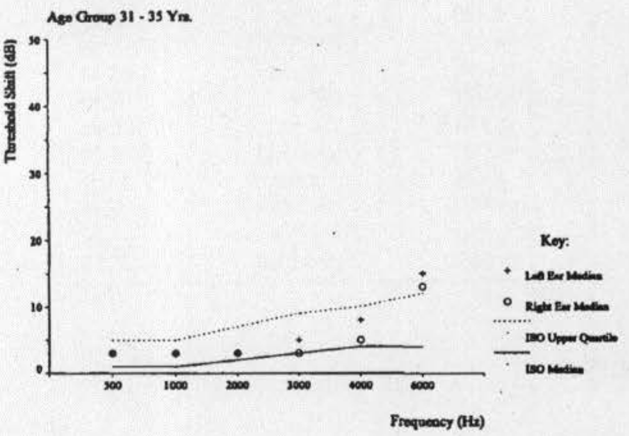

Figure 3. Hearing threshold shift at last audiogram. Aircrew compared to ISO normal males.

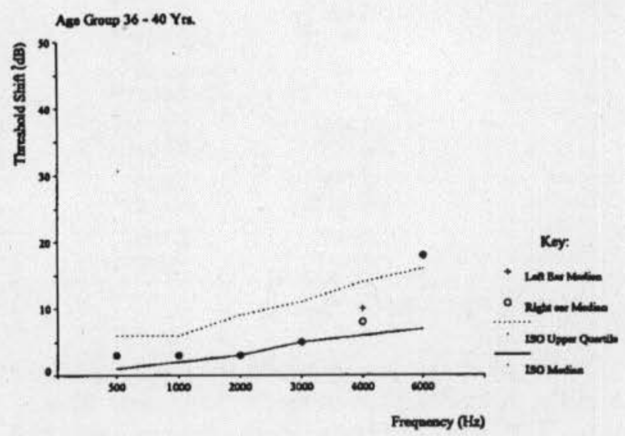

Figure 4. Hearing threshold shift at last audiogram. Aircrew compared to ISO normal males.

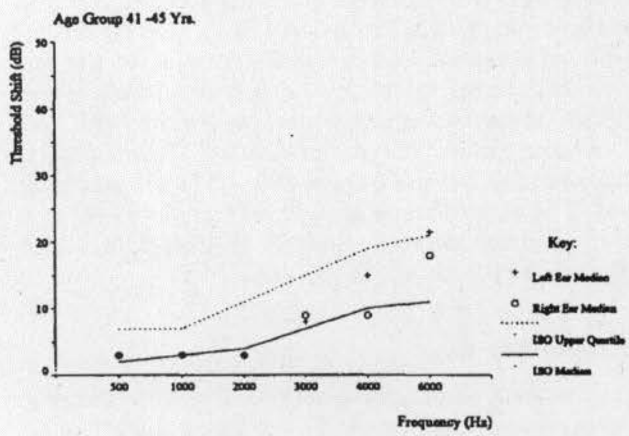

Figure 5. Hearing threshold shift at last audiogram. Aircrew compared to ISO normal males.

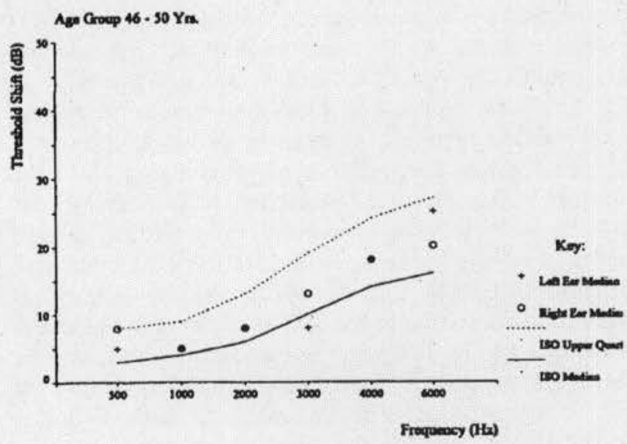

Figure 6. Hearing threshold shift at last audiogram. Aircrew compared to ISO normal males.

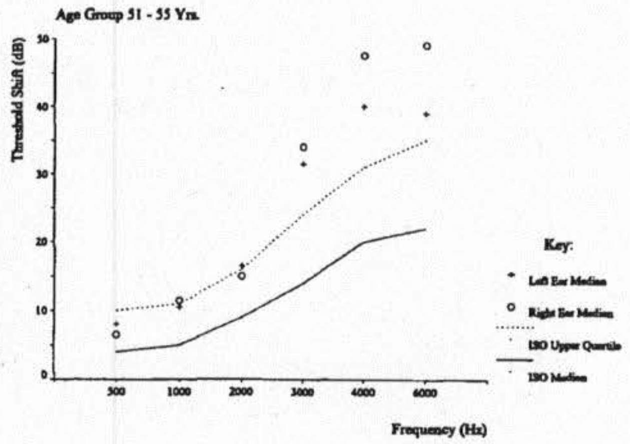

Figure 5. Hearing threshold shift at last audiogram. Aircrew compared to ISO normal males.

For the last audiogram 78 personnel were below the H1 hearing level: one exceeding the limit in the low frequency (0.5, 1 and 2 kHz), 67 in the high frequency (3, 4 and 6 kHz) and 10 in both groups. Seventeen of the aircrew were below the H2 standard (14 cases with high frequency loss and three cases with both high and low frequency loss). The mean hearing deficit for each ear, at each test frequency, was plotted for the last audiogram by 5-year age groups (Figures 1 and 2), and shows an increasing hearing deficit with age.

There was a significant difference between the first and last audiograms for both high and low frequencies in both ears (Table 1), which is not unexpected over a period of ten years or more. However no significant difference was found between the left and right ears for either set of audiograms, which might have been expected within the military environment due to exposure to firearms noise. A large spread in the difference between the first and last audiograms was also noted with some showing an apparent improvement of up to 50 dB in a grouped frequency band (Table 2).

The data from the last audiograms were plotted for each test frequency against the ISO Normal range, (Figures 3–7). This showed that the median values for the aircrew hearing thresholds exceed the ISO Upper Quartile level at 6,000 Hz in three out of the five age groups (31–35 yrs, 36–40 yrs, and 51–55 yrs), and in the left ear in a fourth group (41–45 yrs).

There were 121 personnel for whom both flying and audiometric data was held. These records were examined for the correlation between age, flying experience and hearing status using [redacted] correlation coefficient (Table 3). The flying experience was based on the total hours flying and number of years flying. The hearing status was based on the threshold shift measured at the last audiogram and the difference between the first and last audiograms (both ears, high and low frequencies). The results showed a number of significant correlations between these criteria. The best correlation was between the number of years flying and the threshold shift at the last audiogram ($p<0.001$), with the correlation coefficient ranging between 0.402–0.483.

DISCUSSION

The audiogram results indicate that there is some degree of hearing loss experienced by the aircrew which is in excess of that expected from ageing alone. The graphical representation of the mean hearing loss for each age group (Figures 1 and 2) shows the development of a '4 kHz Notch' especially in the left ears of the 51–55 year age group. The analysis of the difference between the first and last audiograms also shows a more significant change for the high frequencies ($p<0.001$, for both ears) than for the low ones ($p=0.021$ for the right; $p=0.035$ for the left). However caution should be used in this comparison as the quality of the initial audiograms may be questionable. This was evident by the wide spread of changes in threshold between first and last test, with several of the personnel showing an apparent improvement of 30–50 dB in the low and high grouped frequencies. The comparison of aircrew hearing data with ISO 1999 does though support the evidence of there being an excess hearing loss over that due to presbyacusis, notably at 6 kHz.

The correlation of hearing status with flying experience was best when comparing the number of years flying with the high frequency threshold shift for both ears at the last audiogram. A similar picture emerged when correlating hearing status to the age of the aircrew at the last audiogram.

In the study by [redacted] *et al.* of over 700 aircrew, the conclusion was that hearing threshold shift was principally a result of ageing rather than number of hours flying, whilst [redacted] showed hearing loss to be best related to the total number of flight hours.

These results do show a correlation of hearing threshold with age and also with the number of years flying. This is not unreasonable as both of these factors are time dependent. The correlation with flying hours was much less marked, tending to go against the findings of [redacted] From the comparison with ISO 1999 it is apparent that the degree of high frequency hearing loss is greater than that due to age alone, though from this study it is not possible to identify further whether the deficit is due to a flying or non-flying cause.

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Abstract for Aerospace Medical Association Annual Scientific Meeting:

HEARING PROTECTION IN BRITISH ARMY LYNX AND APACHE AIRCREW

[redacted][1], [redacted][2], [redacted][2]

Background: The Lynx and Apache helicopters are the predominant operational rotary wing airframes currently in service with the British Army. However, pilots of the Apache are required to wear the Integrated Helmet And Display Sight System (IHADSS) rather than the UK standard Mk4 rotary wing helmet. The IHADSS helmet provides less hearing protection with a mean insertion loss of 19 dB(A) compared to 22 dB(A) for the Mk4 helmet. It was necessary to assess the impact of this reduction in hearing protection under UK Health and Safety legislation. **Method:** Lynx and Apache pilots with more than five years of exposure and currently serving in the Army Air Corps were surveyed by written questionnaire. Subjects provided information regarding flying hours per annum, use of hearing protection, and subjective ratings of hearing loss and tinnitus. Subjects then had two audiograms with a minimum five year interval analyzed. Age correction for each subject was performed according to data from ISO 7029. Absolute hearing threshold shift and flying career threshold shift were examined. **Results:** Hearing threshold shifts increased with age as to be expected. However, no statistically significant differences in hearing thresholds were found either within groups or between groups. **Conclusions:** The reduced protection provided by the IHADSS helmet does not appear to be adversely affecting the hearing of this cross-sectional cohort of Apache aircrew. The use of Communications Ear Plugs provides subjective improvement in pilots' ability to monitor the cockpit audio environment.

Learning Objectives: 1. To understand the impact of hearing loss on aviator performance. 2. To understand the limitations of passive protection provided by aviator helmets. 3. To understand the impact of Health and Safety legislation on military aviation.

Question: Hearing loss in aircrew is due to:

1. Aircraft engine noise?
2. Inadequate personal protective equipment?
3. Recreational noise exposure?
4. Age-related hearing loss (presbyacussis)?
5. All of the above?

Answer: 5

[1] RAF Centre of Aviation Medicine, Henlow, Bedfordshire, UK

[2] HQ, Army Air Corps , Middle Wallop, Hampshire, UK

APPENDICES

APPENDICES

TABLES

APPENDIX 1

MILITARY PULHHEEMS GRADING SYSTEM - HEARING

The British Military uses a common grading system for medical fitness, called by the acronym PULHHEEMS. The HH grades relate to hearing in the right and left ears respectively, as laid down in Joint Service Publication 346, and shown at Table A1. The other elements of PULHHEEMS are not relevant to hearing. The H grades are based on summed tones, being low tones at 500Hz, 1kHz and 2 kHz, and high tones, being 3kHz, 4kHz and 6kHz. Although the RAF has recorded 8kHz for some years, this has only recently become mandatory, and is still not used in the PULHHEEMS grading.

H Grade	Summed Low tones 500Hz, 1 & 2 kHz	Summed High tones 3,4 & 6 kHz	Plain language
H1	≤45dB	≤45dB	Good Hearing
H2	>45dB ≤84 dB	>45 dB ≤123 dB	Acceptable practical hearing for Service purposes
H3	>84 dB ≤150 dB	>123 dB ≤210 dB	Impaired hearing.
H4	>150 dB	>210 dB	Very poor hearing
H8	>150 dB	>210 dB	Hearing so poor that invaliding is required

Table A1 PULHHEEMS Hearing gradings

In addition to this, the RAF uses a Medical Employment System based on fitness for duties in the Air, on the Ground, and in different Zones in the world, called the AGZ system. An A2 marker is awarded when aircrew require corrective flying spectacles, or their hearing deteriorates into the H2 bracket, but no more than 60dB at the low tones, or 85dB at the high tones.

APPENDIX 3

DATA CHECKING AND VALIDATION

Systematic checks were carried out to ensure that errors in data capture were within acceptable limits.

Audiometry

Each Audiometry forms contained 16 pieces of data on each form. 58 separate audiometry records were checked, giving a total of 928 separate pieces of data.

Errors were found for the following subjects:

B103 x 1

B229 x 1 (effected result)

C 176 x 1

The overall error rate was 5.2%, the significant error rate being 1.7%. If the total number of data checked are used as the denominator instead of the records, the overall transcription error rate falls to 0.3%, and significant error rate to 0.1%.

Questionnaires

Every 10th record was checked against the Access database, being 15 questionnaires in all.

Each questionnaire had 18 main questions and flying log data. If the question sub data was included, there were 71 data fields, with an additional 3 pieces of demographic data, giving 74 data fields in total and 1110 pieces of data in total.

Errors were found for the following subjects:

B107 x1 UAS start year incorrect

B166 x1 Noisy hobby unticked

B195 x1 Noisy hobby days total incorrect

C140 x1 Flying hours incorrect (one years worth missed)

C164 x 1 Noisy hobby unticked

D155 x 1 one extra hour recorded on flying log data

The transcription error rate was therefore 0.6%.

APPENDIX 4

HSE HEARING LOSS CRITERIA

The HSE hearing gradings require summation of hearing thresholds as measured on audiometry to obtain a single value for each ear. Table A4-1 details the relevant gradings as follows:

Category 1 - acceptable hearing ability.

Category 2 - mild hearing impairment.

Category 3 - poor hearing

The table also defines Category 4 as rapid hearing loss if there has been a rapid loss in hearing within the last 3 years.

Category	Calculation	Action
1 ACCEPTABLE HEARING ABILITY Hearing within normal limits.	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz	None
2 MILD HEARING IMPAIRMENT Hearing within 20th percentile, ie hearing level normally experienced by 1 person in 5. May indicate developing NIHL.	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz. Compare value with figure given for appropriate age band and gender in HSE Table	Warning
3 POOR HEARING Hearing within 5th percentile, ie hearing level normally experienced by 1 person in 20. Suggests significant NIHL.	Sum of hearing levels at 1, 2, 3, 4 and 6 kHz. Compare value with figure given for appropriate age band and gender in HSE Table.	Referral
4 RAPID HEARING LOSS Reduction in hearing level of 30 dB or more, within 3 years or less. Such a change could be caused by noise exposure or disease.	Sum of hearing levels at 3, 4 and 6 kHz	Referral

Table A4-1: The HSE categorisation scheme.

The figures used to calculate the age related criteria for males are given at Table A4-2.

Sum of hearing levels 1, 2, 3, 4 and 6 kHz		
Age	Males	
	Warning level	Referral level
18-24	51	95
25-29	67	113
30-34	82	132
35-39	100	154
40-44	121	183
45-49	142	211
50-54	165	240
55-59	190	269
60-64	217	296
65	235	311

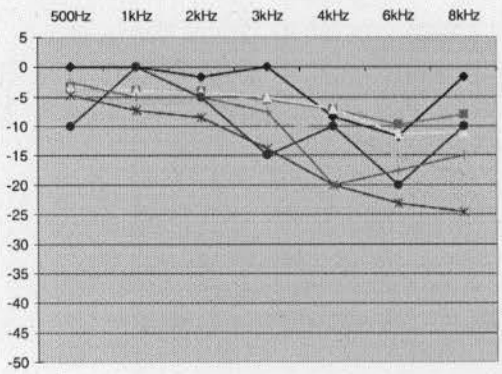
Table A4-2: HSE Criteria for warning and referral levels.

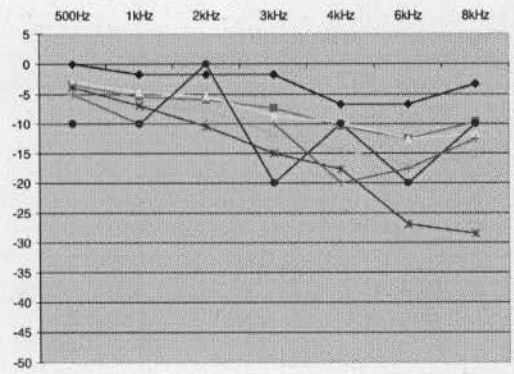
The final HSE criterion is that of unilateral hearing loss. To calculate this, the sum of the hearing levels at 1, 2, 3 and 4 kHz is compared for both ears. If the difference between the ears is greater than 40 dB the individual should be referred.

APPENDIX 5

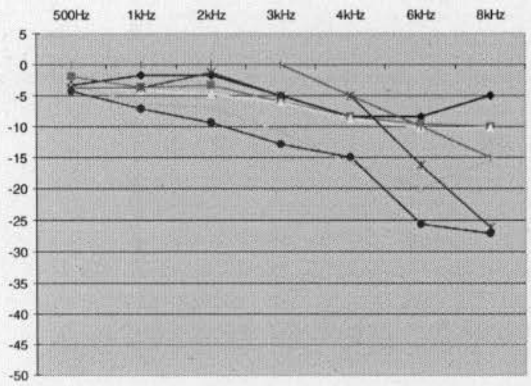
AVERAGED AUDIOGRAMS BY AIRCRAFT GROUP AND AGE

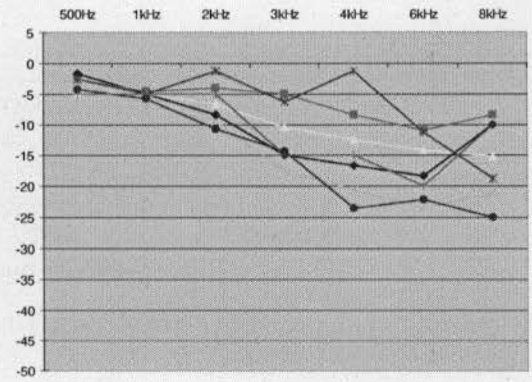
All Subjects by aircraft group



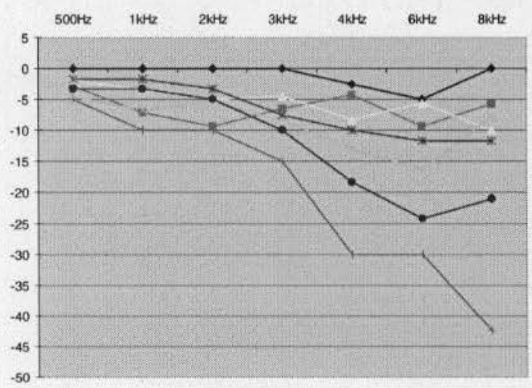


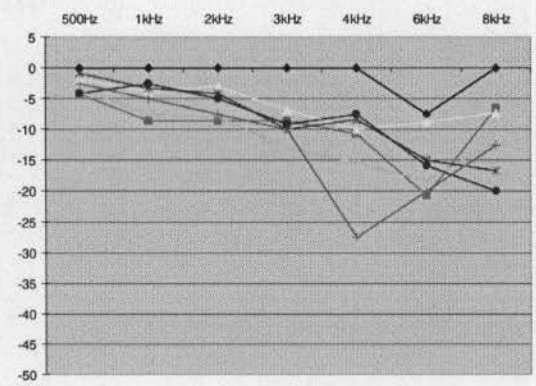
Right **Fast Jet All Subjects** **Left**





Right **Transport All Subjects** **Left**





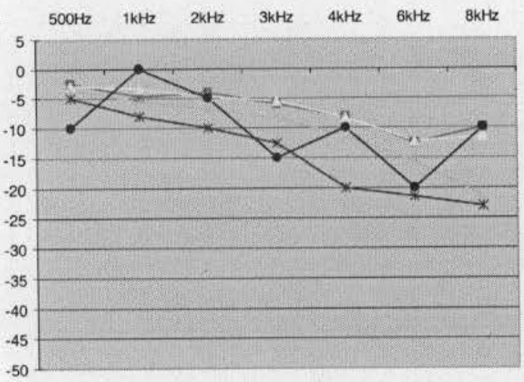
Right **Rotary All Subjects** **Left**

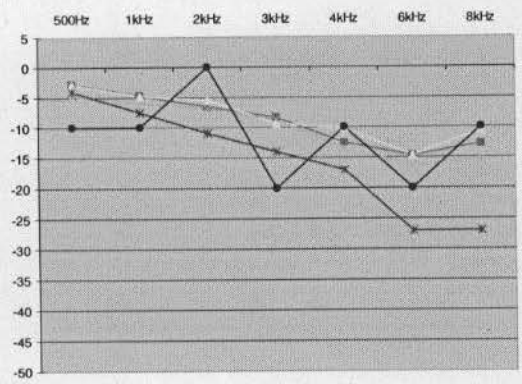
	Age	Fast Jet	Transport	Rotary
	24-29	n= 3	n= 3	n= 2
	30-34	n= 32	n= 21	n= 7
	35-39	n= 51	n= 23	n= 17
	40-44	n= 34	n= 16	n= 12
	45-49	n= 13	n= 4	n= 6
	50-54	n= 1	n= 7	n= 6
	55-59	n= 2	n= 1	n= 2

The appearance of a notch pattern most consistent in youngest age group for both ears and groups, but this is based on low numbers throughout.

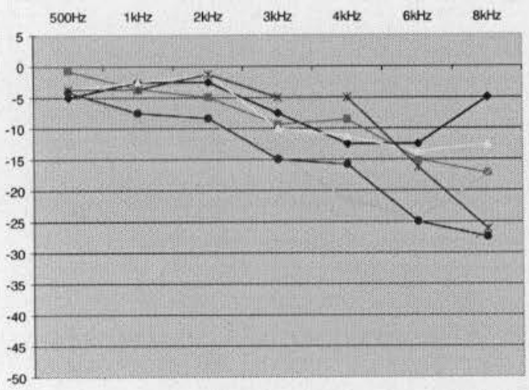
A possible notch pattern seen in rotary 40-44 group, but centred at 6kHz

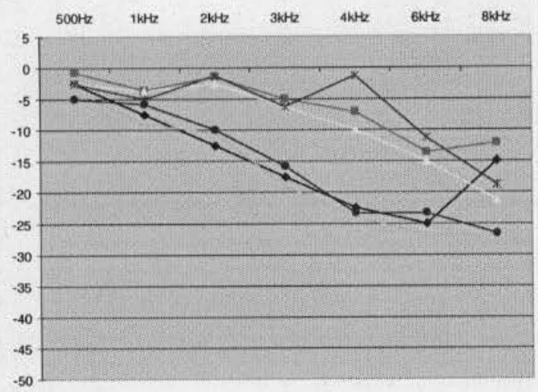
Responders by aircraft group



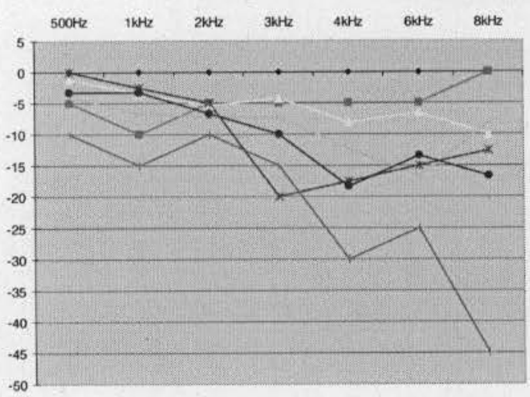


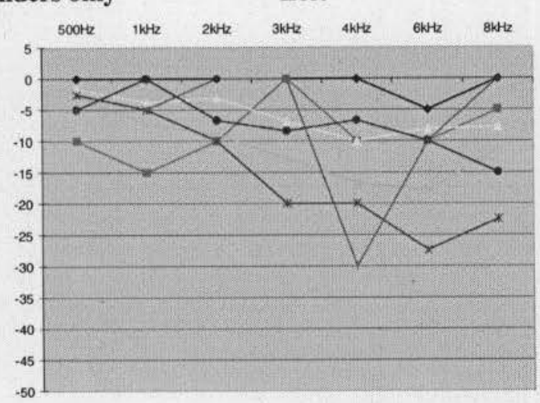
Right **Fast Jet Responders only** **Left**





Right **Transport Responders only** **Left**



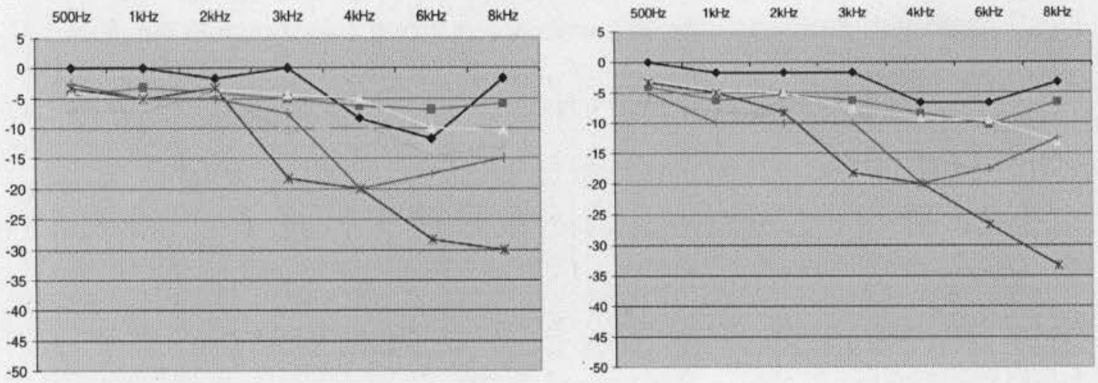


Right **Rotary Responders only** **Left**

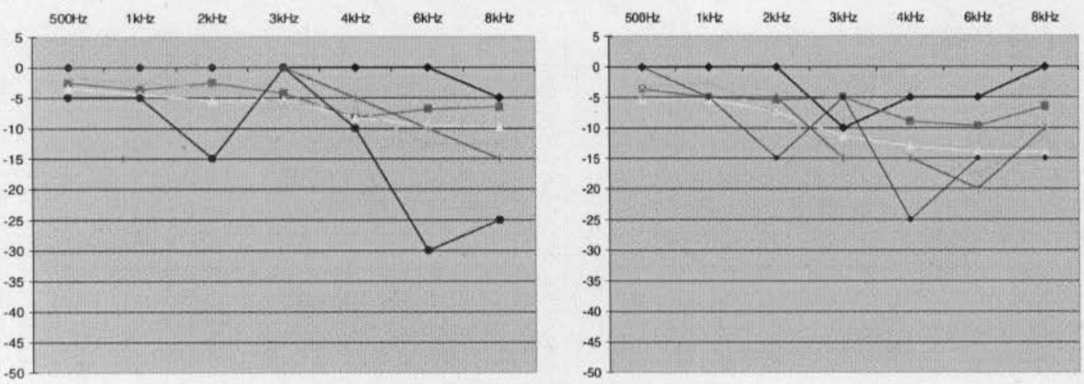
Age	Fast Jet	Transport	Rotary
24-29	n= 0	n= 2	n= 1
30-34	n= 16	n= 7	n= 1
35-39	n= 30	n= 4	n= 13
40-44	n= 21	n= 10	n= 9
45-49	n= 10	n= 4	n= 3
50-54	n= 1	n= 6	n= 2
55-59	n= 0	n= 0	n= 1

In the responders group, the most convincing for kilohertz notch pattern is seen in the transport group right ear in youngest age group, based on low numbers. At 40 to 44 age group in rotary wing has a notch pattern worse at 6 kHz

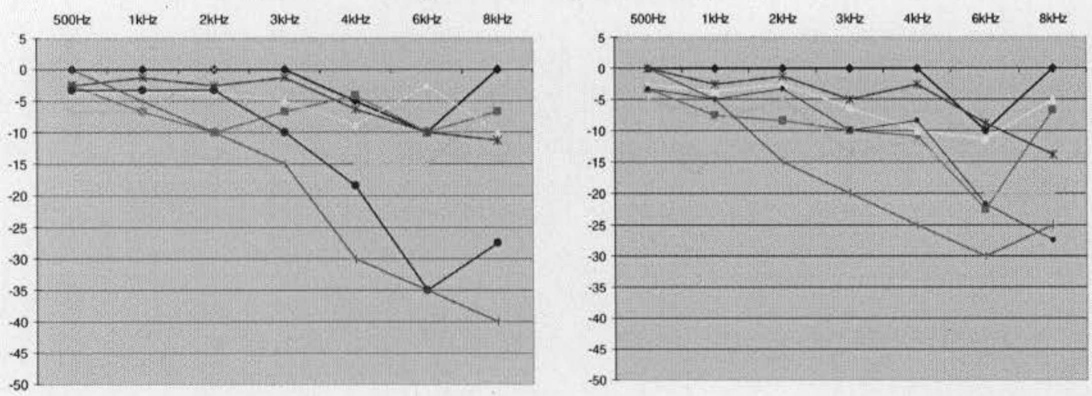
Non responders by aircraft group



Right Fast Jet Non responders only Left



Right Transport Non responders only Left



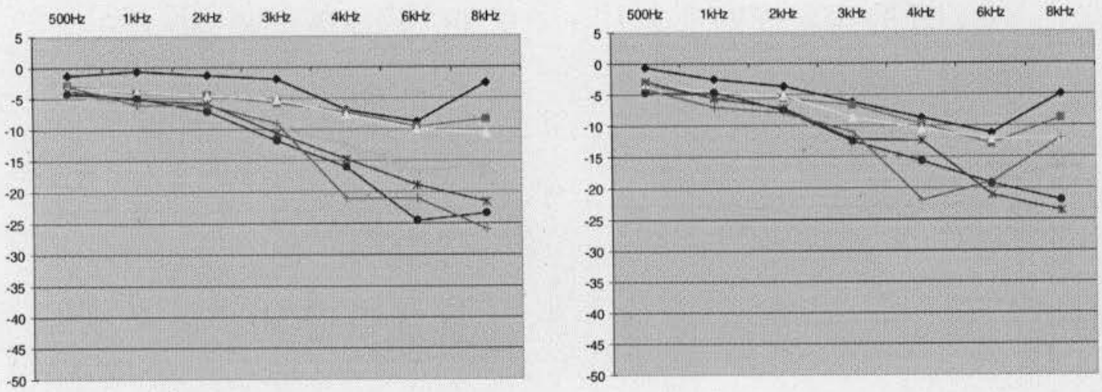
Right Rotary Non responders only Left

	Age	Fast Jet	Transport	Rotary
	24-29	n= 3	n= 1	n= 1
	30-34	n= 16	n= 14	n= 6
	35-39	n= 21	n= 19	n= 4
	40-44	n= 13	n= 6	n= 3
	45-49	n= 3	n= 0	n= 4
	50-54	n= 0	n= 1	n= 3
	55-59	n= 2	n= 1	n= 1

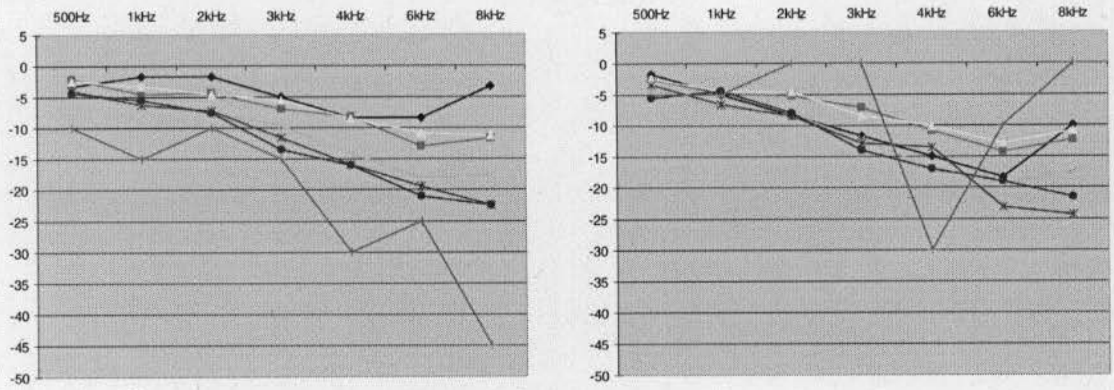
In the non-responders group, the youngest age group for fast jet and transport approximates to 4 kHz notch, but again with low numbers. Age 30 to 34 and 40 to

44 in the transport group left ear has a notch again worse at 6 Hz, with the most convincing pattern being in the age 40 to 44 Rotary Wing right ear.

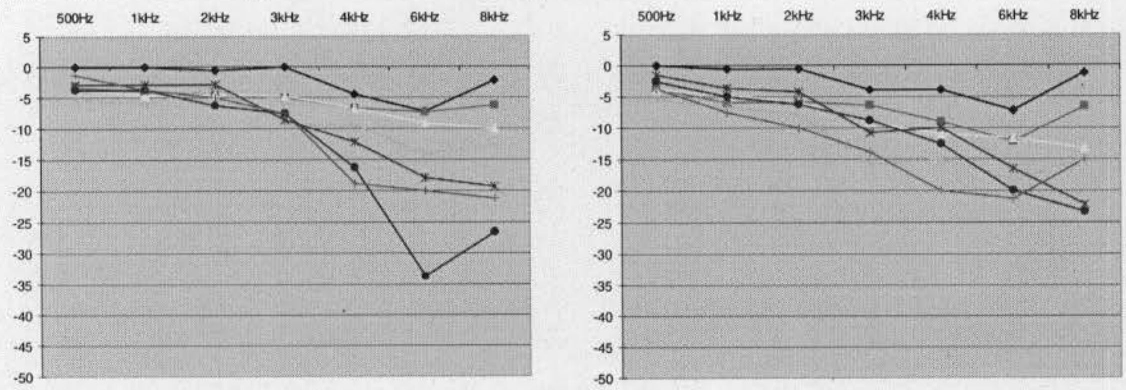
Collated results by all results, questionnaire responders and non responders



Right **All Subjects** **Left**



Right **All Responders** **Left**



Right **All Non Responders** **Left**

	Age	All personnel		Responders only		Non responders	
	24-29	n=	8	n=	3	n=	5
	30-34	n=	60	n=	24	n=	36
	35-39	n=	91	n=	47	n=	44
	40-44	n=	62	n=	40	n=	22
	45-49	n=	23	n=	16	n=	7
	50-54	n=	14	n=	10	n=	4
	55-59	n=	5	n=	1	n=	4

In the collated groups, for all personnel a 4 kHz notch pattern is seen in the youngest age group right ear, and a 6 kHz notch in the left ear. In the left ear, the oldest age group does appear to show a 4 kHz notch. When broken down into responders and non-responders, notch remains in the youngest age group in both groups, some notch pattern being seen in the non-responders group left ear and age 30 to 34 and 50 to 59 as well.

APPENDIX 6

DETAILED STATISTICAL ANALYSES OF SUBJECTIVE VS OBJECTIVE HEARING MEASURES

A number of analyses were conducted using Chi squared and Fishers exact test to compare subjective and objective hearing. These are presented below at Tables A6.

Count		Do you notice problems hearing at work (non flying)?			
		No	Yes	Total	Significance
Hearing worse than expected Right High Tones?	No	80	13	93	
	Yes	36	11	47	0.162
	Total	116	24	140	
Hearing worse than expected Left High Tones?	No	72	10	82	
	Yes	45	14	59	0.072
	Total	117	24	141	
Hearing worse than expected Right Low Tones?	No	72	14	86	
	Yes	45	10	55	0.679
	Total	117	24	141	
Hearing worse than expected Left Low Tones?	No	71	17	88	
	Yes	46	7	53	0.350
	Total	117	24	141	
HSE Warning criteria exceeded in either ear Final audiometry?	False	110	21	131	
	True	7	3	10	0.374 †
	Total	117	24	141	
HSE Referral criteria exceeded in either ear Final audiometry?	False	114	23	137	
	True	3	1	4	0.530 †
	Total	117	24	141	
HSE Unilateral deafness criteria Final audiometry?	False	114	23	137	
	True	3	1	4	0.530 †
	Total	117	24	141	

† Fishers Exact Test

Table A6 – 1: Subjective problems hearing at work vs objective outcomes

		Do you notice problems hearing when flying?			
		No	Yes	Total	Significance
Hearing worse than expected Right High Tones?	No	77	16	93	0.77
	Yes	38	9	47	
	Total	115	25	140	
Hearing worse than expected Left High Tones?	No	68	14	82	0.622
	Yes	47	12	59	
	Total	115	26	141	
Hearing worse than expected Right Low Tones?	No	69	17	86	0.611
	Yes	46	9	55	
	Total	115	26	141	
Hearing worse than expected Left Low Tones?	No	72	16	88	0.919
	Yes	43	10	53	
	Total	115	26	141	
HSE Warning criteria exceeded in either ear Final audiometry?	False	107	24	131	1.00 †
	True	8	2	10	
	Total	115	26	141	
HSE Referral criteria exceeded in either ear Final audiometry?	False	112	25	137	0.562 †
	True	3	1	4	
	Total	115	26	141	
HSE Unilateral deafness criteria Final audiometry?	False	112	25	137	0.562 †
	True	3	1	4	
	Total	115	26	141	

† Fishers Exact Test

Table A6 – 2: Subjective problems hearing when flying vs objective outcomes

		Do you notice problems hearing socially?			
		No	Yes	Total	Significance
Hearing worse than expected Right High Tones?	No	50	43	93	
	Yes	21	26	47	0.31
	Total	71	69	140	
Hearing worse than expected Left High Tones?	No	49	33	82	
	Yes	23	36	59	**0.015**
	Total	72	69	141	
Hearing worse than expected Right Low Tones?	No	45	41	86	
	Yes	27	28	55	0.708
	Total	72	69	141	
Hearing worse than expected Left Low Tones?	No	48	40	88	
	Yes	24	29	53	0.287
	Total	72	69	141	
HSE Warning criteria exceeded in either ear Final audiometry?	False	70	61	131	
	True	2	8	10	0.052 †
	Total	72	69	141	
HSE Referral criteria exceeded in either ear Final audiometry?	False	71	66	137	
	True	1	3	4	0.359 †
	Total	72	69	141	
HSE Unilateral deafness criteria Final audiometry?	False	72	65	137	
	True	0	4	4	0.055 †
	Total	72	69	141	

† Fishers Exact Test

Table A6 – 3: Subjective problems hearing in social settings vs objective outcomes

		When in noisy environments is your hearing				
		Better	The same	Worse	Total	Significance
Hearing worse than expected Right High Tones?	No	2	37	54	93	
	Yes	0	19	28	47	0.935 †
	Total	2	56	82	140	
Hearing worse than expected Left High Tones?	No	1	35	46	82	
	Yes	1	21	37	59	0.747 †
	Total	2	56	83	141	
Hearing worse than expected Right Low Tones?	No	2	33	51	86	
	Yes	0	23	32	55	0.699 †
	Total	2	56	83	141	
Hearing worse than expected Left Low Tones?	No	1	34	53	88	
	Yes	1	22	30	53	0.870 †
	Total	2	56	83	141	
HSE Warning criteria exceeded in either ear Final audiometry?	False	1	54	76	131	
	True	1	2	7	10	0.059 †
	Total	2	56	83	141	
HSE Referral criteria exceeded in either ear Final audiometry?	False	1	55	81	137	
	True	1	1	2	4	0.079 †
	Total	2	56	83	141	
HSE Unilateral deafness criteria Final audiometry?	False	1	56	80	137	
	True	1	0	3	4	**0.016** †
	Total	2	56	83	141	

† Fishers Exact Test

Table A6 – 4: Subjective hearing in noisy environments vs objective outcomes

		Do you think your hearing has been damaged by noise exposure associated with flying?				
		Yes	Not sure	No	Total	Significance
Hearing worse than expected Right High Tones?	No	41	44	8	93	0.672 †
	Yes	23	22	2	47	
	Total	64	66	10	140	
Hearing worse than expected Left High Tones?	No	35	40	7	82	0.575 †
	Yes	30	26	3	59	
	Total	65	66	10	141	
Hearing worse than expected Right Low Tones?	No	42	39	5	86	0.617
	Yes	23	27	5	55	
	Total	65	66	10	141	
Hearing worse than expected Left Low Tones?	No	37	46	5	88	0.225
	Yes	28	20	5	53	
	Total	65	66	10	141	
HSE Warning criteria exceeded in either ear Final audiometry?	False	58	63	10	131	0.309
	True	7	3	0	10	
	Total	65	66	10	141	
HSE Referral criteria exceeded in either ear Final audiometry?	False	62	65	10	137	0.529 †
	True	3	1	0	4	
	Total	65	66	10	141	
HSE Unilateral deafness criteria Final audiometry?	False	63	64	10	137	1.00 †
	True	2	2	0	4	
	Total	65	66	10	141	

† Fishers Exact Test

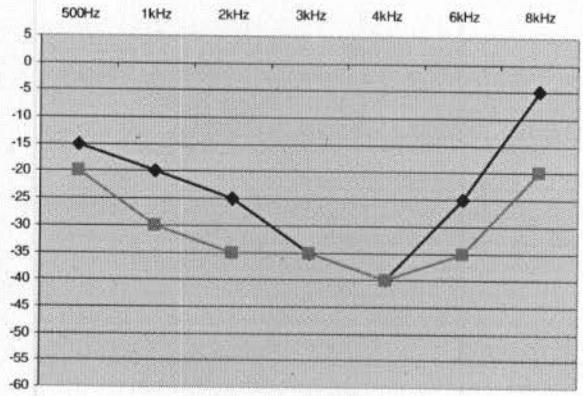
Table A6 – 5: Subjective assessment of flying related hearing damage vs objective outcomes

APPENDIX 7

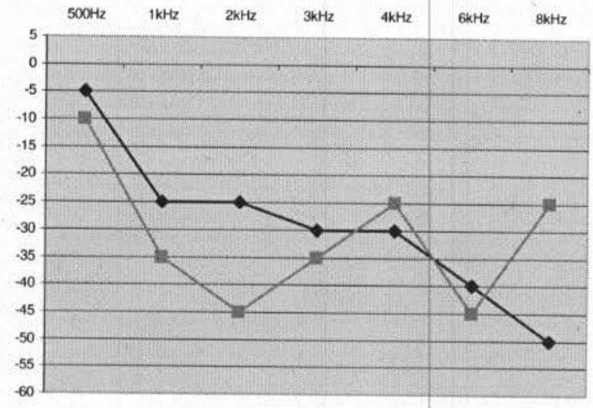
INDIVIDUAL AUDIOGRAMS WITH NOTES

Individual audiograms are presented here for those who were in either the HSE referral or unilateral hearing loss categories at the final audiogram. Comments relating to the individual are tabulated below.

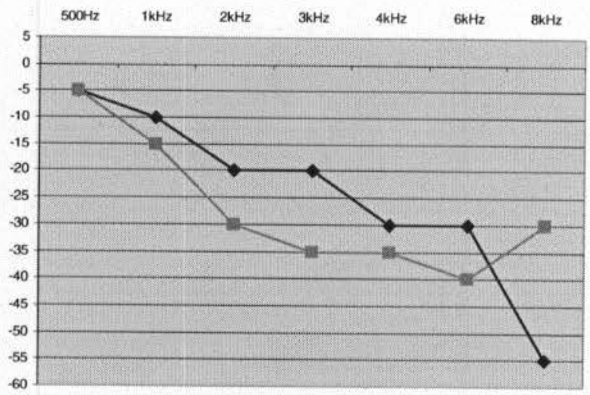
Questionnaire Responders



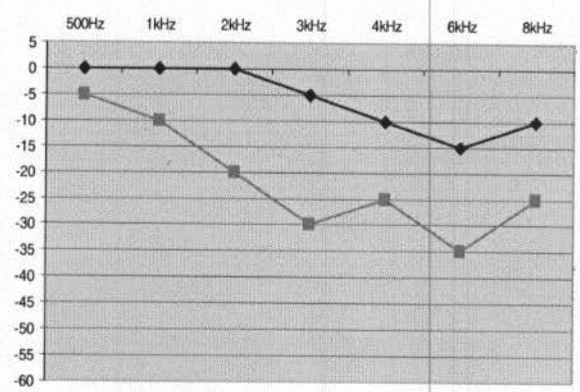
B153 HSE Referral Category



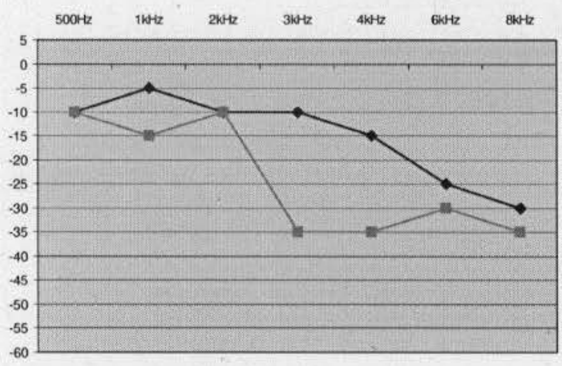
B170 HSE Referral Category



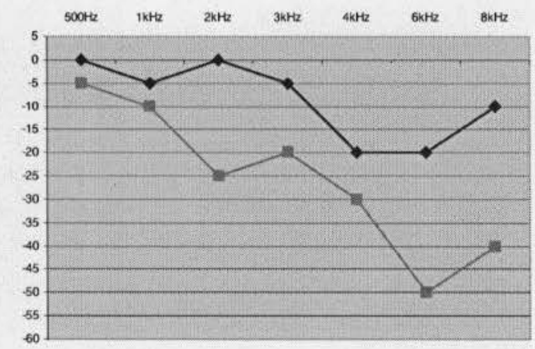
B178 HSE Referral Category



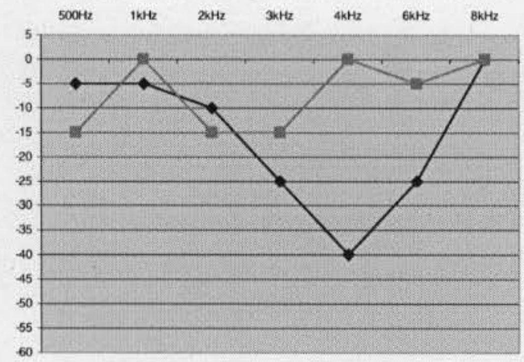
C144 HSE Referral Category & Unilateral Deafness



B107 HSE Unilateral Deafness criteria

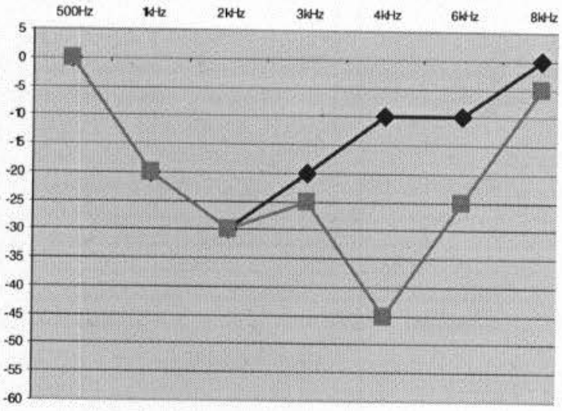


C102 HSE Unilateral Deafness criteria

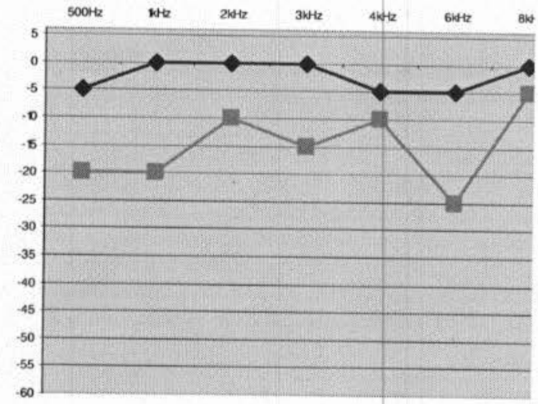


D156 HSE Unilateral Deafness criteria

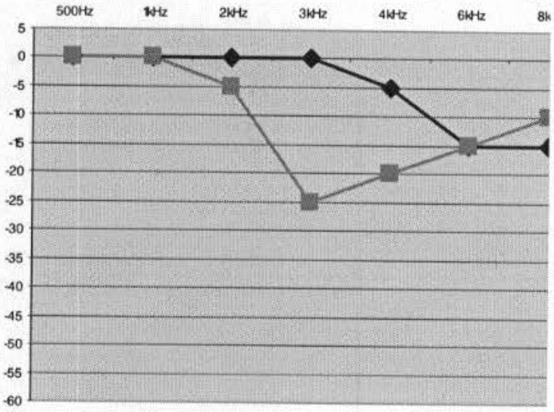
Questionnaire Non-responders



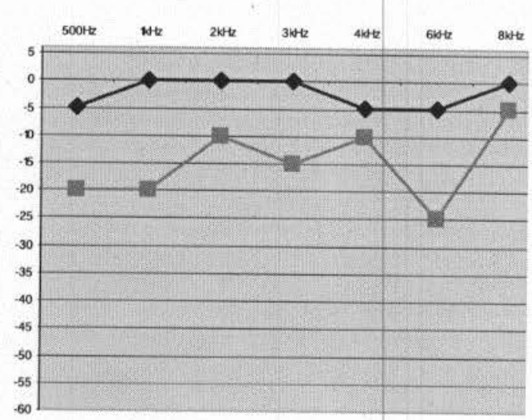
D127 HSE Referral Category



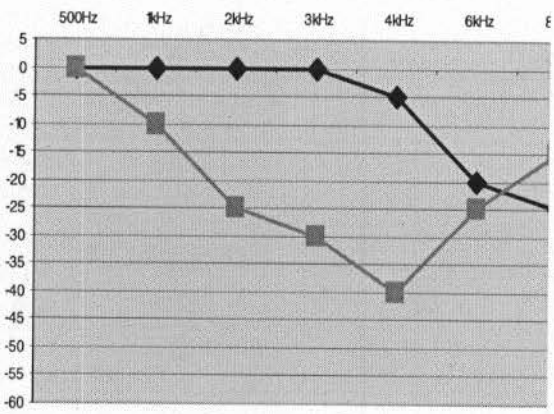
B157 HSE Unilateral Deafness criteria



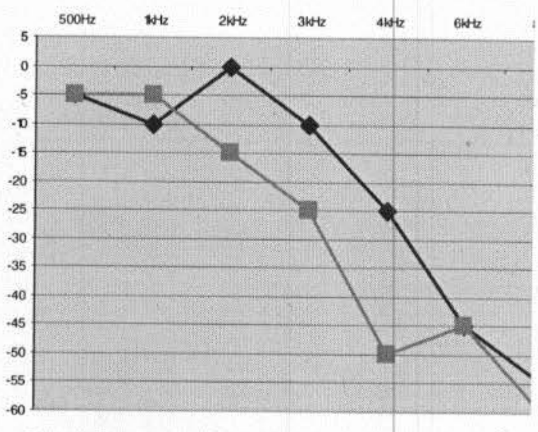
B203 HSE Unilateral Deafness criteria



C134 HSE Unilateral Deafness criteria



C151 HSE Unilateral Deafness criteria



C159 HSE Unilateral Deafness criteria

Case Number	Age	Questionnaire Response?	HSE Category	Comments from medical records and questionnaire
B153	35	Responder	Referral (Left sided)	Barotrauma on several occasions- flying 1995 and 2007, diving 1995 and 1996. History of earache, and has subjective hearing problems. ENT opinion March 2001, grade H3,3, not thought to be NIHL. Specialist audiologist opinion in May 2001 found him H2,2, with normal MRI. Subsequent audiologist review diagnosed hereditary hearing loss.
B170	33	Responder	Referral (Bilateral)	Barotrauma in 1995. Recorded that he had used US helmet with earplugs when in Australia as he found it necessary. Lifetime 100 days noise exposure without hearing protection. Accepted with lowered hearing H2,2, A2 on entry into RAF at age 21.
B178	37	Responder	Referral (Left sided)	History of wax removal, with 2 year episode of otitis externa requiring aural toilet. He has subjective hearing problems, and has seen an ENT specialist.
C144	29	Responder	Referral (Left sided) & Unilateral	Reports tinnitus especially after flying for long periods, and has subjective hearing problems. Lifetime 750 days noise exposure without hearing protection. ENT opinion May 2007, with no pathology found.
B107	39	Responder	Unilateral	Ears syringed twice - once after otitis externa, once after a routine medical (reason unclear - no history of occlusion). Past history of earache, and has subjective hearing problems. Previously noted to have left sided high tone hearing loss, with comments that he shoots.
C102	40	Responder	Unilateral	Concussion twice at school and has subjective hearing problems with tinnitus. Lifetime 30 days noise exposure without hearing protection.
D156 .	51	Responder	Unilateral	Notes difficulty with speech in noisy environments, especially singling out specific speech. Family history of ear disease. Seen by ENT specialist February 2002
D127	34	Non -responder	Referral (Left sided)	Seen by ENT specialist with diagnosis of Noise Induced Hearing Loss.
B157	41	Non -responder	Unilateral	Seen by ENT specialist April 2002 and queried as having early otosclerosis, but audiometry has subsequently improved.
B203	40	Non -responder	Unilateral	Nil
C134	40	Non -responder	Unilateral	Seen by ENT specialist 1993 and 2001, with opinion that high tone hearing loss might be due to shooting

(Continued)

Case Number	Age	Questionnaire Response?	HSE Category	Comments from medical records and questionnaire
C151	38	Non -responder	Unilateral	Seen by ENT specialist November 2003 including MRI. No cause found, although audiogram shows classic 4kHz notch.
C159	38	Non -responder	Unilateral	Previous history of mastoidectomy, and changes to tympanic membrane, with eustachian tune dysfunction and recurrent perforations.

Table A7-1 Comments on cases meeting HSE referral criteria

APPENDIX 8

COMMENTS FROM THE QUESTIONNAIRES

A free text box was provided stating "Are there any comments you wish to make about this study?". Comments received are below, with any identifiable details obscured. Comments such as "No" or "Nil" are excluded.

B107. Sorry for the delay-on terminal leave.

B119. Best of luck-I'm deaf!

B122. Noticeable difficulty in hearing single voice with background noise. Deafness in family resulting from RAF flying career!

B142. Jun 96 I was on gnd duties due to reasons other than medical for a total of eight months.

B147. Sorry it's late. Sqn were away for 2 months and I didn't come over. Hence didn't receive mail.

B143. The Tornado F3 is significantly quieter than the Hawk. Please also note I regularly fly piston and jet ac outside of the RAF.

B153. I have experienced hearing problems throughout my career. I have yet to establish what the cause is which is very frustrating. I genuinely believe that flying has an adverse effect on my hearing ability. More than happy to discuss/follow-up.

B154. Apologies-started with current flying!

B155. I had a 6-year gap of the ground tours 94-200 but flew in my last year on the ground. I am now a sim instructor working for Thales but spend on average 2 days/week on sqn.

B170. Whilst flying in Australia I wore the American-style flying helmet. At all times in Australia I and all other RAAF aircrew wore earplugs. (The standard of helmet made the wearing of earplugs a necessity)

B178. At some stage throughout my flying career had dropped to A2 for hearing.

B179. Hope this is time view. Due to booked to leave I did not receive this until 1200 on 14 Aug 07.

B192. Apologies for the delay. I have now on ** Sqn, ** and the form took a while to catch up with me. I hope it is still useful.

B202. MES downgraded last year A2G1Z1 due to hearing loss.

B205. Note: MES downgraded from Mar 06- Sep 06 - no-fly. Knee injury. Flying hours to date ≈ 3800.

B222. I flew with the Luftwaffe on exchange of the noise protection was so bad I would wear earplugs inside the ear pieces.

B233. Sorry for the delay. I hope your findings are conclusive. I have friends (well not exactly friends!) On the GER nine who could really do with ANR (like FA/2).

B230. 2002-2006 extensive deployments to China Lake-working environment very noisy.

B232. Hearing is noticeably worse for 2/3 hours post-flying. Then returns to normal

C102. No. Happy to take part!

C109. There are restrictions in the RTS on the Hercules C4/5 with regard to max flying hours, crew position and non-ANR ear protection. There are no ANR helmets on the Hercules C4/5 fleet and we are obliged to wear them when deployed on Ops for ballistic protection. I have noticed hearing degradation after Op deployments, but, as I am an instructor, I wear ANR headset the majority of the time. Line pilots are not so fortunate.

C118. Very interested in this study-over the last 5-10 years PMEs have shown a reduction in hearing. Maybe more than natural ageing.

C157. See enclosed letter from CAM/AEIG. Thin sidearms on specs reqd so as not to "break the seal" on ANR headset (as far as I know no one else has been given this option!)

C158. Please come up with noise figures for an NVG compatible helmet as the #46 we use is in non-ANR and the J flightdeck noise can be very fatiguing.

C175. It's a long time coming - NR headsets are the way ahead. Unfortunately it would appear cheaper to pay for claims from aircrew in compensation for hearing loss than to introduce NR headsets fleet wide. Sad really but a reflection of the "money-saving times" we work in. Good luck-but I don't see any changes or improvements forthcoming.

C179. I feel that my hearing has suffered. I am angry that active noise reduction headsets have not been provided for the C130K, unlike the C130J. I did the trials and they were very effective in reducing background noise. I think it is criminal that they were not introduced, merely to save money!

D103. I think a noise cancelling headphones would be a major improvement in comfort and possibly safety. I chose to use an Atlantic headset on the VC10 (not issued until requested).

D112. The Chinook and Sea King flying has included 812 hours with NVG. fitted. More frequent, and tighter, helmet fits have helped, but there is an inevitable - if very slight - reduction in the noise attenuation as a result, especially during rapid head movement.

D 119. 2-3 minutes to change from flying helmet into the wet drill (minimal hearing protection with wet drill helmet).

D 120. During the period Nov 94-Oct 96 I was exposed to helicopter noise at outstations in Northern Ireland. Limitted hearing protection was available/used. Takes 1 minute to change helmet *(wet drill helmet),* with no hearing protection on 20% of sorties.

D123. As SAR road crew a significant amount of time is spent with your head outside the ac in the exhaust stream checking clearances. Whilst wet winching the Gecko helmet is used as the 4B4L is not waterproof therefore hearing protection is reduced.

D124. Always use ear protection whenever possible.

D 125. Changing from electric to wet helmet takes a matter of 30 sex if prepared. I mostly (if time to fit permits) where yellow earplugs under wet helmet. When on SAR Ops + working with casualties helmets are regularly removed or ear protection lifted in order to converse/assess casualties. Similarly when working near a/c with MRT/Cliff rescue/Seamen- helmet often lifted/removed affording no protection. All above difficult to judge length of time but estimate no more than two to 3% of total.

D140. I believe that my most recent hearing test is invalid due to operator error (May 07). I couldn't hear many of the left ear tones, but still passed. Last year I developed a mild tinnitus in my left ear, and last month I began to notice it in my right ear. PS some marks of Navy Sea King employ ANR (Active Noise Reduction) however this is not fitted to RAF Sea King Mk 3s.

D143. As a SAR winchmen there are occasions when I have to talk to a casualty or change in the aircraft while airborne when I have no hearing protection.

D152. Sorry for the delay in completing the paperwork!

D145. *much of this flying (200 hrs?) was done in aircraft with soundproofing removed for maintenance.

D

CI Title: Hearing Protection in JHC Aircraft		Author: SO1 Avn Med
CI No: CI J5003	Last Updated: 10 Jan 17	Next Review: 10 Jan 18
Classification: OFFICIAL	E-Mail Address: JHC [redacted]	Tel No: [redacted]

HEARING PROTECTION IN JHC AIRCRAFT

Reference:

A. Control of Noise at Work Regulations 2005.

Introduction

1. The Control of Noise at Work Regulations 2005 (Reference A) became enforceable on the 6 Apr 06. This legislation reduced permissible noise exposure prompting a reassessment of aircraft cockpit / cabin noise levels and the effectiveness of hearing defence. The hearing protection provided by aircrew and passenger helmets has been shown to be less than adequate within the majority of JHC aircraft resulting in the introduction of augmented hearing protection for the majority of aircrew and passengers.

2. Augmented hearing protection includes the following equipment:

a. In Ear Communication Devices (e.g. Communication Ear Plug).

b. Active Noise Reduction technologies.

c. GS Ear Plugs (yellow foam)[1].

3. In order to meet the requirements of CNAWR 2005, aircraft commanders are to ensure that aircrew and passengers have sufficient hearing protection consistent with the guidance below.

Front Seat Crews

4. Aviation noise exposure depends upon 4 principal variables: aircraft type, the role within the aircraft, use of the aircraft communication system and Personal Protective Equipment (PPE). The communication system may increase personal exposure by a factor of 8x if not set correctly – aircrew must therefore reduce volumes to the lowest setting permissible whilst still retaining clarity and speech intelligibility. The PPE worn (helmet / headset ± augmented hearing protection) within each aircraft must be sufficient to meet the calculated noise exposure within that 24 hr period. The table at Annex A provides a summary of permissible exposures by aircraft and PPE combination.

5. Augmented hearing protection should be regarded as the norm for all JHC aircrew and mandatory where there is risk of exceeding the time limit with the helmet alone. The only exceptions to this are circumstances that would have a significant impact on flight safety, or where their use would produce unacceptable delay in a time-critical sortie (e.g. MERT).

[1] AEARO Classic Foam Earplugs (NSN 6515-99-126-3570).

6. Individuals that have problems with mini-CEPs (e.g. pain and discomfort) should report to the Survival Equipment Section (SES) for helmet modifications and to the Unit Medical Officer who will check for correct use and tip sizing. Aircrew with persisting problems should be referred for VAMP 27 custom moulded ear plugs as per the process outlined here.

7. It is acknowledged that there may be some aircrew who will be unable to use augmented hearing protection options and exceed the Exposure Limit Value (ELV). Aircrew who exceed the ELV must:

a. be assessed by the Chain of Command for suitability to continue in the flight role. Continued exposure beyond the ELV must be justified by Duty Holder risk assessment and exposures must be formally recorded. Measures must also be put in place to reduce the level of exposure to as low as reasonably practicable together with a clear pathway for meeting the statutory requirement in a reasonable time-frame.

b. screened for signs of noise induced damage through audiograms at intervals not exceeding 6 months. Standard medical procedures should come into force for those found to have any recognisable deficit on their audiogram. Flying hours must be restricted in accordance with the table at Annex A.

Passengers and Supernumerary Crews

8. The protection offered by the Mk15 passenger helmet alone is usually insufficient to meet the requirements of the noise legislation. The following policy is to be applied for passengers and supernumerary crew flying in JHC aircraft.

a. **Policy**. Correctly fitted GS Ear Plugs[1] (yellow foam) must be worn in conjunction with the Mk15 passenger helmet on JHC aircraft. Emplaning commanders and rear crew are responsible for ensuring correct use of both GS Ear Plugs and Mk15 passenger helmets.

b. **Exception**. Infrequent passengers[2] wearing the Mk15 passenger helmet that must retain the ability to converse with the crew or use the aircraft communication systems may forgo the requirement for double protection, due to the reduction in speech intelligibility caused by the GS Ear Plugs. Noise exposure must be kept to an absolute minimum and where possible should not exceed the weekly exposure limit for the Mk15 passenger helmet on each aircraft as detailed in Annex A[3]. Frequent fliers should be issued with a correctly fitted aircrew helmet[4] which provides superior impact protection and noise attenuation.

Operations

9. Troops / personnel in an operational environment should use approved tactical hearing protection systems with the combat helmet e.g. GS Ear Plug (yellow foam), Peltor Ear Muff or the Tactical Hearing Protection System (THPS) Basic User (BU) in closed mode. THPS BU is detailed in ABN 81/15.

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[2] Infrequent passengers are defined as those who fly less than once per week and are not otherwise exposed to undue noise levels

[3] Incomplete data will be populated as surveys are completed.

[4] Mk4 series, Mk10RW, APED helmet, Apache IHADSS.

General Advice on Managing Noise Hazards

10. Commanders should ensure that personnel exposed to high noise levels continue to receive appropriate information, instruction and training, that hearing protection zones are clearly demarcated, that equipment is used and maintained appropriately and that personnel receive periodic health surveillance.[5]

[redacted]
Col
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For Comd

Annex:

A. Exposure Limits by Aircraft Type and PPE Combinations

[5] Further guidance on employers' responsibilities can be found at http://www.hse.gov.uk/pubns/indg362.pdf

EXPOSURE LIMITS BY AIRCRAFT TYPE AND PPE COMBINATIONS

			FRONT SEAT CREWS				CABIN OR REAR SEAT CREWS				PASSENGERS IN MK15 ONLY
Aircraft	Report	Helmet/Headset	Helmet/Headset	with CEP	with VAMP27	with ANR	Helmet/Headset	with CEP	with VAMP27	with ANR	Weekly Limit
Apache	OEM 03/08	IHADSS	01:45	>24	no data	xxx	xxx	xxx	no data	xxx	xxx
Bell 212	OEM 05/10	Mk4	01:16	>24	no data	xxx	01:00	>24	no data	xxx	no data
		Mk10RW	no data	no data	no data	xxx	no data	no data	no data	xxx	
Chinook All Mks	OEM 16/06	Mk4	01:00	12:40	15:57	xxx	01:23	12:40	no data	xxx	
		Mk10RW	no data	12:40	10:04	xxx	no data	no data	no data	xxx	
	QQ1101458/1	APED	00:21	13:54	no data	xxx	no data	no data	no data	xxx	xxx
		MERT	xxx	xxx	xxx	xxx	no data	xxx	xxx	xxx	xxx
Dauphin N3	OEM 37/10	Mk4	05:02	>24	no data	xxx	01:16	>24	no data	xxx	no data
	OEM 17/12	APED	00:38	>24	no data	xxx	00:04	06:21	no data	xxx	xxx
	OEM 37/10	Atlantic Headset	xxx	xxx	xxx	xxx	02:00	xxx	xxx	xxx	xxx
	OEM 17/12	Selex Headset	02:31	xxx	xxx	xxx	00:19	xxx	xxx	xxx	xxx
	OEM 17/12	Peltor Comtac XP	01:16	xxx	xxx	xxx	00:09	xxx	xxx	xxx	xxx
	OEM 17/12	Silynx Setup	02:00	xxx	xxx	xxx	00:15	xxx	xxx	xxx	xxx
	OEM 17/12	EAR	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Defender	OEM 37/11	Mk4	01:00	>24	no data	xxx	xxx	xxx	xxx	xxx	no data
	OEM 37/11	Atlantic Headset	xxx	xxx	xxx	xxx	02:31	xxx	xxx	xxx	xxx
Gazelle	OEM 46/06	Mk4	02:15	>24	>24	xxx	no data	no data	no data	xxx	02:42
	OEM 47/13 v3	Mk10RW	no data	>24	20:05	xxx	no data	no data	no data	xxx	
Islander Mk2b	OEM 02/11	Mk4	00:19	08:00	no data	xxx	xxx	xxx	xxx	xxx	no data
	OEM 69/12	BOSE Avn X	00:03	xxx	xxx	03:10	00:07	xxx	xxx	12:38	xxx
	OEM 56/13	Bose A20	00:07	xxx	xxx	>24	00:19	xxx	xxx	>24	xxx
~~**Lynx Mk7**~~	~~QQ1101458/1~~	~~Mk4~~	~~00:50~~	~~16:43~~	~~no data~~	~~xxx~~	~~no data~~	~~no data~~	~~no data~~	~~xxx~~	~~No reliable data~~
	~~QQ1101458/1~~	~~APED~~	~~00:32~~	~~13:16~~	~~no data~~	~~xxx~~	~~no data~~	~~no data~~	~~no data~~	~~xxx~~	~~xxx~~
		~~Mk10RW~~	~~no data~~	~~no data~~	~~no data~~	~~xxx~~	~~no data~~	~~no data~~	~~no data~~	~~xxx~~	~~xxx~~
Lynx Mk9A		Mk4	no data	no data	no data	xxx	no data	no data	no data	xxx	xxx
		A928	no data	no data	no data	xxx	no data	no data	no data	xxx	xxx
		Mk10RW	no data	no data	no data	xxx	no data	no data	no data	xxx	xxx
Merlin Mk3	OEM 39/08	Mk4	08:00	>24		xxx	03:11	>24	>24	xxx	no data
		Mk10RW	no data	no data	no data	xxx	no data	no data	>24	xxx	xxx
Merlin Mk3A	OEM 39/08	Mk4	08:00	>24		xxx	03:11	>24	no data	xxx	xxx
		Mk10RW	no data	no data	no data	xxx	no data	no data	no data	xxx	xxx
Puma 2	OEM 36/13	Mk4	01:00	>24	10:04	xxx	00:19	06:21	no data	xxx	no data
	OEM 47/13 v3	Mk10RW	01:00	>24	06:21	xxx	00:15	06:21	no data	xxx	xxx
Sea King Mk4	QQ1502277/1	Mk4 (v3 ANR)	02:42	xxx	xxx	>24	02:57	xxx	xxx	>24	xxx
	QQ1303162/1	Mk4 (v2 ANR)	02:21	xxx	xxx	00:40	02:21	xxx	xxx	00:34	xxx
	QQ1102418/1	Mk4 (v1 ANR)	02:21	xxx	xxx	11:18	02:21	xxx	xxx	05:02	xxx
		Mk4	06:57	xxx	xxx	xxx	03:14	xxx	xxx	xxx	xxx
Squirrel	OEM 132/06	Mk4	02:31	>24	>24	xxx	no data	no data	no data	xxx	
	OEM 47/13 v3	Mk10RW	no data	>24	>24	xxx	no data	no data	no data	xxx	
Wildcat	QQ/12/02258	Mk4	04:00	>24	no data	xxx	05:02	>24	no data	xxx	no data
	QQ/12/02258	A928	03:10	>24	no data	xxx	04:00	>24	no data	xxx	xxx