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Noise Reduction Advances at Major Defence Facilities in Australia

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ABSTRACT

Major advances have been recently demonstrated from a long-term Noise Reduction Project for the Department of Defence (DoD) in Australia. A review and assessment of noise management practices across the DoD identified a range of deficiencies and recommendations for action to reduce the workplace exposure from military and industrial noise sources. The levels of noise encountered in Defence exceed those experienced in virtually any other industry or work environment. The project goals are to ensure compliance with relevant WHS legislation and to minimise noise exposure and hearing loss risk. Best-practice noise survey assessments at a sample of Defence Bases provided an evidence-based dataset to inform noise control actions. A wide range of noise control measures were developed across the Defence facilities to substantially reduce noise exposure levels. The specified noise controls were carefully evaluated to ensure they are practical and easily implementable as well as effective. Repeat noise surveys/audits and a range of Key Performance Indicators (KPIs) were used to measure the improvements made (and gaps remaining) in noise management over time. Noise management tools were formulated to assist the implementation of controls and achieve real noise reductions, and a quieter future, for Defence.

Keywords: Occupational Noise, Exposure , Noise Control
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1. INTRODUCTION

An ambitious project has been established by the Department of Defence (DoD) in Australia to reduce occupational noise exposure in all workplaces across Defence. Vipac Engineers & Scientists Ltd has worked closely with the Defence Centre for Occupational Health & Safety (DCOHS) since 2009 to develop an Exposure Reduction Plan (ERP) for occupational noise for the DoD (1, 2, 3).

The DoD comprises the Australian Defence Force (ADF) Services of the Royal Australian Air Force (RAAF), the Royal Australian Navy (RAN) and the Australian Army, and the supporting Defence Groups including the Defence Materiel Organisation (DMO), the Defence Estate & Infrastructure Group (EIG), the Defence Science & Technology Organisation (DSTO) and the various Joint Commands (including the Joint Health Command, JHC).

Occupational noise has been identified by the DCOHS as a significant WHS hazard. Defence operations can involve some of the highest noise levels of any workplace and there is extensive evidence of the damage to personnel from hearing loss results and compensation claims data.

The ERP project was developed to assist Defence meet the objectives of the current Defence WHS Strategy 2012-17 (4); in particular, Objective 4: *Preventative Measures – Defence maximises the prevention of injury, illness and disease by identifying the threats to the workforce by process, procedure or materiel*. The ERP project also forms part of the implementation of key Defence plans, including the Defence Occupational Medicine and Occupational Hygiene (OMOH) Capability Plan and the Defence Occupational Hygiene Plan (DOHP).

The main aims of the project were to understand the extent and impacts of occupational noise across Defence and how to develop and implement an improved noise management system. Recently the project has commenced an implementation and integration phase across the whole of Defence, and a range of management plans and tools have been developed to reduce noise exposure and to quantify the progress in noise management and control.

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2. BACKGROUND AND CONTEXT

2.1 Project Aims

A detailed review and assessment of noise management practices was conducted across Defence in the initial phase of the ERP project (1). An evidence based approach was utilised, which involved extensive stakeholder consultation and the analysis of large quantities of WHS data. The review outcomes identified a range of deficiencies and recommendations for action, and allowed prioritisation of the most critical areas for focus.

Defence operations can involve extended periods in close proximity to major noise sources with some of the highest noise levels of any workplace compared to other industries or work environments. Quantitative evidence of the damage to personnel is demonstrated by hearing loss results from audiometric hearing tests and compensation claims data from the Department of Veterans Affairs. Permanent noise induced hearing loss (NIHL) can be one of the most prevalent and serious work health conditions in Defence, is irreversible but can be minimised through effective management.

The analysis of the Defence organisation and internal culture demonstrated the need for a new approach due to a number of prevalent factors, including:

1) the multiplicity of stakeholders;
2) communication and coordination issues;
3) operational tempo and logistical complexities;
4) the posting cycle (rotation of personnel roles);
5) that noise is regarded as something that came with the job;
6) failure of the current approach with no resultant improvement.

The ERP was developed to address the various cultural and organisational impediments to noise management and to determine the most appropriate management actions and noise controls.

2.2 Noise Control Status

There is a reliance on lower level noise control measures in Defence that involve administrative controls (e.g. change of process or personnel task rotation, hearing protection) rather than engineering noise control (1). Within Defence, engineering controls are often not necessarily practical in many cases due to physical or operational constraints, impracticalities or logistical issues. A range of platforms in Defence, such as some aircraft, ships and vehicles, are reasonably old and are either scheduled for upgrade or replacement and therefore may not justify costly controls in the near term.

It was clear from initial analysis that noise control requirements are not always or effectively incorporated early in the procurement and design phase of a platform or system. The use of administrative and hearing protection options may be the only alternative in cases where engineering treatments prove difficult or impractical. However, this can cause a residual liability for noise exposure and demonstrates the importance for Defence, where practicable, to focus on eliminating or minimising noise hazards associated with plant prior to the point of entry. The lack of specific Noise Management Plans throughout Defence highlighted the need for significant improvements.

2.3 Project Outcomes

The initial ERP project outcomes included Briefing Reports and Exposure Reduction Plans (2) developed for each of the stakeholder Services and Groups, with prioritised strategies and initiatives to improve noise management in Defence. The resultant benefits to the DoD would include:

1) demonstrated WHS compliance,
2) reduced noise exposure risk to employees,
3) reduced costs and lower liability for claims,
4) improved capability and operability,
5) Defence's reputation as an employer.

The subsequent preparatory phase of the project involved best-practice noise surveys and assessments at a representative sample of ADF Bases. This systematic approach generated a comprehensive evidence-based dataset, which allowed the development of effective noise control actions in the form of tailored Noise Management Plans (NMP) for each Base (3).

In the recent phase of the project, noise surveys and assessments were repeated at a subset of the ADF facilities as a follow up to the initial comprehensive surveys. This allowed a quantitative measurement of changes and improvements in noise exposure and controls at the facilities, which in turn provided an evaluation of the effectiveness of the implemented noise management plans.

2.4 Regulatory and Defence Requirements

The primary regulatory instrument for Work Health and Safety (WHS) in Australia is the Commonwealth WHS Legislation, comprising the WHS Act 2011 and WHS Regulations 2011. The legislative requirements (5) are briefly described in a previous paper (9).

The key Defence workplace safety document is the Defence WHS Manual (6). The WHS Manual contains the WHS policies and procedures that apply to Defence and all Defence workers and align with the requirements of the new WHS legislation (5). The new policy and procedures for *Noise and Hearing Management* have recently been developed, and the Defence requirements are summarised in a previous INTER-NOISE paper (9).

3. PROJECT PROGRESS AND RESULTS

3.1 Initial Project Findings

The current status of Defence occupational noise management was determined from an evaluation of current practices and levels of compliance, and a gap analysis identified any system deficiencies.

This first project phase involved extensive consultation with a wide range of Defence stakeholders in Canberra and Defence establishments around Australia (1). Previous papers (7, 8) described the process and findings from the initial project work. This paper provides an overview of the results and outcomes from the recent project work.

In summary, it was found that entrenched practices and limited coordination/cooperation across Defence caused substantial inefficiencies which in turn resulted in deficiencies in WHS compliance.

Given the limited and variable amount and quality of relevant data throughout Defence, a program of best-practice noise surveys was implemented at a representative sample of ADF facilities (2, 3).

3.2 Noise Surveys and Risk Assessment

To ensure a systematic and consistent hazard identification process, a *best-practice procedure* for conducting noise surveys and assessments was developed for adoption throughout Defence (which aligns with the WHS legislation).

Comprehensive noise surveys were conducted using the new process at a total of 8 ADF facilities throughout Australia including a field survey of Army combat exercise activities (3). Noise measurements of all facility units/sections, areas, tasks and noise sources were conducted, including sufficient personal *noise dosimetry* samples (over representative work shift periods), extent of *impulse noise* and noise *frequency spectra* (i.e. octave or third octave bands) of major noise sources.

The measurement results from these noise surveys were assessed against the regulatory Noise Exposure Standard (NES); namely, $L_{Aeq,8h}$ 85 dB(A) and L_{Cpeak} 140 dB(C). Comparison was made with the noise measurement results of the previous noise surveys and a risk assessment was conducted for the range of identified Similar Exposure Groups (SEGs).

Other *non-auditory or non-noise factors* can cause hearing loss in addition to the direct exposure from noise, such as *ototoxic substances* and *human vibration* (5). The additive and synergistic impact in combination with noise can lead to greater hearing loss than would be experienced from noise alone. Ototoxic substances are chemicals or materials that cause hearing loss or combine with and exacerbate the effects of noise on hearing. There are three major classes of ototoxic substances: 1) solvents (and fuels), 2) heavy metals and 3) asphyxiants; and can include chemical agents such as:

- fuels (e.g. diesel, kerosene, jet fuel, JP-8 fuel),
- solvents (e.g. ethanol, styrene, toluene, xylenes),
- heavy metals (e.g. lead, arsenic, manganese, mercury),
- carbon monoxide and hydrogen cyanide, and
- various drugs and medications.

The Defence noise surveys included the identification of concomitant exposure to ototoxic substances (such as fuels, solvents, heavy metals etc.) and/or human vibration (particularly hand-arm vibration) that are present in combination any noise. An exposure adjustment or lower noise exposure standard (such as 80 dB(A) instead of 85 dB(A) L_{Aeq}) should be applied in cases where ototoxic substances are present in addition to noise exposure at the workplace. For workers regularly exposed to the combination of high levels of noise (e.g. such as 100 dB(A) or more) and ototoxic substances (e.g. such as aircraft refuellers), then an even lower noise exposure standard may need to be considered.

The noise survey reports included the detailed noise data in tabulated and graphical form. In addition, to enable quick comparisons between units/sections, a snapshot summary of the critical noise

information for each unit/section included the following:

- range, average and highest dosimetry noise levels measured;
- highest L_{Aeq} and L_{Cpeak} attended noise levels measured;
- comparison with the previous noise survey results;
- status of hearing protection area (HPA) signage and highest HPA zone;
- existing hearing protection devices (HPD) available (and whether sufficient);
- observations of high risk tasks and high noise hazard areas/sections;
- identification of noise controls in use (and whether sufficient);
- ototoxic substances present (and whether hand-arm vibration);
- noise management plan actions implemented and outstanding.

The subsequent analysis and assessment of the noise survey data allowed determination of:

- noise exposure levels and extent of exceedance relative to the standard;
- identification and ranking of noise hazards for each workplace unit or section;
- exposure risk profiles for Similar Exposure Groups (SEGs); and
- noise control measures and actions required to meet the requirements.

The measured *noise dosimetry data* was used to determine the noise exposure over work shift periods for a representative sample of personnel/SEGs in each unit/section at each ADF facility. The dosimetry graphs for each individual provide an important insight into the specific tasks and activities that contribute most to the noise exposure over a work shift period – examples of dosimetry graphs are shown in a previous INTER-NOISE paper (9). The cumulative noise exposure for some SEGs can rise significantly during relatively brief and intense tasks (such as riveting, drilling, grinding, cutting, hammering, rattle/needle guns, surface finishing, composite work etc.) and can remain quite high, and in fact well above the noise exposure standard, until the end of the shift period.

A statistical analysis of the noise dosimetry data was also used to determine the range, average and highest dosimetry noise levels for each unit/section at each ADF facility. A graph summarising the statistical analysis of noise dosimetry results for different sections at a facility is shown in Figure 1.

Noise hazards, noise sources and SEGs were ranked and prioritised for treatment using a *risk assessment* based on a likelihood and consequence matrix method. The risk level associated with a noise source or SEG was based on information about the:

a) magnitude of the noise exposure levels (relative to the NES),
b) the frequency of exposure (during a shift or longer periods),
c) the applicable HPA zone requirements,
d) observations of HPD attenuation and use.

The designation and signage for existing HPAs, and the HPA zone requirement based on the survey results, were evaluated. The assessment also reviewed the HPDs currently provided, observations about the use and fitting of HPDs and the specified and likely HPD in-ear attenuation levels.

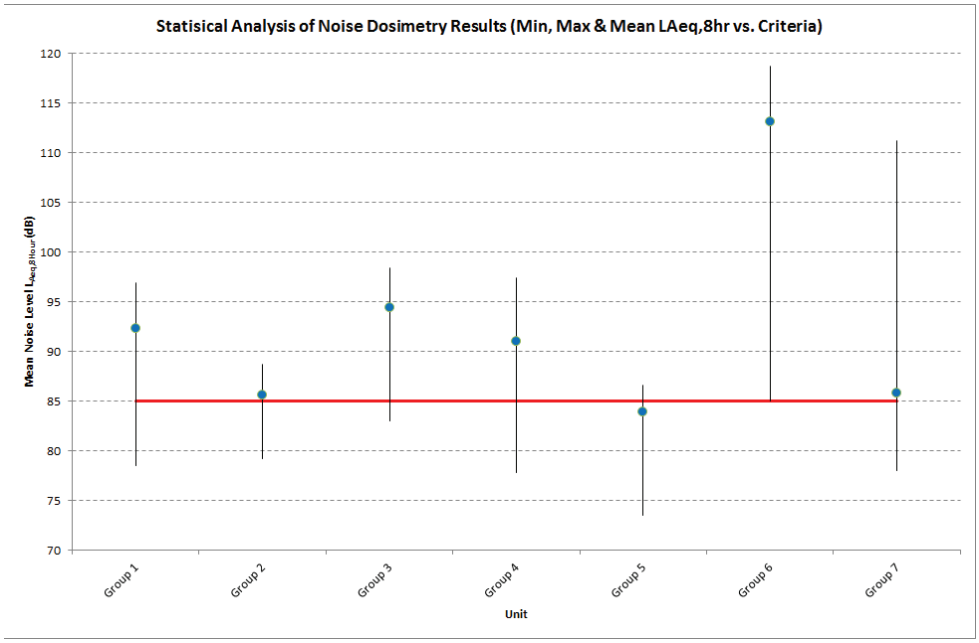

Figure 1 – Noise dosimetry statistical analysis for different sections at an ADF facility

3.3 Noise Exposure Levels

Most of the ADF facilities initially surveyed did *not* demonstrate legislative compliance in all areas nor did they fully meet Defence's own requirements (3, 8, 9). However, repeat noise surveys (see section 3.5), some 4 years after the initial surveys, showed improvements in noise exposure and controls at the facilities (10).

The initial noise survey results confirmed that Defence had:

1) A large number of high noise exposure areas throughout Defence.
2) Widespread significant exceedances of the NES.
3) Likely high levels and extent of hearing impairment (NIHL).
4) Limited noise control measures and noise management plans.
5) Incorrectly or non-existent signposted HPAs and insufficient type or use of HPDs.
6) Limited awareness of the combined effects of noise and ototoxic agents, vibration etc.

The measured noise levels and noise exposures at the ADF facilities typically showed *high to very high levels* (3, 8). The 8-hour equivalent $L_{Aeq,8h}$ noise exposure levels were often over 85 dB(A), and many areas (such as workshops, maintenance sections, hangars, flightlines etc.) showed exposure levels over 90 and 100 dB(A). In some cases, L_{Aeq} noise levels reached between 110 and 120 dB(A) during some tasks (such as vehicle maintenance tasks, hand tools, sand blasting etc.). Very high to extreme impulse noise levels are experienced within the ADF: the L_{Cpeak} levels often exceed the exposure standard of 140 dB(C) during specific activities, such as maintenance tasks (impacts during hand tool use), and reach up to 180 dB(C) during weapons firing (e.g. large calibre artillery).

From Figure 1, the statistical analysis of the *noise dosimetry* data for a particular ADF facility with seven major sections, showed that:

1) three sections had average $L_{Aeq,8h}$ noise exposure levels close to the NES of 85 dB(A);
2) three sections had average $L_{Aeq,8h}$ levels exceeding the NES by 5 to 10 dB(A);
3) one section had extremely high $L_{Aeq,8h}$ levels of 113 dB(A) average and maximum of 118 dB(A);
4) one section with average levels close to the NES had extremely high maximum $L_{Aeq,8h}$ levels of over 110 dB(A) for some SEGs
5) Over 70% of the SEGs showed average $L_{Aeq,8h}$ exposure levels over the NES of 85 dB(A).

The trade groups or SEGs that experience some of the *highest exposure levels* include vehicle mechanics, maintainers, fitters, welders, metalsmiths, structural repair technicians, aircrew, aircraft/avionics technicians, aircraft refuellers, air terminal/hangar operators, ordnance loaders/operators and artillery or combat troops. Many of these trades were also identified as being exposed to a range of ototoxic substances ('ototoxicants' such as paints, solvents, fuels, lead, carbon monoxide etc.) and hand-arm vibration through the use of hand tools and workshop machinery.

A SEG *risk assessment*, based on a WHS consequence and likelihood matrix, showed that a wide range of trades/SEGs display moderate, high and very high risk ratings, with some specific groups registering extreme risk ratings. The risk assessment assists in identifying the most at-risk groups which in turn helps the prioritisation of noise control actions.

A resultant *exposure risk profile* for a particular facility was determined from the SEG noise risk assessment, and an example of a risk profile was provided in a previous INTER-NOISE paper (9).

3.4 Extended Work Shift Adjustments

For work over *extended work shifts* (e.g. greater than 8 hours per day; which can occur in Defence), an adjustment to the noise exposure (or an effective lower exposure standard) was applied.

In such cases, the equivalent noise level over an X-hour shift (i.e. $L_{Aeq,Xh}$) was converted and normalised to an 8-hour equivalent $L_{Aeq,8h}$. Then an adjustment (from +1 to +3 dB) was added to the normalised $L_{Aeq,8h}$ depending on the value of X (in accordance with the WHS Code of Practice and AS/NZS 1269.1). It is important to note that hearing risk increases for a shorter hearing recovery time (between successive work shifts) and in cases when reasonably high noise levels occur during the recovery time (e.g. greater than 75 dB(A)).

Thus for extended work weeks greater than 5 days (e.g. for Navy crew that can be at sea continuously for weeks at a time), a lower exposure standard was applied. In such cases, the equivalent noise level over an X day week (i.e. $L_{Aeq,Xday}$) was converted and normalized to a 5 day week, $L_{Aeq,5day}$ (in accordance with the WHS Code of Practice and AS/NZS 1269.1).

As an example, a lower noise exposure standard of 80 dB(A) $L_{Aeq,12h}$ may be applicable each day for contiguous 7 day 12-hour shifts, and 78 dB(A) $L_{Aeq,16h}$ may be applicable each day for contiguous 7 day 16-hour shifts.

For special or complex noise situations, such as exposure to *high intensity impulse noise* (e.g. in situations such as weapon fire or explosive ordnance activities), other noise exposure standards or adjustments were applied. Other relevant standards (such as US Military Standard MIL-STD-1474E, ISO 13474, ISO 17201) provide guidance on different exposure metrics that may apply in such cases, such as the $L_{IAeq,100ms}$ metric (equal energy model) and Auditory Risk Units (ARU) calculated from the Auditory Hazard Assessment Algorithm for Humans (AHAAH) mathematical model.

3.5 Repeat Surveys and Improvements

Noise surveys were repeated at a subset of the ADF facilities as a follow up to the initial comprehensive surveys (8, 9, 10). These surveys were performed approximately 4 years after the initial baseline surveys to provide an accurate determination of changes and improvements in noise exposure and controls at the facilities since the previous survey and NMP.

The main focus and aims of the repeat survey was to:

1) measure all major noise sources and SEGs at the facilities,
2) compare results with the previous survey,
3) assess the highest risk SEGs and areas,
4) evaluate the existing and required noise controls, and
5) provide evidence-based data for quantifying improvements, and any residual gaps, in noise management across each facility.

Overall, improvements were demonstrated (since previous survey/audit) across and within the facilities in a number of areas, as follows:

- Lower exceedances of the NES (from attended sound level meter measurements).
- Reduction in number of the dosimetry samples exceeding the NES of 85 dB(A) $L_{Aeq,8h}$ – in some areas, the percentage exceeding dropped to about 50% (from over 70% previously).
- Lower number of high noise exposure areas throughout Defence.
- Implementation of some NMP actions and noise control measures.
- Improvement in signposting of HPAs in some areas.
- Improvement in type or use of HPDs in some areas.
- Better knowledge of Defence policy requirements.
- Better knowledge of audiometric testing requirements.
- Commenced use of new noise management tools.

The ADF facilities that had repeat surveys demonstrated legislative compliance in many areas, with some key areas still not demonstrating complete compliance or meeting Defence's own requirements (8, 9, 10). It was shown that improvements were still required in the following areas:

1) Still some significant exceedances of the NES.
2) Limited implementation of previous actions in NMPs.
3) Incorrectly signposted HPAs and insufficient type of HPDs.
4) Still limited knowledge of combined effects of noise and ototoxic agents, vibration,
5) Limited coordination and communication within and across sections/groups,
6) Ineffective handover/takeover (HOTO) process during personnel posting cycle,

Improvement measurement metrics such as quantitative key performance indicators were identified and developed to gauge the level of real changes or progress in noise exposure and control.

3.6 Performance Metrics

A number of Key Performance Indicators (KPIs) were developed to measure the previous and current level of noise management compliance and maturity at ADF facilities (3, 9, 10). A KPI Measurement Status Template (and Guide) was developed for application across Defence (10).

The KPIs were carefully designed and revised to ensure coverage over the relevant aspects of noise management and processes. The KPIs are a mix of (mainly) lead and lag indicators, and comprise both quantitative and qualitative metrics. Note that lag indicators can be flawed and unreliable, and tend to be a measure of post-event failures, i.e. injury, illness or disease, whereas lead indicators tend to focus more on preventive measures.

The KPIs provide a quantifiable and comparable measure of the current status and progress made (e.g. NMP actions) relating to noise management. Hence, the KPIs provide an effective improvement measure for comparison between ADF Facilities (and between units/sections within a facility) and longitudinally over time.

KPI scores were determined for 10 distinct KPI areas for each ADF Facility (specifically tailored to the noise management area) covering the:

a) Current WHS noise management system,
b) Recent noise survey and assessment results,
c) Review of planned and implemented noise controls.

The total KPI score provides a realistic measure of the compliance level of noise management at the facility and a measure of the completeness of the recent noise survey and assessment, and then used over time to compare against previous scores. It enables ADF commanders and managers to see how they perform when compared to other facilities, how they perform over time, critical areas needing improvement and how they can improve their performance.

These KPIs have been used longitudinally over 4 years now and show measurable improvements in noise management practices across Defence. Figure 2 shows a schematic comparison chart of these KPI results for a sample of the ADF facilities surveyed.

The KPI analysis results showed that:

1) in one major ADF facility, the KPI score improved in all 14 units/sections, with the KPI score improving from 'Very Poor' to 'Fair' in 6 units, from 'Poor' to 'Fair or Good' in 4 units and from 'Fair' to 'Good or Very Good' in 4 units.
2) across the ADF facilities resurveyed, the KPI score improved in all major 6 bases, with the KPI score improving from 'Very Poor' to 'Fair' in 2 bases, from 'Poor' to 'Fair or Good' in 2 bases and from 'Poor or Fair' to 'Good or Very Good' in 2 bases.

However, further improvements are still required to comply with the regulations, particularly in the areas of coordination and communication (including hand-over/take-over process of personnel), audiometric testing, control actions and review, and awareness and training.

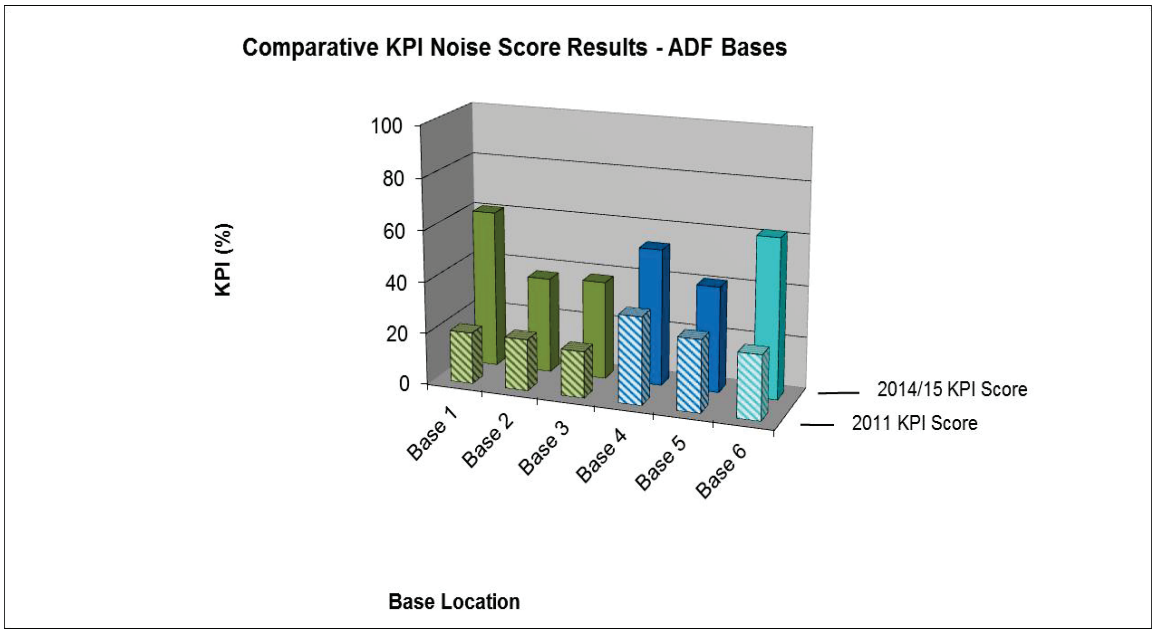

Figure 2 – Comparison of noise survey KPI scores across sample of ADF facilities/bases

4. NOISE CONTROL AND MANAGEMENT

4.1 General Noise Control Process

The noise exposure and SEG risk assessments allowed the identification of the most at-risk groups and assisted in the prioritisation of actions and noise control measures. The assessment of the noise survey results informed the specific noise control actions required. Such actions included engineering controls where practicable and were provided for each ADF facility in the form of detailed Noise Management Plans (NMP) for each unit or section.

A Noise Management Plan (NMP) is an action plan for implementation, indicating clearly how noise exposures can be reduced, by application of the hierarchy of controls, as follows:

1) Removal or elimination of noise sources, if possible;
2) Substitution or isolation of noise sources;
3) Engineering noise control treatments;

4) Administrative noise control or process/operation changes;
5) Personal protective equipment (PPE).

Information in an occupational NMP should include:

- descriptions of specific noise control measures required and their likely effectiveness;
- as a minimum, conceptual information should be provided describing the type and extent of noise control measure (to enable specification/design of detailed noise control measure);
- noise control measures should be prioritised based on the results of the noise assessment, such as critical noise sources, Similar Exposure Groups (SEGs);
- actions for control should also be prioritised based on urgency and nature of hazard.

The specified noise control measures were specific and practical, and considered any functionality or performance constraints that may apply. Noise control actions were developed in the areas of:

1) Engineering noise control.
2) Administrative controls.
3) Hearing Protection Devices (HPDs) and Hearing Protection Areas (HPAs).
4) Further measurement data and audiometric testing.
5) New platforms/systems and procurement process.
6) Improved assessment and management tools.
7) Training and awareness, and revise policies/procedures.
8) Noise Management Plans (NMPs).

An NMP can be established in different forms: 1) an ongoing Noise Management Program (as part of an overarching Noise Hazard or Exposure Reduction Program), 2) the procurement and introduction of new equipment (noise sources) process, and 3) developed specifically in response to in-service noise assessments, incidents or workplace changes.

4.2 Specific Noise Controls

4.2.1 Engineering controls

Engineering or substitution noise controls were specified where appropriate as well as a range of administrative control measures where engineering controls were not practicable.

The range of recommended engineering and substitution noise controls included the following:

Buy quiet equipment (e.g. new equipment):

- Quieter vehicles (e.g. engine/machine shrouding, exhaust mufflers);
- Lower noise fixed and portable machinery (e.g. generator sets, pumps);
- Low noise workshop tools (e.g. air guns, rattle/needle guns, grinders);
- Better maintenance programs (to reduce the effects of wear and tear).

Acoustic screens and barriers (e.g. workshops, welding bays, noisy offices):

- Mobile or portable acoustic screens;
- Sealed enclosures around noisy fixed plant;
- Enclose noisy areas (partitions/walls, enclosures);
- Absorptive baffles or barriers (between areas);
- Absorptive lining/insulation on ceilings/walls;
- Improved air-supply duct design and baffles;
- Barriers around noisy portable and field equipment;
- Bunds/barriers around weapons emplacements.

Low noise fittings and silencers/attenuators (e.g. workshops, tools, vehicles):

- Quieter nozzles and exhaust silencers on pneumatic tools;
- Silencers for compressed air release and generator sets;
- Engine shrouding and exhaust mufflers on vehicles/plant.

Some specific engineering noise controls were implemented in the areas of Army tank maintenance, Navy ship vibro-acoustic controls, generator shrouds, pump enclosures, engine covers, workshop partitions, tool nozzles/silencers, barriers around large calibre weapon emplacements.

4.2.2 Administrative controls

The range of recommended administrative control measures included:

1) job rotation and work scheduling,
2) changing work or task processes,
3) providing quiet rest areas and timing,
4) limiting times for certain tasks,
5) limiting distances from noise hazards,

6) limiting exposure to ototoxic substances and hand-arm vibration,
7) warning systems, warning signs (e.g. HPA signage) and warning/alarm devices;
8) equipment maintenance programme improvements,
9) management and improvement tools, and
10) improved awareness, instruction and training.

4.2.3 Hearing protection

In the area of PPE, actions were stipulated for the improved provision and use of hearing protection for ADF facility personnel including better awareness, training on the effective use and fitting of PPE. Personal hearing protector devices (HPDs) should be appropriately selected and maintained, and Defence should involve workers in the selection process and offer a reasonable choice of hearing protector types. Existing and proposed PPE, including HPDs, must be reviewed for effectiveness, suitability and condition, and should be reviewed as part of the process of routine or baseline surveys and detailed noise assessments. HPDs that are in poor condition (e.g. due to wear and tear, inappropriate maintenance or care) may not be effective or provide the attenuation for which they were designed and manufactured.

Existing Hearing Protection Areas (HPAs) must be reviewed for applicability and effectiveness, and any new HPAs required must be clearly defined and sign-posted. In addition, HPA signs and warning notices should be prominently placed on noisy tools, equipment, plant and platforms that exceed HPA noise criteria. HPA signage needs to be improved throughout most ADF facilities, clearly defined HPA boundaries and effectively sign-posted HPA zones. The project has recommended new HPA zone criteria and sector definitions, which will more closely align with the hearing protection classification levels stipulated in the AS/NZS 1269 standard.

4.2.4 Ototoxic and impulse controls

In the area of ototoxic exposure in combination with noise exposure, control measures such as substitution, isolation and local ventilation should be implemented to eliminate or reduce these chemical exposures. Personal protective equipment should be used to prevent skin and respiratory absorption when other controls are insufficient. SEGs exposed to ototoxic substances (such as naval vessel engineering crew) may require respiratory protectors plus HPDs. This would depend on the number of ototoxic agents exposed to, the exposure levels to ototoxic agents (relative to standard exposure criteria for each chemical agent) and the combination with the level of noise exposure.

Controls for activities that have exposure to high energy impulse noise would include double hearing protection (ear muffs and ear plugs), minimum distance limits, maximum exposure times and a maximum allowable number of rounds per day, in the case of artillery firing.

4.2.5 Audiometric testing

In the area of worker hearing tests, regular audiometric testing has been recommended for a range of the more exposed SEGs. For medium to high risk noise SEGs, audiometric testing has been recommended to occur at annual intervals; and for very high noise and/or ototoxic exposed SEGs, 6-monthly testing is required. For any worker who is frequently required to use PPE to protect them from the risk of hearing loss, Defence must provide audiometric testing must have an audiometric test within 3 months of commencing work and at least every 2 years. Importantly, the results of the audiograms must be reviewed by the relevant manager and any changes to hearing thresholds should be noted and recorded with follow-up action.

Standard audiometric testing using pure tone threshold audiometry (via air conduction) is to be performed in accordance with AS/NZS 1269.4, or by an equivalent method. Other methods, such as bone conduction pure tone audiometry, masking and speech audiometry, may be used in the future when widely established and accepted as a result of proven research and technological improvements. Similarly, evoked otoacoustic emissions (OAE) are a potential effective and objective measurement of the damage caused by noise or ototoxic substances that may also be used in the future.

4.2.6 Training and review

An urgent need has been identified in Defence for improved general and specific noise awareness and training programs in addition to conducting more regular and targeted refresher courses.

Control measures must be reviewed regularly and revised where required. In addition, reviews must be conducted in situations when existing control measures are no longer effective (e.g. due to degradation over time), when there are significant changes to noise sources and workplace environment or conditions, when there are adverse health surveillance results or incidents and in response to new noise surveys and assessments.

By staging the implementation of the recommended control actions, Defence will be able to prioritise targeted corrective and preventative measures that:

1) reduce the extent and impact of workplace noise throughout Defence,
2) reduce the level of noise-induced hearing loss and claims,
3) improve Defence's worker health, capability and reputation, as well as
4) providing substantial cost savings and efficiency improvements over time.

4.3 Procurement Process

The project has determined that the acquisition or procurement of new equipment, plant and platforms must consider equipment with the lowest sound emission levels that are technologically feasible, and that are compatible with Defence's own performance and environmental requirements. Defence policy stipulates that Defence must identify alternate quieter noise sources (i.e. "buy quiet") and processes, where available and practicable, in order to assist in minimising worker exposure.

It is recommended that Defence have a *design aim of 75 dB(A)* for all plant and equipment (to be measured at 1 metre or nearest distance to worker/operator), where possible. This plant design aim is 10 dB(A) lower than the noise exposure standard in order to:

1) align with the WHS Code of Practice and accepted industry practice,
2) provide a reasonable safety margin relative to manufacturers' noise data,
3) partly account for multiple plant items (installed with other noise sources),
4) partly account for the degradation due to wear and maintenance issues over time,
5) noting the effects from exposure to ototoxic substances, vibration, long work shifts,
6) noting hearing protection often is not used all the time (or used or fitted incorrectly).

If the design aim is not reasonably achievable, then Defence should design to 'so far as is reasonably practicable' (SFARP). All possible and available noise control measures are to be considered and applied where practicable. Any residual risk needs to be addressed by the application of the hierarchy of controls.

It is important that noise controls are implemented during the procurement phase and may include redesign or engineering noise controls implemented by the original equipment manufacturer (OEM) for new materiel. A redesign or retrofitting off-the-shelf (e.g. commercial or military) noise control treatments may be required in cases such as:

1) procurement of secondhand materiel (e.g. from other countries or agencies),
2) in-service procurement (i.e. outside of normal major acquisition processes), and
3) in-service modification or upgrade of plant and equipment.

4.4 Management Tools

A range of management tools were customised to support the implementation and integration of the improved noise management process across Defence (3, 8, 9, 10). The tools developed included:

1) A standardised Noise Survey Procedure and Statement of Work was developed to provide consistent scope requirements for carrying out noise survey assessments (and aligns with the new WHS legislation), and help ensure a consistent best-practice approach across Defence.

2) A new innovative tool was developed for application to the primary noise sources in Defence – a Noise Safety Data Sheet (NSDS) provides a snapshot of the noise properties of the source and highlights the noise safety requirements associated with its operation and use (e.g. maximum exposure times and minimum safe distances).

3) A clear Noise Management Plan (NMP) template has been developed for application to individual units at a Base. Each NMP action is given an action type based on the priority level and urgency or whether it requires minor or major effort and resources. The NMP is monitored by the relevant managers, along with audit against agreed KPIs.

4) A template for a noise-specific Risk or Hazard Register was generated for use by each Unit and Base based on a template developed including a list of NSDSs. In addition, noise-specific Standard Operating Procedures (SOP) were developed for Units.

5) A range of checklists have been developed including a Noise Inspection Checklist, a Noise Workplace Audit Checklist, a Noise Hand-over/Take-over Checklist (for new personnel postings), a KPI Measurement & Status Template and a Questionnaire Template for providing feedback responses about current noise management status.

6) A number of helpful guides have been developed including a Statement of Work Guide, a Guide on Noise KPI Measurement, a Guide on Ototoxic Substances, a Guide on Extended Work Shifts, a Guide on Buying Quiet Equipment and a Guide on Hearing Protection Area Zones.

These tools, checklists and guides have now been made available and accessible on the Defence intranet website (with information/awareness sessions) and have started to be used by Defence groups to integrate and streamline their noise management processes.

The regular review and monitoring of the change in KPI scores is needed to gauge the effectiveness of the NMPs, the actual progress achieved and to assist in the reprioritisation of actions over time.

5. CONCLUSIONS

An innovative noise reduction project has demonstrated improvements in the management and control of occupational noise exposure in Australian Defence workplaces. Customised noise management plans and effective noise management tools have been integrated across Defence to improve noise control practices and reduce noise exposure.

To measure progress and improvement, specific KPIs were developed to provide a quantifiable and comparable measure of the current status and progress relating to noise management. These KPIs have been used longitudinally over 4 years and show measurable improvements in noise management practices across Defence. In addition, they highlight areas for further improvements still required to comply with regulatory and Defence policy requirements.

Commitment and continued improvement (building on the improvements realised to date) will provide ongoing corrective and preventative measures that reduce the extent and impact of workplace noise in Defence, reduce the level of noise-induced hearing loss and claims, provide substantial cost savings over time and improve Defence's capability and the health of its workers.

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