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BRE Client Report

A review of insulation standards, building regulations and controls related to airport noise insulation schemes. Final Report.

Prepared for:	**Mr Stuart Dick, Analyst, Independent Commission on Civil Aviation Noise**
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Introduction

ICCAN is the Independent Commission on Civil Aviation Noise and are a non-statutory, advisory body created to provide impartial advice to the government, regulators and the UK Aviation industry in relation to the management of aviation noise.

For major infrastructure types in the UK other than aviation there are regulations, such as the Noise Insulation Regulations 1975 (Statutory Instruments, 1975), associated with the sound insulation of existing properties impacted by noise due to either new assets (e.g. new railway lines) or improvements/ changes to existing assets (e.g. motorway widening). These regulations contain specific guidance on identification of properties eligible for acoustic insulation and detailed, prescriptive solutions for addressing noise ingress.

For aviation noise, there are no specific statutory requirements at a national level (when airports are created, runways added or flight capacity increases). Section 79(6) of the Environmental Protection Act 1990, as amended, specifically exempts aircraft noise from the general noise nuisance controls which exist under that legislation (Butcher, 2017). However, planning authorities may impose conditions or agree to undertakings when considering applications for development of airports.

Individual airports consult with their local authority concerning which properties may be adversely affected by the noise they produce and are eligible for works to improve sound insulation from aircraft noise. The sound insulation improvements typically include a package of works including upgrades to windows, ventilation, doors and sometimes the roof of the property. Properties may become eligible to receive sound insulation works for a number of reasons such as increases in aircraft numbers, increased airport capacity, change in airport infrastructure, Noise Action Plans, consultation with nearby communities via airport consultative committees and airspace changes. Airport sound insulation schemes were often historically based on regulatory schemes associated with road and rail noise. These regulatory schemes were established in 1975 and the package of work offered has changed little since the mid-70s. While many airport schemes have evolved to offer packages of sound insulation based on more current products and design options, there is little consistency across the UK. As a result, these packages have the potential to vary in terms of quality and effectiveness over the country.

ICCAN have identified that it would be beneficial for the aviation industry to develop practical best practice guidance aimed at the householders and airports.

The purpose of this project is to collate and report relevant background information for ICCAN to develop best practice information and provide advice to the relevant authorities in respect of acoustic insulation packages for existing residential properties. These packages may include one type of acoustic insulation product or system, or multiple products and systems deployed at the same time.

BRE understand that ICCAN uses the term “insulation product” to standalone elements such as windows, secondary glazing, doors and through wall ventilators, and the term “system” to solutions formed of multiple elements such as whole house ventilation systems.

Executive Summary

This report presents the outcomes of research conducted by BRE on behalf of ICCAN. The research reviews the provision of airport sound insulation schemes, considering types of products and systems installed to reduce aircraft noise intrusion into existing residential properties. It considered

- standards used for characterising sound insulation products,
- available means for objectively measuring the in-situ noise impact and
- considerations in respect of installing acoustic insulation products.

It also overviews Building Regulations that apply to the retrospective installation of the sound insulation measures and approaches to quality management.

For each of the different types of products/systems considered in this review a clearly defined mechanism for declaring acoustic performance characteristics was available. These were generally in the form of British and European standards which provide details of appropriate test methods and quantities to be determined. Where a British or European standard was not available, other national industry standards were identified. In all cases the standards characterise acoustic performance without performance targets. The acoustics performance required from a product or system will vary depending on the situation.

Different methods for establishing internal noise levels from aircraft were considered. Given the variable nature of aircraft noise, the most appropriate means for establishing long-term internal noise levels was found to be through a combination of in-situ testing and making use of noise contours published by the airports.

Based on the airport schemes reviewed, the packages of work and how they are deployed varies between different airports. Many of the schemes aim to insulate on a room-by-room basis and tend to operate with a pre-defined set of sound insulation works. The offers made by airports often include options, chosen in scope and scale by the building occupants. Internationally the approach was seen to be broadly similar, apart from recent schemes undertaken in Australia. These allowed for a much more tailored set of measures and considered the building as a whole rather than simply treating individual rooms. Whilst this “perimeter approach” is likely to yield some advantages in terms of noise reduction achieved, the costs are increased as they were very tailored to each property.

Installation of acoustic insulation products, as with any retrofitted products or materials, have the potential to impact on the overall building performance and dynamics. The Building Regulations impose requirements on such works, with the person undertaking the works required to competently discharge these responsibilities.

Whilst there are several competent persons, and other quality management, schemes associated with the types of product used for acoustic insulation they do not necessarily focus on issues that may impact on the in-situ sound insulation performance. The reason for this is that the schemes are focussed on Building Regulations compliance, and the ingress of noise into a building is not controlled by Building Regulations. Consequently, the aspects of installation that could impact on acoustic insulation will not always form part of the requirements of the schemes.

Description of the project

The project was split into five distinct workstreams:

Workstream 1: Insulation products and systems

Workstream 2: Testing of properties

Workstream 3: Installation of insulation

Workstream 4: Building Regulations

Workstream 5: Quality Management

Workstream 1

Within this workstream the core work consisted of a review of products and systems which can be retrofitted to properties aimed at mitigating the noise ingress from aircraft related noise.

This workstream identifies key acoustic attributes of insulation products and systems, and the means for determining them, and typical/achievable performance values.

We have also considered the potential effectiveness of deploying acoustic insulation products, along with other building works, to reduce aircraft noise transmission into properties. This section introduces solutions and ranges of sound insulation in internal levels that may be achievable.

Workstream 2

Testing of properties in-situ is common and different approaches may be taken by different airports and testing organisations. This workstream identifies available testing techniques and details findings in terms of likely accuracy, complexity to undertake and relevance.

No physical testing has been undertaken as part of this research. Approaches best suited to testing depending on the purpose of the measurements are reviewed.

Workstream 3

The reduction of internal noise levels from aircraft due sound insulation packages will depend on the approach taken and products/systems used. Within this workstream a literature review of different insulation approaches used within the UK and, where practicable, overseas has been undertaken. The benefits and disadvantages to the building occupants and for those implementing the measures are overviewed.

Workstream 4

This workstream considered the current Building Regulations relating to retrofitting of products and systems that are intended to improve the sound insulation properties of a domestic building envelope. Additionally, the workstream reviewed potential unintended consequences of installing insulation products in respect of building comfort or unintended impacts on the use of the building.

Workstream 5

As with many retrofit technologies, the quality of installation is of paramount importance for noise insulation work. Simply selecting an appropriate product is not in itself sufficient, it must also be installed correctly in order to maximise its effectiveness. This workstream reviewed the different approaches to quality assurance and available schemes. The section focuses on established schemes, already in operation and their applicability to airport sound insulation schemes.

Glossary of terms

Airborne sound

Sound propagating through the air such as e.g. voices, music or noise from aircraft

Airborne sound insulation

The ability of building elements or structures to reduce the transmission of airborne sound.

Airflow resistivity

The resistance to air flow passing through a porous material such as mineral wool.

A-weighting

A frequency response used in sound measurement devices to take account of the way the sensitivity of the human ear varies with frequency.

Building envelope

The exterior of a building including all elements such as walls, windows, doors and the roof.

$D_{at,E,2m,n}$

Normalized single event level difference is the difference in sound pressure level between outside and inside a building due to single events (e.g. individual aircraft movements going past or over a property) which has been normalised to a reference value of sound absorption within the receiving room.

$D_{at,E,2m,nT}$

Standardized single event level difference is the difference in sound pressure level between outside and inside a building due to single events (e.g. individual aircraft movements going past or over a property) which) which has been standardised to a reference value of reverberation time in the receiving room.

Decibel (dB)

The unit, using a logarithmic scale, used for many acoustic quantities to indicate the level with respect to a reference level.

$D_{n,e}$

The element-normalized level difference is measured in an acoustic laboratory and quantifies the airborne sound insulation performance of small, technical building elements less than 1m^2 such as window ventilators against frequency in either octave bands or third-octave bands.

Frequency

The number of pressure variations (or cycles) per second that gives a sound its distinctive tone. The unit of frequency is the Hertz (Hz).

Harmonised product standard

Harmonised product standards provide a framework for declaring relevant performance characteristics to enable CE marking of construction products.

Internal noise levels

Within the context of this report, internal noise levels refer to sound within a home resulting from noise sources outside of the home e.g. from aircraft.

Impact sound

Sound resulting from direct impact on a building element e.g. footsteps on a floor.

Impact sound insulation

The ability of building elements or structures to reduce the transmission of impact sound.

$L_{Aeq,T}$

The equivalent continuous A-weighted sound pressure level. This is a notional steady sound which, over a defined period of time *T*, would have the same A-weighted acoustic energy as a fluctuating noise.

L_{den}

The day-evening-night level is the equivalent continuous sound pressure level over a 24-hour period with penalties given to sound pressure level during the evening and night-time by adding 5 dB and 10 dB respectively.

L_{max}

The maximum sound pressure level during a measurement period or noise event. Often used with A-weighting applied to give L_{Amax}.

LOAEL

Lowest Observed Adverse Effect Level, in the context of noise policy it refers to the level of noise above which adverse effects on health and quality of life may be observed.

Lr_k

A-weighted average sound pressure level for a day with average peak service and a correction based on the number of flight operations from small aviation. Specific to noise from aircraft.

Lr_n

A-weighted average sound pressure level for a night with average peak service and a correction based on the number of flight operations from small aviation. Specific to noise from aircraft.

Octave band

A frequency band in which the upper limit of the band is twice the frequency of the lower limit. Octave band measurements are used when the frequency composition of a sound needs to be determined.

R

The sound reduction index is measured in an acoustic laboratory and quantifies the airborne sound insulation performance of building elements such as walls, doors and windows against frequency in either octave bands or third-octave bands.

Reverberation time

The time, in seconds, taken for the sound to decay by 60 dB after a sound source has been stopped.

SEL

The Sound Exposure Level (SEL) generated by a single aircraft at the measurement point, measured in dB A. This accounts for the duration of the sound as well as its intensity. Typically used to assess the risk of potential sleep disturbance from aviation sound at night. This metric is also to assess daytime sound levels from individual aircraft.

SOAEL

Significant Observed Adverse Effect Level, in the context of noise policy it refers to the level of noise above which significant adverse effects on health and quality of life occur.

Sound power level

The total acoustic power radiated by a sound source in all directions, expressed in dB.

Sound pressure level

The amplitude of the sound pressure at a particular location due to a sound source, expressed in dB.

Spectrum

The composition of a particular sound in terms of separate frequency bands and their associated levels.

Third-octave band

Each octave band can be split into three, third-octave bands. Third-octave band measurements are used when the frequency composition of a sound needs to be determined at a higher resolution than octave bands would allow to enable more detailed analysis.

UKCA

UK Conformity Assessment (UKCA) marking is a new product marking for the UK and will apply from 1st January 2021 to most goods currently subject to CE marking. There is currently a one-year transition period for manufacturers to be able to continue to use CE marking up to 1st January 2022, for the majority of products.

Workstream 1: Insulation Products and systems

The first aim of this workstream was to investigate the most relevant standards that can be used to identify acoustic insulation products and their performance characteristics, with specific focus on retrofitting of residential properties.

The following products were identified by ICCAN and BRE for consideration:

- Windows: Double/Triple Glazed
- Rooflights
- Pedestrian entrance doors (e.g. external doors)
- Glazed doors and sliding doors e.g. patio doors
- Secondary Glazing
- Acoustic Trickle Ventilators
- Passive attenuated in-wall vents
- Mechanical ventilation units (single room)
- Mechanical ventilation units (whole house)
- Loft and cavity wall insulation e.g. mineral fibre/glass fibre

The initial focus of this workstream was to consider what standards were available to characterise performance of these acoustic insulation products. The next stage was to consider industry standards and other publications to establish whether these could be used to further inform approaches to acoustic performance characterisation.

The second aim of the workstream was to understand the variability in approach taken by different UK airports in respect of product standardisation. BRE reviewed seventeen active insulation schemes, three in development and one which had closed.

The third aim of the workstream was to inform whether the use of non-acoustically rated products have been shown to mitigating aircraft noise and to quantify what levels of internal noise could be achievable.

Types of standards

Within the context of this workstream, standards are documents which specify requirements for testing and declaring performance or characteristics of insulation products. For the UK, the National standards are controlled by the British Standards Institute (BSI) and are prefixed by the letters BS. Standards controlled by the European Committee for Standardisation (CEN) are denoted by the prefix of the letters EN. Standards controlled by the International Organisation for Standardisation carry the ISO prefix before the standard number. Depending on the origin of the standard, they may carry one or more of the prefixes. BS EN ISO denotes an ISO standard that has been adopted as both a European standard and UK national standard, a BS EN standard would be a European standard which has been adopted as a National standard whereas an EN standard is a European standard that has not been adopted as a National standard.

We have considered only standards that either European (EN) or British (BS) standards that are available to characterise performance of acoustic insulation products within this review.

Other standardisation organisations, such as American Society for Testing and Materials (ASTM), exist throughout the world, but, unless adopted by ISO/CEN, the standards tend to be specific to their local requirements and regulations and so have not been included within the review. ISO consider standards produced by other standardisation bodies in order to develop their own to provide a unified approach. If, however, consensus of the relevant ISO committee cannot be reached then the standard is not adopted by ISO and would be stand alone as a national standard for the originating country.

Within acoustics, the way that performance is expressed varies throughout the world. Often test outcomes undertaken in accordance with say ASTM standards cannot be directly compared with those from the closest BS/EN standard due to underlying differences in laboratory requirements or calculation methods.

Within this section standards fall into one of three general categories:

1. Test standard: This type of standard provides detailed guidance on test method, equipment to be used for testing and calculation methods to enable computation of the test result. Testing standards are not generally specific to a product type.
2. Rating standard: this type of standard is not as common as product or testing standards. They provide a mechanism(s) for the data generated from a test to be expressed in a simpler way than the output from a Test Standard. Within acoustics, they are often used to simplify spectral (e.g. frequency based) test results to a single number.
3. Product standard: This type of standard describes the performance characteristics relevant to a product. It may include specific requirements in terms of test set-up and methodology, but usually cross references to one or more testing standard, rating standard and classification standard. Harmonised product standards are used within Europe to define the essential performance characteristics that need to be measured for CE Marking purposes along with some that are optional. This type of standard can provide minimum performance requirements for certain characteristics (thresholds) but often it is left to individual countries/sectors to introduce their own performance requirements in regulation or sector specific best practice/guidance.

Unless otherwise stated, information relating to standards used in this section has been sourced from the British Standard Online web portal and the most current version was used.

Sound insulation test standards

Within the context of product performance evaluation, sound insulation is currently measured within a laboratory in accordance with the BS EN ISO 10140 series of standards. The predecessor to the BS EN ISO 10140 series was the BS EN ISO 140 series of standards and included both laboratory and field test standards (which are discussed in Workstream 2). The results of testing to the superseded and withdrawn BS EN ISO 140 laboratory standards are still generally considered to be valid, provided the product has not changed, and reference to this series is still prevalent within older product standards and manufacturers' literature.

BS EN ISO 10140-1 (British Standards Institute, 2016) provides application rules for testing of specific product types in terms of test sample arrangement within the laboratory in a series of annexes as follows:

Annex A (normative) Walls — Airborne sound insulation

Annex B (normative) Doors — Airborne sound insulation

Annex C (normative) Windows — Airborne sound insulation

Annex D (normative) Glazing — Airborne sound insulation

Annex E (normative) Small technical elements — Airborne sound insulation

Annex F (normative) Floors — Airborne and impact sound insulation

Annex G (normative) Acoustical linings — Improvement of airborne sound insulation

Annex H (normative) Floor coverings — Improvement of impact sound insulation

Annex I (normative) Shutters — Airborne sound insulation

Annex J (normative) Joints filled with fillers or seals — Sound reduction index

Annex K (normative) Roofs, roof/ceiling systems, roof windows and skylights — Rainfall sound

Within the context of acoustic insulation products, within the scope of this project, Annexes A-E and G are relevant.

BS EN ISO 10140-2 (British Standards Institute, 2010) provides the general test method(s) relating to airborne sound insulation. Airborne sound refers to sound generated in or transmitted through the air and would include sources such as aircraft, televisions and voices. Airborne sound insulation is the ability of a construction or product to reduce airborne sound passing through e.g. from outside of a building to a room inside.

BS EN ISO 10140-2 specifies several different variations on test method to suit different facilities and they are all considered equivalent in terms of accuracy. BS EN ISO 10140-2 also provides the necessary formulae to process the raw data to express sound insulation performance in terms of either sound reduction index (R) for large specimens (walls, floors, doors, windows etc) or element-normalized level difference ($D_{n,e}$) for small samples (vents). The data from the tests is presented in one-third octave bands to show how sound insulation varies with frequency. The standard requires results to be presented over a frequency range of 100Hz to 3150 Hz, though this is often extended to cover frequencies from 50Hz to 5000 Hz to provide more information to acoustic practitioners or the manufacturers. An example graph is provided in Appendix B.

BS EN ISO 10140-3 (British Standards Institute, 2015) provides the general test method(s) for impact sound insulation. Impact sound insulation relates to the transmission of impact sounds such as footfalls on a walking surface and it is not considered relevant in respect of insulation products relating to aircraft noise.

BS EN ISO 10140-4 (British Standards Institute, 2010) provides more detailed guidance on the measurement of airborne and impact sound insulation. It is an essential part of the series and must be used in combination with BS EN ISO 10140-2 to ensure correct results.

BS EN ISO 10140-5:2010+A1:2014 (British Standards Institute, 2014) provides detailed guidance on the laboratories and test equipment required for measuring sound insulation. It is an essential part of the series and must be used in combination with BS EN ISO 10140-1 & -2 to ensure correct results.

Sound Insulation rating standards

BS EN ISO 717-1 (British Standards Institute, 2013) is the current rating standard for sound insulation. The one-third octave band sound insulation data relating to a product or test is compared against a reference curve defined in BS EN ISO 717-1 until certain conditions are met. The rating process results in a single number quantity which summarises the sound insulation performance to enable simple comparison between test results or products/systems

When designing a sound insulation solution, specialist acoustic consultants generally do not rely on the single number quantity and they tend to be used for simplified calculations or marketing purposes.

For sound reduction index measurements (e.g. walls, floors, windows and doors) the single number quantity is weighted sound reduction index (R_w) and for element-normalized level difference(e.g. vents) the single number quantity is the weighted element-normalized level difference ($D_{n,e,w}$).

In addition to these single number quantities, spectrum adaptation terms C and C_{tr} can also be calculated. These terms are intended to convey how a product may perform when exposed to a particular noise source, when combined with the relevant single number quantity. BS EN ISO 717-1 Appendix A identifies that *C* is relevant for jet aircraft at a short distance, C_{tr} is relevant for jet aircraft at a long distance and C_{tr} is also relevant for propeller driven aircraft. By way of example, if a window were to achieve an R_w test results of 35 dB and an associated C_{tr} of -5 dB then it would be expected to offer an overall reduction to the noise from propeller driven aircraft of approximately 30 dB (e.g. 35 dB -5 dB).

Sound Power Testing

Insulation products that include moving parts for air handling, such as a powered ventilator unit, can generate noise through their operation. It is general practice to establish the sound power level in relation to noise emission from products. Sound power is a measure of the emitted airborne sound energy from a device, which is independent of the environment in which it is measured.

The BS EN ISO 3740 series of standards rely on the measurement of sound pressure level, and the selection of any individual method will depend on accuracy level required, facilities and direction from a product standard. Table 1 of BS EN ISO 3740 (British Standards Institute, 2019) provides a reference table summarising the various standards along with their grade of accuracy and requirements relating to test facilities.

The BS EN ISO 9614 series of standards require measurement by sound intensity and again gives options in terms of different techniques to achieve different grades of accuracy.

The quantities determined in sound power testing, regardless of the testing standard used, are the same and include the emitted sound power level against frequencies in octave or one-third octave bands (L_W). The A-weighted overall sound power level (L_{WA}) is also generally presented to provide a single number quantity which summarises the sound power emitted to enable simple comparison between test results or products/systems.

Product Standards

For each of the different acoustic insulation products we have mapped them to the most appropriate, available product standard. Where harmonised products were available for the product type, these have been used in preference since these are used for CE marking purposes (and UKCA from the 1st January 2021). Where harmonised product standards were not available, we have referenced product standards used by industry to declare performance and where product standards were not available, we have identified an appropriate source of UK-based industry guidance.

EU Member states regulate different characteristics of construction products. Product standards list all these essential characteristics that are regulated in EU Member States. These can range from safety critical aspects, through more specific characteristics such as weathertightness requirements. Hence, not all essential characteristics are required to be tested and declared in all EU member states. Where it is not necessary to declare the performance of a characteristic by the regulations of the country in which the product is traded, and there is no threshold specified in the product standard, then the manufacturer can declare "NPD" – No Performance Determined". In addition, product standards can include characteristics which can be determined but not included in the CE Marking.

Windows: double and triple glazed

The most relevant harmonised product standard relating to windows in the context of this project is BS EN 14351-1 (British Standards Institute, 2016)

BS EN 14351-1 lists acoustic performance as a characteristic which can be declared "where required", and there is no "minimum" performance requirement or threshold given. BS EN 14351-1 currently references the superseded BS EN ISO 140 and BS EN ISO 717 series of standards for measuring and rating sound insulation. However, the references to these standards do not make reference to a publication year and BS EN 14351-1 states "For undated references, the latest edition of the referenced document (including any amendments) applies". Consequently, testing to the BS EN ISO 10140 series is considered appropriate.

Annex B of BS EN 14351-1 recommends a test sample size to suit an aperture of 1250mm x 1500mm in line with the requirements of BS EN ISO 10140-1, and provides a means for extrapolating results to cover different sized windows. Pre-test checks include operating (opening and closing the window) five times to ensure it is operable and functions as intended. BS EN ISO 10140-1 places requirements in terms of boundary and installation conditions for the test specimen, and for the perimeter gap (10-13mm) states it "should be filled with absorbing material (for example mineral wool) and made airtight using an elastic sealant on both sides or in accordance with the manufacturer's instructions.". This perimeter detail is critical to the measured performance, and indeed performance in-situ.

Rooflights

BS EN 14351-1 applies to roof lights, with the exception of those covered by either BS EN 1873 (British Standards Institute, 2016) and BS EN 14963 (British Standards Institute, 2006)(see below), and the situation relating to acoustic performance is essentially the same as for windows and doors. It is noted that BS EN 14351-1 does not specify a recommended sample size for acoustic testing of rooflights and this aspect is also not addressed specifically in BS EN ISO 10140-1 for airborne sound insulation.

BS EN 1873 specifies requirements for rooflights made of plastic materials (e.g. GF-UP, PC, PMMA, PVC) and rooflights with upstands made of e.g. GF-UP, PVC, steel, aluminium or wood for installation in roofs. In respect of sound insulation, BS EN 1873 again does not always require its declaration in terms of performance but states "This characteristic shall be assessed when subject to regulatory requirements and may be assessed voluntarily". There is no specific regulatory requirement in the UK and so performance is only likely to be tested as and when required for a specific installation or project. Table 1 of BS EN 1873 provides generic data that can be used to assess potential performance of plastic rooflights.

BS EN 14963 specifies requirements for continuous rooflights made of plastic materials (e.g. GF-UP, PC, PMMA, PVC) with or without bearing profiles to be used with upstands made of e.g. GF-UP, PVC, steel, aluminium, wood or concrete, for laying in roofs. In respect of sound insulation, BS EN 14963 again does not always require its declaration in terms of performance but states "This characteristic shall be evaluated and declared when subject to regulatory requirements, and may be evaluated and declared when not subject to such requirements.".

Pedestrian entrance doors, glazed doors and sliding doors e.g. patio doors

BS EN 14351-1 applies to pedestrian entrance doors, glazed doors and sliding doors, and the situation relating to acoustic performance is essentially the same as for windows. It is noted that BS EN 14351-1 does not specify a recommended sample size for acoustic testing of doors. BS EN ISO 10140-1 Annex B places requirements in terms of boundary and installation conditions, however these are quite loose and state "The test opening for doors shall be arranged such that the lower edge is situated near to the level of the floor of the test rooms and such that conditions in the building are reproduced. The door shall be installed for test such that it can be opened and closed in a normal manner.". Perimeter detailing and seal is critical to door performance in the lab and the field. These should be clearly documented in the lab test report and replicated on-site. Pre-test checks include operating (opening and closing the door) five times to ensure it is operable and functions as intended.

Secondary Glazing

We have not been able to locate a product standard relating to secondary glazing products.

BS 6262-2 (British Standards Institute, 2005) contains general guidance on the measurement of sound insulation, referencing the BS EN ISO 140 series, and also typical performance that might be expected for different configurations.

The lack of product standard is almost certainly down to the fact the performance achieved through installing a secondary glazing product will be dependent on the base performance of the primary window unit. Declaring the performance of the unit in isolation would not give a true reflection of the performance likely to be achieved in-situ unless reference primary units were also declared. It is often the case that secondary glazing suppliers will either provide performance values in relation to the glass only or using a previously tested configuration. The challenge with using a previously tested configuration is that the performance measured relates only to the configuration tested and may not easily be extrapolated.

Acoustic Trickle Ventilators

BS EN 13141-1 (British Standards Institute, 2019) provides the industry recognised framework for declaring performance of the relevant characteristics, although it is not a harmonised product standard.

BS EN 13141-1 does not define that any of the parameters must be characterised, or provide threshold values, but does provide methods for doing so.

In respect of acoustic performance, BS EN 13141-1 calls up BS EN ISO 10140-2 as the appropriate test standard and requires the testing is conducted with the ventilator in the fully open position, mounted onto a specific thickness of board depending how the product shall be used e.g. whether mounted in the window glass, window frame or through the external wall.

For this type of test element, BS EN ISO 10140-1 refers to them as “small technical elements” and Annex E provides the test specimen mounting guidelines. Annex E recommends that the test specimen is placed in different positions representative of real-life installations (section E.2.5 provides details). The standard provides examples to include such as when products will be away from room boundaries, or close to walls, corners or ceilings in real installation to account for any influence due to acoustic reflections/interference.

Passive attenuated in-wall vents

Passive attenuated in-wall vents also fall under the requirements of BS EN 13141-1 and so the guidance given in BS EN ISO 10140-1 Annex E would also apply.

Mechanical Ventilation Heat Recovery (single room)

BS EN 13141-8 (British Standards Institute, 2014) provides the industry recognised framework for declaring performance of the relevant characteristics, although it is not a harmonised product standard. It does not require that any of the parameters must be characterised, or provide threshold values, but does provide methods for doing so.

In respect of acoustic performance, BS EN 13141-8 provides direction for characterisation of radiative sound power in the indoor or outdoor space and for sound insulation.

The radiative sound power relates to the noise emission from the product which will quantify the sound energy passed to the inside of the house or externally. The product mounting conditions are accurately described and several different standards for measuring sound power level are referenced ranging from precision to engineering grade methods.

The sound insulation characteristics are required to be measured in accordance with BS EN ISO 10140-1, -2 &-5. The requirements presented in BS EN ISO 10140-1 would apply since the standard requires presentation of data in terms of $D_{n,e,w}$.

Mechanical Ventilation (supply only, single room – with and without integral passive ventilator)

Within this product group we have considered both stand-alone units and those which also include an integral, passive air transfer device (e.g. trickle ventilator).

BS EN 13141-4 (British Standards Institute, 2011) provides the industry recognised framework for declaring performance of the relevant characteristics, although it is not a harmonised product standard. BS EN 13141-4 provides several different categories for installation. Wall fans are classified as installation type A, and detailed guidance is provided for measuring only sound power emitted from both the inlet and the outlet side.

BS EN 13141-4 refers to BS ISO 13347-2:2004 (British Standards Institute, 2004) for making measurements of sound power level. BS ISO 13347-2 provides guidance in terms of instrumentation, mounting method and test environment but then ultimately calls up several different standards for measuring sound power level ranging from precision to engineering grade methods.

There is no reference within BS EN 13141-4 relating to measuring the sound insulation performance of this type of product. Where the product incorporates integral passive ventilation then it could be addressed under BS EN 13141-1, and the relevant comments relating to Acoustic Trickle Ventilators and Passive attenuated in-wall vents could be applied.

However, where the product is acting as simply a supply or extract fan to a single room then the sound insulation measurement performance characteristics would not be captured by the BS EN 13141 series. The description of small technical elements given in BS EN ISO 10140-1 Annex E would apply to this type of device, which states “This annex is applicable to small technical elements, for instance air intakes and other elements smaller than 1 m^2, such as profiles and shutter boxes.“. The risk with this type of product is that without a clear direction in a product standard identifying sound insulation, manufacturers or purchasers may not be aware that the sound insulation characteristics should also be determined if they are to be used as part of an airport sound insulation scheme.

Mechanical ventilation units (whole house, MEV & MVHR)

Whole house MVHR systems have been included as potential ventilation systems when considering an approach to insulate the entire property from aircraft noise. BS EN 13141-7 (British Standards Institute, 2010) provides the industry recognised framework for declaring performance of the relevant characteristics, although it is not a harmonised product standard.

BS EN 13141-7 provides details for acoustic performance to be characterised in terms of sound power emitted(radiated) from the casing of the main unit and sound power within the connecting ducts.

For casing radiated sound power level, a variety of test methods are listed ranging from precision to engineering grade and a schematic is provided in terms of test-set-up along with some general guidance. The preferred format of test results is in terms of L_W and L_{WA}, and octave-band levels of L_W from 125Hz to 8kHz, or third-octave bands from 125Hz to 10kHz

For sound power within the connecting ducts, reference is made to using either BS EN ISO 5135 or BS EN ISO 5136. Both test standards carry specific and detailed requirements in terms of test set-up and there is no preference expressed by BS EN 13141-7 as to which to select. The sound power within the connected duct can be used to determine the levels emitted to rooms, though this would be a calculation performed by a professional rather than being able to be used directly since it needs to take account of duct layout, termination grills and other installation factors.

Loft and cavity wall insulation e.g. mineral fibre/glass fibre

Loft and cavity wall insulation can take a variety of forms ranging from insulation wool manufactured from molten rock, slag or glass through expanded polystyrene and natural animal products. The products can be supplied in many different forms including rolls, batts, boards, beads, fibres for blown installation to expanding foams. The most common reason for installing these products tends to be for thermal performance, but they are also specified as part of some of the airport sound insulation schemes to control noise transmission via the roof or cavity walls.

BS EN 13162:2012+A1:2015 (British Standards Institute, 2015) is the harmonised product standard relating to factory made mineral wool products in either roll or flat (e.g. batts/boards) format which lists various performance characteristics for mineral wool products ranging from thermal performance to reaction to fire. Where it is not necessary to declare a performance level for a characteristic, then the manufacturer can declare “NPD” – No Performance Determined”.

In terms of acoustic performance, BS EN 13162 allows for characterisation of various parameters. Within the context of aircraft noise insulation, the most relevant are sound absorption and airflow resistivity. The dynamic stiffness characteristic listed is only for products used under screeds as a means for isolating them from a (concrete) base floor.

Sound absorption is relevant when the surface of a product is exposed to the sound field and acting as a sound absorber. In the context of this project it relates to when insulation products are laid in the loft space with the surface of the material exposed to the roof space. BS EN 13162:2012+A1:2015 refers to BS EN ISO 354 (British Standards Insitute, 2003) as the relevant test standard. BS EN ISO 354 is a prescriptive test standard and provides clear direction as to how samples of this nature should be tested in terms of sample size (10-12m^2), mounting and perimeter details. BS EN 13162:2012+A1:2015 then requires performance to be presented in terms of practical sound absorption coefficient, α_p, in octave bands from 125 Hz to 4 kHz and the weighted sound absorption coefficient, α_w, as evaluated in accordance with BE EN ISO 11654 (British Standards Institute, 1997).

Airflow resistivity is an appropriate characteristic to consider when a porous insulation product is within a cavity such as between loft boarding and ceiling boards, or within a cavity wall since it acts as a damping element in this configuration. BS EN 13162:2012+A1:2015 refers to BS EN ISO 29053 (British Standards Institute, 1993) as the appropriate test method which provides clear guidance in terms of sample preparation and details two test methods with no clear preference. BS EN 13162:2012+A1:2015 refers to BS EN ISO 29053 as an undated reference which has now been withdrawn and replaced by BS EN ISO 9053-1:2018 and BS EN ISO 9053-2:2020. For undated references, BS EN13162 states that the latest edition of the referenced document (including any amendments) applies. The value of air flow resistivity shall be declared in levels with steps of 1 kPa·s/m^2.

The European Commission website (European Comission, 2020) lists product standards relevant to construction products. Currently there are 32 harmonised standards relating to different types of insulation that could be used in either loft spaces or cavity walls. Many of the standards do not include acoustic performance characteristics. Where they do, they are treated in the same way as for BS EN 13162:2012+A1:2015 in terms of either sound absorption or airflow resistivity or both.

Industry publications and other guidance

Within this section we have reviewed relevant industry guides, specifications and other published information for the UK which may be able to provide a framework for declaring acoustic performance of sound insulation products and systems.

Noise Insulation Regulations 1975

The Noise Insulation Regulations 1975 (Statutory Instruments, 1975)(NIR 1975) set out requirements under which buildings may qualify for statutory (and in some cases discretionary) noise insulation. The requirements apply to when buildings are exposed to noise, or see a change in noise level, due to the construction of a new road or alteration to a new road. NIR 1975 provides descriptive and performance-based solutions for addressing noise ingress into homes for both secondary window and ventilation products.

NIR 1975 does not apply to aircraft noise, however most of the airport sound insulation schemes reviewed carry reference either directly to it in when specifying sound insulation solutions or describe works very similar to those presented in NIR 1975. The NIR 1975 specifications are also referenced within other sources used for this review.

Schedule 1 of NIR 1975 provides specifications for the noise insulation work. For windows it provides a description rather than a performance requirement and is presented in Figure 1.

Specification for Windows

4.—(1) The existing window shall either be retained and converted to a double window by the installation of a new inner window, or replaced by a new double window if this is essential, and the following conditions shall be complied with—

(a) subject to the requirements of sub-paragraph (c) below, any gaps in the outer window shall be effectively sealed if this is possible by compressible resilient strip or other means;

(b) the inner window may be framed in wood, metal or plastic, shall be well fitted into the existing window reveal or planted on the wall face round the reveal, with the junction between wall and window frame fully sealed by means of mastic packing, cover strips or other equally effective means, and shall be glazed with glass having a thickness of not less than 3 millimetres;

(c) both the outer and inner windows shall be adequately openable for direct ventilation when required, and the inner window shall be adequately openable for cleaning purposes, but the opening lights of the inner window shall be well sealed round their edges either by compressible resilient strip or other equally effective means;

(d) if the window is a bay window or bow window the inner window shall either follow the shape of the outer window, or shall be taken straight across the bay or bow, and any projecting surround or window board required to close off the window cavity shall have a weight of not less than 10 kilogrammes per square metre;

(e) at least two reveals of the window opening between the outer and inner window shall be lined with sound absorbent material;

(f) the shortest distance, or, in the case of a bay window or bow window where the inner window is taken straight across the bay or bow, the mean horizontal distance, between the glass of the outer window and the glass of the inner window shall not be less than the distance specified in the second column of Table 1 below in relation to the thickness of glass of the inner window specified in the first column of that Table:

TABLE 1

Less than 4 mm and not less than 3 mm thick	200 mm
Less than 6 mm and not less than 4 mm thick	150 mm
6 mm thick or more	100 mm

(2) Where it is not practicable to comply with any of the specifications in this paragraph the most practicable alternative specification may be used, provided that in every case the windows shall be adequately openable for direct ventilation.

Figure 1: Extract from NIR 1975, Schedule 1 relating to works to existing windows

The specification goes on to require installation of a venetian blind between the primary and secondary glazing units.

NIR 1975 requires installation of powered, attenuated single room ventilation units and provides specification for this type of unit in terms of airflow and acoustic performance. The sound insulation test methods, BS 2750 (British Standards Institute, 1956) cited are out of date, but are similar to those presented in BS EN ISO 10140-2. It provides third-octave band limits for sound insulation which equate to $D_{n,e}$, in current terminology, and places some specific requirements on the laboratory construction.

NIR 1975 also provides an acoustic specification for passive, permanent ventilators and reference the same sound insulation performance requirements as for the powered ventilators.

For noise emission from powered ventilators, The Noise Insulation Regulations 1975 provides two different targets depending on the back pressure seen by the unit in terms of a room sound pressure level normalised to take account of the reverberation time. There is no detailed test method rather general information is given. The noise emission data can be calculated from measurements of sound power level, but access to raw test data would be required.

The limits in terms of normalised sound pressure level are:

- 35 dB(A) at a ventilation rate of 31 litres per second against a back pressure of 10 pascals, and
- 40 dB(A) at the maximum ventilation rate of the units against a back pressure of 30 pascals.

Robust Details Handbook

Approved Document E to The Building Regulations 2010 (Secretary of State, 2015) (AD E) is the centrally issued guidance provided to assist with demonstrating compliance with the requirements of Part E of The Building Regulations.

In respect of sound transmission between adjoining homes, the normal way to demonstrate compliance with Requirement E1 is through building walls and floors that perform a separating function such that they comply with numerical performance standards listed in AD E. This requirement applies to purpose-built dwelling-houses, flats and rooms for residential purposes and those formed by conversion of other buildings (e.g. material change of use). Pre-completion testing of a sample of properties on a development is used to demonstrate compliance with the numerical performance requirements. The exception to pre-completion testing is for new-build dwelling-houses and flats for which an alternative means for demonstrating compliance is through use of design details set out by Robust Details Limited.

The Robust Details handbook (Robust Details Limited, 2020) is available online and contains the separating wall and separating floor constructions that have achieved the status of Robust Details for Part E of the Building Regulations (England and Wales) and Part G of the Building Regulations (Northern Ireland), “Resistance to the passage of sound”.

The process underpinning the Robust Detail Scheme consists of an initial application incorporating a specified number of field tests, a review by a technical committee in terms of likely robustness and buildability and then further field testing to demonstrate performance. Once approved, the developed details are monitored in the field by visual inspection and testing by designated, expert, Robust Detail Inspectors. The Robust Detail Inspectors are acousticians that have demonstrated competence in terms of testing and inspection experience to the satisfaction of Robust Details Limited.

The handbook provides detailing in terms of external wall and room-in-roof constructions but only with a view for satisfying the relevant performance requirements of the Building Regulations noted above.

The appendices contain various benchmarking protocols for proprietary products to be used with the various details such as floating floor treatments, resilient bars and recessed downlight products.

The various constructions are described in good detail showing gaps and separation required, material specifications and junction requirements.

Whilst the approach outlined above could, in principle, be adapted to suit aircraft sound insulation packages the Robust Details scheme in its current form does not address noise transfer from outside of the building since it is only concerned with sound insulation between adjoining properties and only applicable to new-build properties. The testing and inspection regimes would need to be adjusted as would be the detail approval process. It is also possible that specific inspectors may need to be trained or recruited to consider aircraft noise ingress, if the current inspectors do not have sufficient expertise in the area.

DEFRA Publications

DEFRA have provided a number of publications relating to aircraft noise but they tend to be on the topics of Noise Action Plans and noise exposure e.g. the management of noise, rather than on products/constructions aimed at mitigating the effect of noise exposure. The advice and guidance tend to be more general in nature and steers towards the Noise Policy Statement for England (Department for Environment, Food and Rural Affairs, 2010).

MHCLG Publications

MHCLG have not published guidance for noise insulation products in relation to aircraft noise. However, in 2001 the Office of the Deputy Prime Minister (ODPM) published Proposals for amending Part E (resistance to the passage of sound): consultation (Office of the Deputy Prime Minister, 2001) which contained suggested changes to the Building Regulations, Part E to address sound transmission into buildings. Within Section 7 basic guidance was provided on meeting the proposed requirements using standard constructions with the selection based on external noise bands, while Annex C provided a performance-based approach.

Annex C includes specific guidance relating to aircraft noise and details measurements, prediction and calculation methods to consider appropriate sound insulation means. It provides key points to watch, guidance on installation and typical performance values for walls, windows, doors and roof constructions and ventilator performance.

The document stops short of providing product level performance requirements but does reference appropriate test (laboratory and field) and calculation standards. Those referenced were current at the time of publication, and most have now been replaced by the current versions already discussed.

When the 2003 edition of Approved Document E published; all requirements and guidance relating to the control of noise from external sources, such as aircraft, entering properties proposed in the consultation documents were not included.

Approved Document F to The Building Regulations 2010 (Secretary of State, 2013) provides some limited guidance relating to noise from ventilation systems but states that noise “is not controlled under the Building Regulations”. The general guidance it provides references that sound attenuating products may be required depending on the external noise level and any planning conditions.

In respect of ducted/power ventilation systems it lists some common issues for consideration, and outlines suggested room limits as follows:

“To ensure good acoustic conditions, the average A-weighted sound pressure level in noise sensitive rooms, such as bedrooms and living rooms, should not exceed 30 dB $L_{Aeq,T}$ (see Note below). In less sensitive rooms, such as kitchens and bathrooms, a higher level would be acceptable, e.g. 35 dB $L_{Aeq,T}$. Noise from a continuously running mechanical ventilation system on its minimum low rate should not normally exceed these levels, and should preferably be lower to minimise the impact of the ventilation system.”

These guidelines are not particularly helpful from a product specification perspective since they relate to the noise levels experienced within the home rather than the noise levels emitted by the product.

Glass and Glazing Federation

The Glass and Glazing Federation provide a document on acoustics (Glass and Glazing Federation, 2015) for their members. The document is an information guide for their members, though aimed at homeowners, and explains the basic principles of acoustic performance surrounding glass and glazing. The document stops short of providing performance criteria and underlines the need for test evidence and references CE marking. It notes that CE marking does not apply to secondary glazing, echoing our previous finding that there were no harmonised product standards relating to secondary glazing.

The Glass and Glazing Federation also produce a guide for triple glazing (Glass and Glazing Federation, 2016) aimed at manufacturers and installers which provides information relating to the design for triple glazing and also presents some typical performance ranges for some specific configurations.

The Glass and Glazing Federation provide a collection of datasheets covering various aspects of work and products associated with the work their members are involved with, collectively referred to as The Glazing Manual. The Glazing Manual document 5.10 (Glass and Glazing Federation, 1990) provides a useful reference for design and installation and provides approximate performance values. Document 5.10 mentions laboratory testing but does not offer guidance in terms of test samples and arrangement. Consequently, the only guidance available for testing this form of treatment would be to follow the procedures in BS EN ISO 10140 following suitable identification of an appropriate primary unit reflective of site conditions.

Other publications that the Glass and Glazing Federation produce which have been reviewed relate to trickle ventilators, good practice guides to installation for replacement windows and doors along with various specification documents.

FENSA

FENSA are a subsidiary of the Glass and Glazing Federation and is a government-authorised scheme relating to replacement windows and doors. The FENSA Guide for Compliance (FENSA, 2014) provides a detailed look at the issues for compliance with Building Regulations. It provides clear guidance on safety critical issues and thermal performance, and practical advice along with best practice notes. There is no specific product performance related guidance in relation to sound insulation properties of windows. The role of FENSA as a competent person's scheme is discussed in Workstream 5.

Current approaches in airport sound insulation schemes to product standardisation

The review of airport schemes turned up very few detailed technical specifications within schemes run by the airports relating to product standardisation. They tended to be discussed in general terms, such as 'secondary glazing', 'high performance double glazing', 'loft insulation' and 'ventilation'. Pane configurations for double glazing or the appropriate spacing for secondary glazing, for example, were rarely quoted. For the full list of schemes reviewed please see Appendix A.

Most schemes shared the following characteristics:

- A choice of secondary glazing or high-performance double glazing.
- Pedestrian entrance doors included if they open directly into habitable rooms.
- Inclusion of shading devices such as blinds, particularly for south facing rooms and between secondary glazing panes
- Ventilation included. However, not many of the schemes list it as part of the sound insulation works or refer to it in terms of acoustic performance. Often it is included as a health and safety item, or in a catch all statement about ventilation meeting Building Regulation standards. In a few schemes it is described as optional. This is an area where more clarity and consistency are recommended
- Loft insulation tends to be treated as a separate option, often with its own fixed sum towards materials and towards installation.

The following schemes had points which were less common:

- The proposed Heathrow scheme reviewed states that its most affected properties (71 dB $L_{Aeq,16hr}$ /66 dB $L_{Aeq,8hr\ night}$) would receive a bespoke package of measures rather than their standard approach. This was the only reference to bespoke sound insulation installations and works in such a high noise contour. Most schemes addressed properties in contours of 69 dB or more in the context of relocation assistance, which Heathrow also provides.

The following schemes contained more detailed specifications:

- London City – three detailed specifications for different contours (57 dB, 63 dB and 66 dB) contained in a lengthy S106 agreement. They include secondary glazing air gap and pane thickness (100 mm with 4 mm glass or 75 mm with 6 mm glass), lining of reveals, double glazing configuration (4-20-4[laminated] or 10-12-6.8[laminated], sealing, draught stripping of doors, vents (acoustic, permanent/mechanical configuration), loft insulation (250 mm mineral wool). Specific products are mentioned suggest degree of standardisation for works for the ventilators. An in-situ performance specification provided as 25 dB average sound reduction for First Tier of scheme.
- Belfast – secondary glazing (100mm airgap, minimum pane thickness 3mm), double glazing (6-12-10 or equivalent, states similar acoustic performance to secondary). Specific products are referenced for loft insulation.
- Bristol – secondary glazing (minimum 6mm laminated panes, at least 100mm airgap), double glazing (should be sealed units with at least one laminated pane and achieve a weighted sound reduction index of R_w 38dB lab tested and rated), sealing, optional lining of reveals, vents (optional but covered, detailed acoustic performance specification including $D_{n,e,w}$ 40dB+10*log(no. of vents), performance and maximum mechanical noise output 40dB L_{Aeq} at maximum duty)
- Gatwick – Specific products: brochures provided by the approved contractor contain the following double-glazing configurations giving glass pane-cavity-glass pane specifications in mm and associated acoustic performance (product specific performance) in dB(sound insulation descriptor not specified): 4-16-4 (33 dB), 4-16-6 (35 dB), 4-12-7 (38 dB).
- Birmingham - Specific products mentioned suggest degree of standardisation for works for ventilators. Discussion of hood vents vs mechanical vents is also provided to inform householders choice.
- Manchester -Secondary glazing is defined (panes as wide apart as possible and of different thicknesses). Specific products for loft insulation are included.
- East Midlands - Secondary (minimum gap about 100 mm, minimum pane thickness of the secondary pane 3 mm), high performance double glazing (6-12-10). Specific products for loft insulation are included.

There are clearly different approaches to product standardisation adopted by different airports, as detailed in their schemes. Within the review it was identified that most airports appoint contractors, and many have preferred suppliers/contractors. It may be that within their contractual documentation they have further specified performance characteristics or have standardised their approach, but this was not evident in the information available.

Use of non-acoustically rated insulation products

All insulation products will have some inherent resistance to sound transmission, but the amount afforded will be dependent on the design, materials used and quality of insulation. The overall façade performance will be dependent on the weakest performing element and so the performance of all products installed as a package of works are equally important to be quantified and appropriately specified.

Characterisation of acoustic performance is an important step in gaining confidence that an insulation product will provide the attenuation required to protect the building occupant for aircraft noise intrusion.

Using products that have not been tested, or those that are judged “similar” to those that have been tested, carries an inherent risk that the desired outcome in terms of sound insulation will not be achieved particularly where high levels of sound insulation are required.

Generic published data (Office of the Deputy Prime Minister, 2001), (Glass and Glazing Federation, 1990) is available to inform what may be achievable from non-tested products and they should only be used as an initial guide to specification. Specific performance data should be used to inform final selection of products for deployment with due consideration given to test conditions including perimeter gaps and method of sealing.

Acoustic performance data is widely available from suppliers and manufacturers via datasheets available in the public domain or on request. Provided that an appropriate performance requirement is established for a property, or group of properties, using insulation products of known performance is the first step to ensuring the desired outcome.

Internal noise levels

The internal noise level due to aircraft noise is a result of the external noise level impacting the property and the overall acoustic attenuation due to the building envelope. The noise aviation noise affecting a property is variable due to proximity to the airport, flight paths and air traffic. The overall sound attenuation of the building envelope is determined by a combination of the sound insulation properties of the principle transmission paths:

- The external wall,
- The windows,
- External doors
- Means of ventilation, and
- The roof construction (including upper ceiling).

Sound attenuation afforded by the building envelope

The first step to establishing achievable internal noise levels is to consider the level of sound insulation afforded by the building envelope.

Annex C of consultation to amend Part E (Office of the Deputy Prime Minister, 2001) provides some insight into likely significance of transmission paths both in terms of general text (reproduced below) and tabulated, generic performance data.

"C3.26 For masonry walls, such as a 225mm solid brick wall, a brick/block cavity wall or a brick clad timber frame wall, the performance will normally be such that the windows, ventilators and, in some cases, the roof will dictate the overall sound insulation of the building envelope.

C3.27 Timber frame walls with lightweight cladding and other lightweight systems of construction normally provide a lower standard of sound insulation in the low frequency region, where road traffic and air traffic noise peaks. This can result in a low airborne sound insulation, unless the cladding is specifically developed to control low frequency noise transmission."

The tabulated, generic performance data has been reproduced in Table 1 and Table 2.

Building Envelope Element	**Sound Reduction Index (*R*) dB Octave band centre frequency (Hz)**				
	125	250	500	1000	2000
External walls:					
Brick/block cavity wall	41	45	45	54	58
Timber frame wall with lightweight cladding	24	34	40	45	49
Well sealed window:					
4mm single glazing	20	22	28	32	33

6mm single glazing	20	24	31	35	27
10mm single glazing	26	27	34	35	36
4/12/4 mm double glazing	24	20	25	34	37
6/12/6 mm double glazing	20	19	29	38	34
10/12/6 mm double glazing	26	27	34	40	38
6/100/4 mm or 6/100/6 mm double window	26	34	44	44	38
6/150/4 mm double window	29	35	45	56	52
10/200/6 mm double window	35	46	46	46	56
Solid core door, 25 kg/m2, well sealed	20	25	27	28	32
Roofs:					
Tiled/slated roof, 12 mm plasterboard ceiling, no sound absorbing layer above ceiling	21	26	33	33	35
Tiled/slated roof, 12 mm plasterboard ceiling, sound absorbing layer (e.g. 100mm mineral wool)	24	34	40	45	49
Tiled/slated roof, 25 mm plasterboard ceiling, sound absorbing layer (e.g. 100 mm mineral wool)	27	37	43	48	52
Flat timber-joist roof, asphalt on boarding, 12mm plasterboard ceiling, sound absorbing layer (e.g. 100mm mineral wool) in cavity)	22	37	43	49	57
Flat roof, 100mm reinforced concrete (230kg/m2)	39	40	49	53	57

Table 1: Sound reduction index data from Table C5 of Part E consultation

For the window descriptions in Table 1, the numbers separated by "/" are used as shorthand to denote the glass panes and the separating cavity width in millimetres. By way of example; 4/12/4 consists of a double-glazed window unit comprising 4mm glass, a 12mm cavity and 4mm glass. The secondary glazing configurations are those with 100mm or greater cavities e.g. 6/100/4, 6/150/4 and 10/200/4.

Ventilators:	Element-normalized level difference ($D_{n,e}$) dB (open areas corrected to 4000mm^2) Octave band centre frequency(Hz)				
Hit-and-miss trickle ventilator	34	39	34	41	31
Trickle vent with indirect air path	36	36	36	34	35
Trickle vent with direct air path	35	35	34	36	34
Acoustic trickle ventilator	34	38	43	42	34
Through-wall vent (100mm diameter) plus grilles	45	41	35	36	42
Passive attenuated in-wall ventilator	42	43	43	49	64
Powered attenuated ventilator, complying with the requirements of the Noise Insulation Regulations 1975 (from manufacturers data)	42	48	52	58	65

Table 2: Element-normalized level difference data from Table C5 of Part E consultation

The data presented above should not be used in lieu of measured data for specific products, however it can be used to calculate potential sound insulation values for typical intervention packages of sound insulation products. The data presented above is also somewhat historic and it is likely that well designed, modern products could well outperform these in terms of acoustic performance.

Modelled in-situ performance

Using an engineering method (British Standards Institute, 2017), we have presented a number of scenarios below with associated potential reductions that may be achieved, in-situ. The modelling only applies to the generic situation modelled and does not take account of secondary transmission paths such as those due to poor sealing of the building envelope.

The performance calculated is presented as an average of a likely range and is provided for illustration purposes. The actual predicted performance for any individual scenario will depend on the room geometry, the relative areas of the different components making up the building envelope and the frequency spectrum of the aviation noise affecting the property. In all scenarios modelled we have assumed a reverberation time of 0.5s to be representative of living rooms/bedrooms, and that the external wall is brick/block construction. We have not made an allowance for enhanced ventilation for a combustion appliance as defined in NIR 1975.

We have used a generic aviation noise spectrum to calculate a potential level difference (*D*) which can be applied to an external noise level due to aircraft to give a likely internal level later in the analysis.

The first scenario to be modelled account for fairly basic products in terms of the lowest performing double glazed windows(4-12-4) and one of the lower performing trickle ventilators(Hit and miss trickle ventilator) presented in Table 1 and Table 2, with loft insulation and brick/block external wall.

Scenario 1

External wall: Brick-block cavity wall Windows: 4/12/4 mm double glazing

Ventilation: Hit and miss trickle ventilator

Roof: Tiled/slated roof, 12 mm plasterboard ceiling, sound absorbing layer (e.g. 100mm mineral wool)

Potential level difference (*D*) = 25 dB

Adjusting the scenario by removing transmission by the trickle ventilators increases the performance predicted performance to 29 dB(*D*) and indicates that they are the weakest path for this configuration.

By subsequently removing transmission via the roof e.g. assuming the roof/ceiling is upgraded or that the room is below the top floor level such as a mid-height flat or ground floor room yields a predicted performance of 30 dB. This outcome suggests that while potential level difference is starting to be influenced by transmission via the roof, the most limiting element for sound transmission is currently the windows. If a significant improvement was made by omitting transmission via the roof then this would be identified as the main transmission path.

Based on the outcomes of the first modelling scenario, the second scenario to be modelled takes into account using the highest performance double glazed windows(10/12/6) and improved ventilators (acoustic trickle ventilators) presented in Table 1 and Table 2.

Scenario 2

External wall: Brick-block cavity wall

Windows: 10/12/6 mm double glazing

Ventilation: Acoustic trickle ventilators

Roof: Tiled/slated roof, 12 mm plasterboard ceiling, sound absorbing layer (e.g. 100mm mineral wool)

Potential level difference (*D*) = 30 dB

Removing transmission via the roof completely for this scenario results in a 3 dB uplift in predicted level difference, bringing it up to 33 dB.

Alternatively, changing the roof specification it to the 25mm plasterboard ceiling achieves a potential level difference of 31 dB and subsequently substituting the acoustic trickle ventilator for the NIR 1975 ventilator provides an expected level difference of 33 dB.

Altering the scenario by removing transmission via the roof while retaining the NIR 1975 ventilator gives rise to an expected performance of 36 dB, level difference.

For the final modification to the scenario was to remove transmission from both the roof and ventilator paths which yields the level difference of the upper limit for the windows of 37 dB.

For the next scenario, we have modelled the implementation of the full NIR 1975 specification, based on the data in Table 1 and Table 2, with an upgraded ceiling construction of 25mm plasterboard.

Scenario 3

External wall: Brick-block cavity wall

Windows: 6/100/4 mm double window

Ventilation: Powered attenuated ventilator, complying with the requirements of the Noise Insulation Regulations 1975 (from manufacturers data)

Roof: Tiled/slated roof, 25 mm plasterboard ceiling, sound absorbing layer (e.g. 100mm mineral wool)

Potential level difference (*D*) = 35 dB

No change is made to the expected level difference in this scenario by increasing the glass separation for the secondary glazing suggesting that the roof is limiting the performance that can be achieved.

When the scenario is altered to remove transmission through the roof, the potential level difference increases to 39 dB, which can be increased by a further 1 dB to 40 dB if the window used in the calculation is then increased to 10/200/6 mm double window.

Limitations of modelling work

The modelling work is based on the generic, published data presented in this report (Office of the Deputy Prime Minister, 2001). However, in practice the ability of a product or construction to perform will depend on many factors. In our experience, ventilator performance can vary significantly with many “conventional” trickle ventilators outperforming or underperforming the generic data used. Similarly, trickle ventilators designed specifically for acoustic performance can significantly outperform the generic data presented.

Equally the performance of “acoustically rated” windows can also vary significantly depending on glass type, frame design and seal design.

The performance of secondary glazing inherently depends on the performance of the primary unit, which makes it particularly variable in terms of any uplift in performance.

The roof performance data used in the modelling appeared to significantly limit the predicted level difference that could be achieved. Whether the level of sound insulation performance used in the model is too low or too high as a baseline is critical to understanding the potential performance of a deployed sequence of measures in a real scenario. Further research is required to confirm sound insulation performance of current roof/ceiling constructions in-situ and any improvements in acoustic performance due to retrospective treatments. The Sydney Kingsford Smith Airport noise insulation programme (Burgess, 1997) discussed the addition of loaded vinyl layers in the roof space, but we were unable to source test data relating to this form of treatment that could be incorporated into the modelling.

It is likely that further insight into performance in-situ may be able to be sourced from the airports that undertake testing pre and post works. An alternative approach would be to measure performance within a test laboratory of a variety of common roof constructions to confirm the accuracy of the generic performance data used and to consider options for retrospectively improving them in a more controlled environment.

Secondary transmission paths can undermine the maximum sound attenuation achievable and include:

- Gaps and cracks,
- Window seals,
- Door seals, and
- Presence of fireplaces.

It was not possible to take account of these secondary transmission paths within the modelling, so these secondary paths have not been allowed for. It is reasonable to consider that the secondary transmission paths could be identified by a survey or test of the property after installation of insulation products.

Resulting internal noise levels

Taking the outcomes from the modelling exercise and some of the more practical configurations (e.g. only including options that include ventilation) can be broadly summarised give three bands in terms of overall performance (Note: Actual performance of products should be determined prior to installation):

Scenario 1: Level difference 25-30 dB – likely to be achievable with thermal double-glazed windows and trickle ventilators with no likely upgrade to roof constructions

Scenario 2: Level difference 30-35 dB - likely to be achievable with enhanced double-glazed windows and acoustic trickle ventilators/NIR 1975 compliant ventilators and potential upgrade to roof constructions depending on current performance/construction

Scenario 3: Level Difference 35-40 dB – lower end of range may be possible through enhanced double glazing and acoustic trickle ventilators, majority of cases secondary glazing required with NIR 1975 compliant ventilator and likely upgrade to roof in most cases, depending on current performance.

The source (external level) combined with the likely attenuation can be used to provide an estimate of likely internal noise level, based on a generic aviation noise spectrum.

We have considered the following noise levels externally, during the daytime:

1. 51 dB (this contour has been most recently identified as representing LOAEL during the day (Department for Transport, 2018))
2. 54 dB (this contour has been proposed as a level for eligibility of sound insulation works withing Aviation 2050 (Department for Transport, 2018))
3. 57 dB (this contour is considered within current UK aviation policy to represent "the average level of daytime aircraft noise marking the approximate onset of significant community annoyance" (Secretary of State for Transport , 2013)so would be higher than LOAEL)
4. 63 dB (this contour is used as threshold at which government policy expects airport operators to offer acoustic insulation, and is above LOAEL but below SOAEL for airport noise)
5. 69 dB (at a noise contour of 69 dB and above, the building occupants are usually offered a re-location package so within the context of NSPE this represent SOAEL)

Noise level, $L_{Aeq, day}$	Resulting internal noise level, based on modelled scenario, $L_{Aeq, day}$		
	Scenario 1	Scenario 2	Scenario 3
51 dB	21-26 dB	16-21 dB	11-16 dB
54 dB	24-29 dB	19-24 dB	14-19 dB
57 dB	27-32 dB	22-27 dB	17-22 dB
63 dB	33-38 dB	27-33 dB	23-28 dB
69 dB	38-43 dB	33-38 dB	28-33 dB

Table 3: Potential noise levels within dwellings due to external noise level and outcomes from modelling work in accordance with an engineering method.

The Table 3 shows that different interventions will result in markedly different internal noise levels.

Comparison with internal noise level targets

The World Health Organisation (WHO)Guidelines for Community Noise (Berglund, et al., 1999) is a well-recognised source for internal noise targets. For dwellings, the WHO guidelines present internal and external noise limits. The external noise limits would be most relevant for use when planning airport changes and operational issues, and this aspect cannot be affected by the installation of insulation products to dwellings.

The guidelines for dwellings relating to daytime noise are presented in Table 4.

Specific Environment	Critical health effect(s)	L_{Aeq} (dB(A))	Time base (hours)
Dwelling, indoors	Speech intelligibility & moderate annoyance, daytime & evening	35	16

Table 4: Guideline values for community noise in specific environments, taken from Table 1 from Guidelines for Community Noise

Comparing the outcomes presented in Table 3 with the indoor guideline values provided by WHO, presented in Table 4 indicates that:

- Below 54 dB, all scenarios should be capable of achieving the inside WHO daytime level
- Between 54 and 57 dB (daytime, L_{Aeq}) the Scenario 1 works should capable of achieving the internal, daytime WHO level.
- Between 57 dB and 63 dB (daytime, L_{Aeq}) the Scenario 2 works should capable of achieving the internal, daytime WHO level.
- Between 63 dB and 68 dB (daytime, L_{Aeq}) the Scenario 3 works should capable of achieving the internal, daytime WHO level, and in some cases Scenario 2 works may be sufficient.

It is important to note that the above analysis and commentary assumes that windows will be shut, and that adequate ventilation will be afforded with windows closed. It does not take into consideration mitigation required to reduce the risk of summer overheating (see Workstream 4).

Similar comparisons may be made against the criteria relating to night-time noise presented in the Night Noise Guidelines for Europe (World Health Organisation, 2009). However, WHO internal noise targets are in terms of either L_{Amax} and $L_{Aeq,8hr}$ during the night-time whereas the metrics used for noise contour production are usually in terms of SEL or N contours for night-time periods. To understand the likely internal noise levels and whether they would comply with relevant internal noise limits, both the external levels and associated internal noise limits would need to be in the same metrics.

Conclusions from Workstream 1

For each of the acoustic insulation product types there is a published framework for testing, reporting and declaring acoustic performance. The product type with least guidance in terms of performance characterisation is secondary glazing however, the prescriptive nature of the specifications within NIR 1975 go some way to bridging the gap.

There is a lack of consistency in terms of product standardisation between different airport operators for noise insulation packages. Some operators have published a performance-based approach, and others provide named products, suppliers or contractors to undertake the works. It may be beneficial to develop a minimum framework for the specification of products, based on the standards identified in this review, to ensure all aspects are consistently addressed across all schemes. Performance based approaches to specifications allow for more greater flexibility in the approach and more innovation.

Whilst generic data can be used to gain insight into the potential level of acoustic insulation offered by constructions or products it should not be solely relied on for specifying works, products to be installed or be used to define measures for an insulation scheme. Instead, the generic data can be used to narrow down the search for an appropriate product, and then the product specific data published by the manufacturer should be used to confirm suitability. Failing to appropriately specify all aspects of the façade insulation package is likely to result in underperformance in practice.

From the scenarios modelled, based on generic performance data available in the public domain, we have shown that the installation of acoustic insulation products should be capable of resulting in internal noise levels during the daytime that achieve current guideline values. The package of products necessary to achieve the guideline values varies depending on external noise level considered. This exercise demonstrates flexibility in approach for airport sound insulation schemes may be appropriate to give the best outcome to both the occupants and airport operators.

Transmission of sound via the roof structure appears to be one of the more challenging to address, particularly when high levels of sound insulation are required (e.g. above 30 dB), though it is noted this analysis is based on data that may be reasonably old and may not necessarily reflect current performance. Further study or expert insight following on-site testing would be able to inform whether improvements to the roof are required, on an individual basis.

The actual performance of a building envelope will depend on many factors including the performance of the products themselves, the quality of installation and the addressing of secondary transmission paths through the existing building elements.

Workstream 2: Testing of Properties

The first aim of this workstream was to identify testing methods to be able to determine the level of noise intrusion entering properties from aircraft noise before and after installation of acoustic insulation works.

In order to determine the level of noise entering a property, two potential testing options have been considered:

1. Measurement of aircraft noise within the property
2. Measurement of the sound insulation of the building envelope

Measuring aircraft noise within the property, in principle, may represent the simplest approach to establishing the level of noise intrusion from aircraft.

Using in-situ testing of the sound insulation characteristics of the building envelope (combined sound insulation of the roof, windows, external wall, doors and other paths) in conjunction with knowledge of external noise levels would allow for determination of the noise intrusion into a property.

The approach taken for establishing the level of aircraft noise within a property will depend on the purpose of the testing, which will be discussed later in this section.

The second aim of the workstream was to evaluate which of the different methods and likely to be most effective and to identify the advantages and disadvantages from a practical perspective.

Internal measurements of aircraft noise

The majority of British standards concerned with measuring noise levels from environmental noise sources, including aviation noise, tend to be focussed on measuring noise outside the property. BS EN ISO 16283-3 (British Standards Institute, 2016) provides a procedure for measuring levels within a property due to individual aircraft noise events, but this is in the context of sound insulation testing.

The Association of Noise Consultants (ANC) is a trade association for acoustic and vibration consultancy practices in the UK and provides guidance to assist their members with various topics. The ANC guidelines (Association of Noise Consultants, 2020) provides detailed information necessary for measuring sound levels within properties due to internal and external sources.

In respect of aircraft noise, the ANC guidelines define this type of sound source as “non-steady, intermittent” and provides specific and detailed guidance on measurement of noise sources of this type. The guidelines discuss measurement positions and sampling techniques for both resulting sound levels and reverberation time. It is not prescriptive in terms of measurement duration but recommends that “a sufficient duration to provide a representative sample of all events to quantify the spread of sound levels experienced throughout the reference period”.

Overall, the guidelines are useful and provide a detailed framework, though it is written for a technical audience e.g. practicing acousticians, and there is an expected level of prior experience and knowledge.

It is well established (Independent Commission on Civil Aviation Noise, 2020) that aircraft noise will vary over the course of a day, week or year due to many factors. In order to accurately determine the internal noise levels due to aircraft noise within a property, long duration measurements may need to be considered.

For longer measurement durations, there would need to be a high degree of confidence that the levels measured internally were only as a result of aircraft and not due to extraneous noises either within the property(e.g. generated by the building occupants, white goods or building services) or outside of the property(e.g. neighbour noise, other sources of transport noises or local events).

It may be possible to assess the performance improvement due to changes in a building façade, using the ANC guidance, by measuring internally pre and post works. This may not necessarily represent the most robust approach to establishing the effectiveness of installing noise insulation products to a property as the external noise level may well be quite different between the two measurement periods as they are likely to be separated by days, weeks, months or even years.

To account for the expected variation in the external noise environment over different measurement periods, external noise monitoring would need to be made in parallel to the internal noise measurements. This approach forms the basis of measuring the in-situ sound insulation performance of a building envelope.

In-situ sound insulation testing

Sound insulation testing of a building gives information on the ability of a building envelope, façade, or façade element to reduce sound transmission. Within the context of acoustic insulation products and packages of works, it is the amount that the building envelope or façade reduces aircraft noise entering the dwelling from outside.

BS EN ISO 16283-3 (British Standards Institute, 2016) provides detailed guidance in undertaking field measurements of the sound insulation characteristics of building façades for a wide range of sources including aviation. The standard presents a total of eight different test methods depending on the purpose of the investigation, the test methods split into two broad categories:

> **Element:**
>
> These are the preferred method types when the aim is to estimate the performance of a façade element such as a window. The results can, under certain conditions, be used to compare against test results obtained under laboratory conditions in accordance with BS EN ISO 10140-2 (British Standards Institute, 2010).
>
> **Global:**
>
> These are the preferred method types when the aim is to estimate the outdoor/indoor level difference and considers all sound transmission paths that may contribute to this performance.

BS EN ISO 16283-3 states that the Global air traffic method presented in Annex E is the preferred solution when the aim of the testing is to estimate the global sound insulation of a façade exposed to sound from aircraft traffic.

BS EN ISO 16283-3 provides a general frequency range from 100 Hz to 3150 Hz but allows for this to be extended to cover from 50 Hz to 5000 Hz, both of which would be applicable to aircraft noise. The procedure for measurement is detailed and gives guidance on a variety of methods for sound field sampling and selecting appropriate equipment. There are specific procedures relating to low frequency measurement but notes these should not be applied when using a traffic noise source as there is insufficient experience of using them in this way at the time of publication.

BS EN ISO 16283-3 Annex E requires simultaneous indoor and outdoor measurement of a minimum of 5 discrete noise events e.g. individual aircraft movements past or over the property.

The external measurements are made at 2m from the building façade, at a height corresponding to 1.5m above the floor of the indoor (receive) room being evaluated, in the middle of the façade. There is further guidance to be applied for multiple measurement locations if the room being evaluated has more than one external wall or the façade is very large.

For internal measurements, either the microphone is placed at a minimum of 5 fixed positions or shall be continuously moving. Where fixed positions are used, it is permitted to use one indoor position for each noise event.

The individual noise events must be of a sufficiently high level inside the room being tested such that it exceeds the background noise level within the room by a significant margin. The background noise level within the room is the noise level in the room when aircraft noise is not present and may be due to other sources of external noise such as road traffic or noise sources within the property. Where the level due to aircraft noise events doesn't significantly exceed the background noise, the sound insulation performance will be underestimated. If the background noise inside the building under test is too high, then the loudspeaker method may be used as an alternative.

The loudspeaker method requires placing a loudspeaker outside the property, at locations specified within the standard, operated at a high level driven by signal generator and power amplifier. Measurements are made outside and inside the property either simultaneously or concurrently depending on the tester's preference and equipment used.

The testing methodologies presented in BS EN ISO 16283-3 is relatively complex, and likely to require an experienced, competent operator to achieve reliable results.

The results from testing using the global method, with air traffic as a noise source, can be used to yield two different parameters, in one-third octave bands and octave bands:

- Normalized single event level difference, $D_{\mathrm{at,E,2m,n}}$
- Standardized single event level difference, $D_{\mathrm{at,E,2m,n}T}$

Within the UK, the standardized level difference is generally used for predicting internal levels within a building due to an external sound source since it requires less knowledge regarding the room geometry and finishes to use.

BS EN ISO 10052 (British Standards Institute, 2010) provides a survey method for measuring sound insulation of building elements and includes reference to façade sound insulation testing. As a survey method, it is a grade of accuracy below the engineering method described in BS EN ISO 16283-3 and so would be expected to have higher levels of uncertainty associated with the test outcomes. The test methods only include for using loudspeaker and road traffic noise as a sound sources, though the procedures described are similar to those given in BS EN ISO 16283-3 but less detailed. The other core difference is that BS EN ISO 10052 provides an option to make use of estimated corrections for reverberation time rather than being based on measured data. This approach leads to a reduced testing time but will lead to increased uncertainty particularly if comparing pre and post-works testing where it is conceivable that the level and orientation of soft furnishings (beds, sofa, curtains etc) within a room change between measurements. The test outcomes in terms of parameter are the same as for BS EN ISO 16283-3, for road traffic and loudspeaker sources, though it does not allow for the performance to be evaluated in terms of single events.

BS EN ISO 717-1 (British Standards Institute, 2013) can also be used to evaluate single number quantities of sound insulation performance measured in accordance with either BS EN ISO 16283-3 or BS EN ISO 10052. The process is the same as described previously, but this time the measured data is that resulting from the in-situ test of sound insulation.

For single event level difference measurements measured in accordance with BS EN ISO 16283-3 the single number quantities derived are weighted normalized single event level difference, $D_{\mathrm{at,E,2m,n,w}}$, and weighted standardized single event level difference, $D_{\mathrm{at,E,2m,n}T,w}$.

In addition to these single number quantities, spectrum adaptation terms C and C_{tr} can also be evaluated, using BS EN ISO 717-1 as discussed in Workstream 1 for laboratory measurements.

Choosing the best approach to testing of properties

The best approach to be taken to evaluating aircraft noise levels entering a property depends on the purpose of the measurements.

If the purpose of the measurements is to consider the impact of individual events or series of events over a short-duration then measuring in-situ levels within the property of interest will provide this information, however this doesn't seem suited for aircraft noise considering the variability over time. Whilst is may provide some specific insight into a particular event, it is likely to need to be supplemented by longer terms measurements to confirm any apparent outcomes.

Where the objective of the measurements is to look at either the current sound insulation performance of the façade or the evaluate the difference made by deploying acoustic insulation works, sound insulation testing in accordance with BS EN ISO 16283-3 is considered to be the most accurate test method.

Experienced testers/acousticians could use the sound insulation data to better understand noise transmission paths and potentially optimise any package of works to a given property. Typically, all sensitive rooms in a property could be tested within around half a day by an experienced testing organisation.

If it is desirable to understand the noise levels within a home over a long duration e.g. over the course of a year or more, the more reliable method may be to determine the sound insulation performance of the building envelope in conjunction with long term, predicted external noise levels.

Provided that the noise contour information is considered a sufficiently accurate picture of the external noise environment, then sound insulation testing allows for quite an elegant means of determining internal noise levels, works required to reduce noise transmission into a property or to appraise the success of works undertaken.

From the review undertaken of airport sound insulation schemes, the London City Airport scheme was the only one we could locate a sound insulation target for works. The target is presented only against the 57 dB noise contour (First Tier) and places performance requirements on the works to achieve "an average sound reduction not less than 25 dB averaged over 100 to 3150 Hz in accordance with BS EN ISO 16283-3:2016". It is likely that at London City Airport, they have considered a target internal noise level when setting this performance requirement though this is not explicitly mentioned in the scheme details.

The rate of testing undertaken by airports currently is not publicised, though several of the airports report to undertaking testing work but don't necessarily provide details of the success or otherwise of works. Consequently, it is not possible at this stage to recommend specific sampling rates. It is unlikely to be necessary to test every property to ensure good outcomes, and it is likely that the rate of testing will need to be informed by condition, noise exposure and construction of property.

Approved Document E (Secretary of State, 2015) outlines a rate of testing of approximately one in ten properties of each different construction type as being appropriate. However, this is in the context of sound transmission between adjacent dwellings rather than in the context of building envelope sound insulation. The rate of testing described in Approved Document E was determined due to known issues of variability in performance within the context of sound transmission between homes. Currently there is insufficient published data relating to building envelope sound insulation performance to determine whether a similar rate of testing would be appropriate or if it would need to be increased/decreased.

The appropriate proportion of testing and surveys may depend on several factors including construction, age and design. However, it is worth noting that differences such as loft conversions, window types, door design or penetrations to the building envelope such as cat flaps could have a significant impact on the sound insulation properties which may not be always be apparent from a brief visual check.

Conclusions from Workstream 2

Between industry guidance and standards published by BSI, there are established protocols for testing properties for levels of noise pollution, determining current acoustic performance of the building envelope and assessing the effectiveness of sound insulation package deployed. All the testing methods reviewed are likely to require competent testers or professionals with experience in acoustic measurements and knowledge of the airport affecting the property/location to avoid measurement bias/unnecessary inaccuracies.

Within the context of evaluating what works are required to reduce noise ingress or to appraise the effectiveness of works, BS EN ISO 16283-3 represents the most robust and time efficient approach of available techniques.

Combining knowledge of the sound insulation performance of the building envelope, established through testing, with external noise levels from published noise contours is considered to represent a relatively robust approach for determining noise levels from aircraft movements within properties.

Workstream 3: Installation of insulation

The aim of this workstream is to review different approaches that can be taken for insulating properties against aircraft noise within the UK and overseas and evaluate the benefits of the different approaches. The information that formed the basis of this section is publicly available and sourced during the review of airport sound insulation schemes, described in Appendix 1.

UK Approaches

The general approach taken by the UK airports is to deploy sound insulation measures on a room-by-room approach when above the 63 dB noise contour and below the 69 dB noise contour. The measures that were generally observed as being in common included:

- A choice of secondary glazing or high-performance double glazing. In a limited number of schemes, the householder will be expected to make a contribution for double glazing, but not for secondary glazing.
- Entrance doors to properties included if they open into habitable rooms for the majority of schemes.
- Inclusion of shading devices such as blinds, particularly for south facing rooms and between secondary glazing panes
- Ventilation is generally mentioned in the various schemes. However, not all of the schemes list it as part of the sound insulation works or refer to it in terms of acoustic performance. Often it is included as a health and safety item, or in a catch all statement about ventilation meeting Building Regulation standards. In a few schemes it is described as optional and at the discretion of the homeowner.
- The schemes largely cover habitable rooms only. However, three of the schemes reviewed extend it to include some other spaces such as landings and/or bathrooms(Belfast, Gatwick, Southend and Dublin).
- Most schemes nominate the contractor or approve the householder's choice in limited cases where the householder wishes to appoint their own. Of the schemes reviewed, only the Bristol and Edinburgh schemes ask householders to get their own quotes.
- Very few properties are given an unlimited budget for sound insulation. Schemes usually either allow the householder to nominate a fixed number of rooms for treatment or set a limit on the grant contribution. Many schemes vary the grant limit with noise contour so that properties in noisier areas receive more protection. A few of the schemes reviewed (Belfast, Bristol, Liverpool and Manchester) set both a limit and a householder contribution, but where changes to schemes are discussed, householder contributions appear to be losing favour compared to grant maxima which the householder is free to top up.
- Eligibility is determined by noise contour. It was common that the schemes mentioned a survey visit to inform works but the documents rarely go into detail about what the survey entails. The schemes do not mention testing to establish the amount of improvement needed by individual properties, or the use of acoustic specialists. Heathrow has a clear commitment to third party assessment but does not state whether that party should be an acoustic specialist.
- Loft insulation tends to be treated as a separate option, often with its own fixed sum towards materials and towards installation.

Within the UK Schemes reviewed, only the Heathrow airport scheme, currently in consultation, offers a bespoke set of works and only in exceptional circumstances. Tiered approaches to packages based on different noise contours are in place for three of the schemes (Doncaster, East Midlands, London City and Luton) reviewed and in development for two of the airports(Heathrow and Stanstead). The approaches are to either provide different specifications to homes in different noise contours or to vary the amount of grant available for the works.

The schemes for Manchester and East Midlands, which are part of the same group, only cover brick-built properties.

International Approaches

The search for information relating to international airports was relatively limited, and is overviewed in this section by individual airport, since the approaches vary. We have included eligibility criteria provided by the airports for information though we have not provided a conversion to where the noise quantity used to describe the contours differs from those used in the UK. Where costs have been attributed to schemes or works, we have provided GBP equivalents based on current exchange rates (Source: XE website, accessed 04 December 2020) with no allowance made for inflation.

Paris Charles de Gaulle

Paris Charles de Gaulle Airport has provided Autorite De Controle Des Nuisances Aeorportaires (ACNUSA) sound insulating grants (ACNUSA, 2020) since 1995. The ACNUSA approach is consistent to all twelve of France's main airports. A noise Disturbance Plan (PGS) is developed for each French airport annually. This is based on forecasts of air traffic for the following year and identifies three zones for which residents are eligible for sound insulating grants.

- Zone I - a very high level of disturbance within the L_{den} 70 (and above) noise contour;
- Zone II - a high level of disturbance between the L_{den} 70 and L_{den} 65 noise contours;
- Zone III - a moderate level of disturbance between the L_{den} 65 and L_{den} 55 noise contours.

Applications for grants must also provide proof that when the construction permit was issued the property was outside the zone by the relevant airport's Noise Exposure Plan (PEB).

Grants are funded by a tax on airport noise pollution which is paid by airlines. €214m(£190m) of grants were provided between 2007 and 2014 (Earnst & Young LLP, May 2016). Sound insulating grants cover eighty percent of the price of the work required, although the total cost of the services may not exceed a cap set on the basis of the home's characteristics. Specific details relating to sound insulation measures have not been found within the timescale of the project.

Zurich

Zurich Airport implemented the Zurich Airport Noise Protection Programme 2010 from 1999 (Zurich Airport, 2020). The scheme was concluded in 2017.

Properties which fell within the Noise Abatement Ordinance IGW sensitivity level for residential zones (SLII) were eligible (Lr_k: 60 dB; Lr_k: 60 dB; Lr_n 1: 55 dB; Lr_n 2,3: 50 dB) were eligible. Properties with the same renovation priority were grouped into redevelopment areas and these groups were remediated in the following order of priority; both day and night IGW limit exceeded, IGW night limit exceeded, IGW day limit exceeded.

Approximately CHF 236.5m (£194m) was spent on sound insulation measures to 5900 buildings (Zurich Airport, 2020).

The project planners developed a renovation action plan for each property, which they agreed with each owner. Typically, the acoustic treatment included installation of windows attenuating 32 dB of outside noise. Additionally, where the exposure limit for night was exceeded sound attenuating fans, or time-controlled window closing mechanisms were to be installed to bedrooms.

The building owner was responsible for appointing the window supplier, with the full cost of the eligible measures paid to the building owner by the Airport. However, if the acoustic properties of other elements of the building envelope (roof, façade etc.) were such that replacing windows wouldn't lead to a noticeable reduction in noise, then the building the owner was responsible for first improving these features at their own expense.

Frankfurt

Frankfurt Airport has provided the first and second phases of the Residence Insulation scheme since 2001 (Earnst & Young LLP, May 2016). So long as the current residents occupied the building before 13th October 2011 then buildings located within the following zones are eligible for improvements (Umwelt und Nachbarschaftshause, 2020):

- L_{eq} day 60 dB(A) - Day protection Zone 1
- L_{eq} day 55 dB(A) - Day protection Zone 2
- L_{eq} night 50 dB(A) - and L_{max} = 6 x 53 dB(A) Night Protection Zone

The annual expenditure of the project is approximately €115m to €120m(£102m-£107m). Sections 9 and 10 of the Law on Protection against Aircraft Noise entitle owners of buildings that lie within a defined noise protection zone for the cost of structural noise protection measures.

The approach to treatment measures is to provide passive noise protection such as glazing or ventilation fans. These are applicable to living spaces. Some monetary compensation is also available for outdoor living areas such as terraces, balconies or gardens.

Chicago O'Hare

Chicago O'Hare Airport operates the O'Hare Residential Sound Insulation Program (RSIP) which was established in 1982 (Chicago Department of Aviation, 2020). Properties are eligible for improvement if the noise level is greater than a specific threshold and they fall within the Federal Aviation Administration's (FAA) approved O'Hare Modernisation Programme Build out Noise Contour (Chicago Department of Aviation, August 2018). Participation in the scheme is by invitation only and to be eligible properties must have been constructed before 30th September 2005. Hallways, stairwells and entrances are not eligible for treatment.

To date the scheme has cost $339m(248m) and has treated 11,500 homes. Eighty percent of the funding has been provided by the FAA through Airport Improvement Grants, with the other twenty percent provided by the City of Chicago (Chicago Department of Aviation, 2020) using approved airport revenue sources.

A home inventory appointment is scheduled for every home to be improved through the scheme and each homeowner selects their preferred sound insulation package. This might include; acoustic glazing, solid-core wood entry doors, acoustic sliding glass door; solid wood baffles for through-wall air conditioners or acoustically rated storm doors. Once the treatment measures are selected the airport appoints a contractor to carry out the work.

San Francisco International

San Francisco International Airport has run two noise insulation programmes termed the Replacement Initiative and Second Chance Initiative, the first of which began in 1983 (San Francisco International Airport, 2020). Eligible residences are those that fall within contours of the FAA San Francisco 65 dB noise map. Residences that fall outside this map can also apply for treatment and are considered on a case by case basis (San Francisco International Airport, 2019). The structure and significant additions must have been built before 1st October 1998.

The total programme expenditure to date exceeds $192m (£140m) and has involved treatment of more than 15,200 properties (San Francisco International Airport, 2020). The current expenditure is approximately $100m (£73m) per year and is funded through a combination of FAA grants and San Francisco International Airport funds.

Treatments are provided at no cost to the building owner and are based on recommendations by a San Francisco International Airport consultant team. These may include; double pane/high-performance glazed windows, doors, caulking, weather-stripping and installation of central fresh air ventilation systems. Once the treatment measures are selected the airport appoints a contractor to carry out the work.

Sydney Kingsford Smith

In 1995 Sydney Kingsford Smith Airport established a noise insulation programme due to construction of a third runway (Burgess, 1997). This scheme is now closed. To be eligible residential buildings needed to be located within the 30 and above ANEI noise contours.

The total programme cost approximately A$400m (£217m)and was funded through an aircraft noise levy. The maximum funding per household was A$45,000 (£24,400) increasing to A$50,000(£27,120) over the duration of the programme.

A perimeter insulation approach was adopted. The project team were responsible for inspecting each property and selecting appropriate measures from a list (menu) of approved treatments. Following this the building owner was responsible for getting three quotes for improvement works, the lowest of which was selected.

Works on the menu included provision of air conditioning or mechanical ventilation plus measures to improve the attenuation of:

- external doors by replacement and/or seals;
- external walls by blocking vents and openings;
- windows by replacement and/or secondary glazing;
- roof/ceiling by soft fibre insulation and loaded vinyl;

It found that a menu approach was a balanced and equitable means for choosing measures and that overall improvement was good. However, for houses of lightweight construction, the items in the Menu needed to be reconsidered to take into account the lower noise reduction for untreated lightweight walls. Lack of attention to detail such as correct installation of seals, appeared to be the main reason for low values of aircraft noise attenuation.

Adelaide

Between the years 2000 and 2013 Adelaide Airport implemented the Adelaide Airport Noise Insulation Program (Dimitrov, 2002). To be eligible residential buildings needed to be located within the 30 and 35 ANEI noise contours (Adelaide Airport, 2014). Noise measurements are carried out in the residences before any acoustic treatment is applied and after the work on the residence is completed.

A total of A$63m £34m) funding was invested in the scheme, which was funded through an aircraft noise levy on passengers. Approximately 600 residential buildings were treated, and some public buildings were also eligible.

A perimeter insulation approach was adopted with treatments including; sealing gaps between roof and external walls, replacement of existing window glazing with 6mm laminated glass, treatment of lightweight external walls, new 10mm thick laminated glazing to the French door in the family/dining room, laying the ceiling with 85mm 20kg/m^3 fibreglass batts and 4kg/m^2 flexible vinyl loaded acoustic barrier, lining exhaust fan ducts, sealing of wall and subfloor vents, treatment of skylights, replacement of external door with solid core timber door fitted with seals, sealing of the fireplaces and chimney.

Overview of approaches

Ingress of noise from an external source takes a variety of different routes depending on the building envelope construction, quality of existing build and any gaps/penetrations (intentional or otherwise). It is well known that without detailed knowledge of the potential primary and secondary transmission routes into a property, initial works may not necessarily meet expectations as evidenced in the very early studies into aircraft noise intrusion conducted by BRS (Scholes & Parkin, 1968) and the more recent work conducted at the airports in Sydney and Adelaide.

The approaches outlined in the UK schemes generally only involve installing products aimed at reducing noise transfer through either openings into the eligible rooms in the façade (windows, doors and ventilators) or through the roof/ceiling. This approach is appropriate, provided secondary paths such as chimneys or external doors that do not directly serve rooms do not limit performance. From the review undertaken an initial survey is generally undertaken prior to implementing works, but the detail of these surveys was not able to be found. It may be that these surveys take account of secondary transmission paths, or that they are just concerned with general condition/construction of the property.

Within most of the UK schemes' approach there is a clear assumption that the external walls do not represent a significant transmission path. The Sydney Kinsford Smith (Burgess, 1997) study highlights that lightweight external walls can represent potential weaknesses, as does research conducted within the United states of America (Airport Cooperative Research Program, 2013) where these constructions are more common than in the UK.

Pre-determined solution vs. tailored approaches.

Most current UK schemes appear to be based on a pre-determined solution in that the products and solutions appear to be defined in the scheme itself, albeit often with some limited householder choice. A similar approach is the same as is taken in the scheme of works developed for road (and more recently rail) traffic noise in the NIR 1975. The specification was originally developed mainly on a "what can be done practically" approach based on available research at the time (Scholes & Parkin, 1968), rather than setting an internal noise level target and designing a solution/specification/performance target around that. This approach to regulation and noise is not unique. For example, it formed the original basis for setting sound insulation performance requirements between dwellings (Part E). Part E doesn't attempt to achieve a level of received noise in an adjoining property from its neighbour, rather it sets a requirement for the separating element to achieve a "reasonable resistance to the passage of sound". Whilst numerical targets have been developed since the first inception, and presented within centrally issued guidance, the underlying requirement remains relatively unchanged.

The approach of relying only on a threshold trigger to prescribe the works does not allow for a tailored solution to be adopted. This could mean that the treatment installed is either less effective than it could be, or that products are installed that don't need to be reducing the available monies that could be better spent. However, the complexity of tailoring a solution to individual property exposure or existing façade sound insulation may be more costly than providing a prescribed or predefined solution regardless of noise exposure, due to requiring expert input and detailed assessment.

Testing properties prior to installing sound insulation appears to give a good balance to enable optimisation of preferred, tailored solution and this approach is used in other fields of application. The testing process is likely to take between half and a full day per property, depending on the size of the property and number of rooms, and would need to be undertaken by a qualified specialist. The fees charged for testing will depend on the number of properties and experience of staff but is likely to be in the region of £1,000 per property.

For it to be truly effective, however, testing needs to be accompanied by a clear criterion in terms of the expected outcomes post-works. Whilst the overriding principle could be to achieve an acceptable, internal noise level the current UK schemes do not necessarily aim to do this. It may be more practical to target an acoustic insulation value in terms of level difference for the building envelope for given noise exposure categories above the LOAEL and SOAEL levels.

The core strength of a performance-based approach is that it allows a far greater level of freedom to develop solutions with new and emerging technologies, than rely on a predetermined solution.

Grant vs airport appointed contractor

There are two different routes comprising either a grant provided to the homeowner, or the airport appointing a contractor.

It has not been possible to locate evidenced based information in order to evaluate both types of scheme for installation, so the comments below are more general in nature.

The homeowner may not necessarily be competent to make decisions regarding product and contractor selection, depending on their background. It is also possible that the homeowner is an absent landlord that may not necessarily have a directed interest in the sound insulation performance of the works. As such homeowners may not necessarily prioritise the spend appropriately in terms of maximising sound insulation performance. Many of the grant schemes only allow for 80% of the costs or a fixed upper limit to cover the works. Individual householders may not have enough funds to top up the grant that is made available.

Using an approved contractor basis would be expected to lead to more consistent outcomes, particularly when contractors are required to demonstrate compliance/competence or re-tender for the works. It also takes some of the decision making out of the hands of the residents, though they are often offered (approved) choices in selection.

For either approach, some form of quality check made post installation (visual inspection or acoustic testing, see Workstream 2) would give greater confidence that the deployed package is achieving the required sound insulation performance. Similarly, using suppliers/installers who are part of an approved competent persons scheme may also provide further reassurance, see Workstream 5. In the schemes reviewed, follow-up surveys with residents were mentioned but acoustic performance checks or inspections by qualified professionals were not generally referenced.

Room vs. perimeter approach

Generally, the UK Schemes are for insulation products targeting habitable rooms rather than the entire property (perimeter approach).

Taking a room approach means that the whole property is not necessarily being treated as a system, however the provisions in the NIR1975 specification are built around the concept of only treating individual rooms (often just on a single façade) meaning that they should be fit for purpose. Most of the schemes reviewed did not have a room limit for the grant. One key advantage to this type of package of works is the simplicity of installation. The provision of through-wall ventilators and secondary/replacement windows is not too disruptive to the occupant. However, secondary glazing can present difficulties in terms of cleaning and robustness. Furthermore, unless the building occupant has a good understanding of the need to use powered ventilators (if installed) they may not always be switched on which could relate in poor ventilation and consequently poor indoor air quality in the home.

The perimeter approach, as described by the Australian airport documents, relies on significant input from experts including initial survey work (building and acoustic) and development of a “menu” of solutions. The works include upgrading doors, door seals, loft space work, window replacement and sealing of existing envelope penetrations. This approach was demonstrated as being very effective and well-liked by the building occupants. However, the cost of the works is likely to be very significant as funding caps of £24,400 per property were used, compared with the typical range of £3,000-£5000 for the UK capped grant-based schemes. The works employed are likely to have been more disruptive to the occupant than the room approach, this may be offset in part if the residents have been involved with the selection process.

Based on the findings from the Sydney scheme, there are clear advantages to surveying the buildings prior to works and for tailoring the solutions offered to specific properties or property types in terms of outcome to the occupants. The proposed Heathrow scheme states that its most affected properties (71 dB $L_{Aeq,16hr}$ /66 dB $L_{Aeq,8hr\ night}$) will receive a bespoke package of measures rather than their standard approach. This was the only reference to bespoke sound insulation installations and works in such a high noise contour found in our review for UK airport schemes.

Conclusions from Workstream 3

The general approach to schemes in the UK is that of a predefined solution approach, and most airport schemes reviewed shared many common themes. Some of the airports are starting to take a tiered approach to noise insulation packages which is likely to be beneficial in terms of cost to the airport and also, potentially, to the home occupants.

Whilst making use of an established, predefined set of works this holds benefits to the airport operators in terms of simplicity to administer, it is not necessarily the best approach from the perspective of the home occupant.

It is accepted that a degree of input or choice for the occupants appears to lead to better, perceived outcomes for the occupants based on international studies. However, very tailored solutions may not always be necessary and could be cost prohibitive.

Grant based schemes in the UK are generally less common than airports appointing contractors to undertake the installation of acoustic insulation products. The airport appointed contractor approach is considered likely to achieve more consistent outcomes in terms of performance and quality.

Treating individual rooms is expected to be less disruptive to occupants than treating the entire property, however, it may not necessarily address all transmission paths. The perimeter approach to installing acoustic insulation identified in the Australian airport schemes reviewed appear to have advantages in terms of occupant satisfaction and with providing targeted works. However, the cost of this approach compared to a room by room approach is likely to be significantly higher.

Workstream 4: Building Regulations relevant to sound insulation products

This workstream overviewed Building Regulations requirements likely to apply to the installation of acoustic insulation products for the purpose of reducing aircraft noise into exiting dwellings. Where possible, the review overviews where an installation could lead to any significant unintended consequences for the building or building occupants that would not otherwise be addressed through compliance with the requirements of the Building Regulations. The Building Regulations in the UK are functional performance-based regulations, rather than being prescriptive regulations with defined solutions.

This review considered the installation of insulation products and not regulations concerned with the manufacture or production of the products themselves.

Applicable Building Regulations

The relevant Building Regulations for England and Wales are currently aligned. For Scotland and Northern Ireland Regulations are separate but the principles are similar for the installation of airport sound insulation works. Specific guidance is issued by the respective governments in the form of Approved Documents (England, Wales and Norther Ireland) and Technical Handbooks(Scotland) on achieving the standards set out in the relevant regulations.

The Building Regulations (Secretary of State, 2010) sets out the legislation under the Building Act 1984 for the construction and modification of buildings in England and Wales. For Northern Ireland The Building Regulations (Northern Ireland) 2012 (Northern Ireland Assembly, 2012) applies and for Scotland The Building (Scotland) Regulations 2004 (Scottish Government, 2004).

In this section we have detailed how the Building Regulation in England and Wales apply to works likely to be undertaken in respect of aircraft sound insulation schemes, since this will cover most UK airports.

Within the context of retrospectively installing acoustic insulation products to an existing building, some or all of the works may be defined as “building work” or as an alteration which is considered “material”. These are defined terms within the Building Regulations for England and Wales and the relevant section from Part 2, Regulation 3 is reproduced for ease of reference in Figure 2.

Meaning of building work

3.—(1) In these Regulations "building work" means—

(a) the erection or extension of a building;

(b) the provision or extension of a controlled service or fitting in or in connection with a building;

(c) the material alteration of a building, or a controlled service or fitting, as mentioned in paragraph (2);

(d) work required by regulation 6 (requirements relating to material change of use);

(e) the insertion of insulating material into the cavity wall of a building;

(f) work involving the underpinning of a building;

(g) work required by regulation 22 (requirements relating to a change of energy status);

(h) work required by regulation 23 (requirements relating to thermal elements);

(i) work required by regulation 28 (consequential improvements to energy performance).

(2) An alteration is material for the purposes of these Regulations if the work, or any part of it, would at any stage result—

(a) in a building or controlled service or fitting not complying with a relevant requirement where previously it did; or

(b) in a building or controlled service or fitting which before the work commenced did not comply with a relevant requirement, being more unsatisfactory in relation to such a requirement.

(3) In paragraph (2) "relevant requirement" means any of the following applicable requirements of Schedule 1, namely—

Part A (structure)

paragraph B1 (means of warning and escape)

paragraph B3 (internal fire spread—structure)

paragraph B4 (external fire spread)

paragraph B5 (access and facilities for the fire service)

Part M (access to and use of buildings).

Figure 2: Extract from SI No.2214 Part 2, Regulation 3

Part 2, Regulation 3 goes on to require that where any works to an existing building are undertaken that fulfil the definition of either "building work" or an alteration which is "material" then as a minimum the requirements relating to Part A and Part M apply in addition to paragraphs B1, B3-B5 of Schedule 1 to the Building Regulations.

For completeness, the following is a listing of all Parts listed in Schedule 1 of the Building Regulations:

Part A - Structure

Part B - Fire Safety

Part C - Site preparation and resistance to contaminants and moisture

Part D - Toxic Substances

Part E - Resistance to the passage of sound

Part F - Ventilation

Part G - Sanitation, hot water safety and water efficiency

Part H - Drainage and Waste Disposal

Part J - Combustion appliances and fuel storage systems

Part K - Protection from falling, collision and impact

Part L - Conservation of fuel and power

Part M - Access to and use of buildings

Part N - Glazing Safety (Withdrawn)

Part P - Electrical Safety

Part Q – Security

Part R - Physical infrastructure for high speed electronic communications networks.

Part E is the relevant part Building Regulations for England and Wales covering sound transmission. However, for domestic properties Part E only addresses sound transfer between adjoining dwellings (Requirement E1), within a dwelling (Requirement E2) and for the control of reverberation in common spaces(Requirement E3). Part E does not control ingress of noise from outside to inside.

In addition to the requirements of Regulation 3, Regulation 4 places an overarching requirement on completed building works in that it must comply with the applicable requirements contained in Schedule 1 of The Building Regulations (e.g. all relevant parts) and in doing so it doesn't cause a failure to comply with any other requirements of Schedule 1 of the Building Regulations.

Where a previous installation did not comply with current regulations before the works, for example if completed under a previous version of the Building Regulations, then the completed building works must be "no more unsatisfactory" in relation to compliance with the applicable requirements of Schedule 1 than they were before the works started. Figure 3 shows the relevant extract from the Regulation 4.

Requirements relating to building work

4.—(1) Subject to paragraph (2) building work shall be carried out so that—

(a) it complies with the applicable requirements contained in Schedule 1; and

(b) in complying with any such requirement there is no failure to comply with any other such requirement.

(2) Where—

(a) building work is of a kind described in regulation 3(1)(g), (h) or (i); and

(b) the carrying out of that work does not constitute a material alteration,

that work need only comply with the applicable requirements of Part L of Schedule 1.

(3) Building work shall be carried out so that, after it has been completed—

(a) any building which is extended or to which a material alteration is made; or

(b) any building in, or in connection with, which a controlled service or fitting is provided, extended or materially altered; or

(c) any controlled service or fitting,

complies with the applicable requirements of Schedule 1 or, where it did not comply with any such requirement, is no more unsatisfactory in relation to that requirement than before the work was carried out.

Figure 3: Extract from SI No. 2214 Part 2, Regulation 4

For each of the different acoustic insulation product considered an initial review of potentially applicable Building Regulations has been completed. The requirements will depend on the individual approach to the works, the products used and the method of installation.

However, it is important to highlight how the works are delivered for the homeowner as it is specifically the responsibility of the person undertaking the works to demonstrate compliance with the Building Regulations. For many of these types of interventions (insulation products), compliance can be demonstrated by using providers operating under a 'competent person scheme' (Government Digital

Service, 2020). Self-certification followed by approval by the relevant Building Control authority may also be an option.

External windows and doors – replacement

External windows and doors are a "controlled fitting" (PlanningPortalQuest, 2020) under the building regulations, meaning replacement or modifications to external doors and windows would be considered to be "building work" on the basis that they may constitute a "material" alteration.

The requirements from Schedule: 1 Part B, Part F, Part L and Part K apply to replacement windows and in addition Part M will apply to replacement doors. For skylights, Part A also applies.

Secondary glazing

Secondary glazing would constitute a "material" alteration to a "building" meaning that the requirements from Schedule: 1 Part B, Part F(where the secondary glazing obscures any existing ventilation means e.g. trickle vents) and Part K may be expected to apply. Additionally, consideration may need to be given to Part C.

Ventilators (Passive including trickle ventilators)

Altering the existing ventilation strategy for a building through either replacing existing trickle vents with acoustically rated trickle vents or using passive attenuated through wall vents could constitute a "material" alteration to the "building". The requirements from the requirements from Schedule: 1 Part B, Part F and Part L would be the most relevant.

Mechanical Ventilation (single room, whole house)

Mechanical ventilation (single room or whole house) would be a "material" alteration to a "controlled fitting" since they would affect the ventilation strategy for the building. Consequently, requirements from Schedule: 1 Part B, Part F and Part L would be the most relevant. Additionally, the building work required to make the electrical connection would cause Part P may be relevant to consider.

Loft Insulation

Installation of loft insulation would be classed as "building works" due the works being done to a "thermal element", however it would not be defined as "material" alteration since it falls under the requirements of Regulation 3(h). Consequently, the work would only need to comply with the requirements of Part L of Schedule 1. Provisions relating to electrical safety (Part P), control of moisture (Part C) and sanitation, hot water safety and water efficiency (Part G) may also need to be considered in the context of installing loft insulation.

Cavity Wall Insulation

Installation of loft insulation would be classed as "building works" due the works being done to a "thermal element", however it would not be defined as "material" alteration since it falls under the requirements of Regulation 3(h). Consequently, the work would only need to comply with the requirements of Part L of Schedule 1. Provisions relating to control of moisture (Part C) and sanitation, hot water safety and water efficiency (Part G) may also need to be considered in the context of installing loft insulation.

Unintended consequences due to acoustic insulation product installation

The majority of unintended, non-acoustic consequences due to installation of acoustic insulation products are addressed through complying with the Building Regulations requirements. Within this section, we have only commented on consequences that would not otherwise be addressed through appropriate compliance with Building Regulations. BRE are not aware of how commonly defects arise following the installation of sound insulation products for controlling aircraft noise intrusion, since no information was not located. We have outlined potential issues based on our current knowledge, which may be related to sound insulation works if not installed correctly or in accordance with the Building Regulations.

Overheating

Currently, there are no specific requirements relating to overheating in The Building Regulations (Association of Noise Consultants, 2020). Approved Documents F and L1A briefly mention thermal comfort and overheating but with no detailed explanation or requirements. The Association of Noise Consultants Acoustics, Ventilation and Overheating Guide (Association of Noise Consultants, 2020) gives the following definition of overheating (taken from a publication by the Zero Carbon Hub):

"the phenomenon of excessive or prolonged high temperatures in homes, resulting from internal or external heat gains, which may have adverse effects on the comfort, health or productivity of the occupants"

The risk of a property overheating is affected by a number of factors including; solar gain, fabric airtightness and thermal insulation (Dengel, et al., 2016).

Installing secondary glazing may reduce the options to remove excessive solar heat gains, i.e. window opening, increasing the risk of overheating compared to the pre-works condition. NIR1975 recognises this and requires that venetian blinds are installed between the primary and secondary units which may go some way to reducing solar gains. Installation of secondary glazing may impact on natural air infiltration rates of a room, resulting in heat gains being contained within the room, increasing the risk of overheating.

Whilst NIR1975 provides details of ventilation means, these were primarily aimed at maintaining indoor air quality (Committee on the Problem of Noise, 1963) and should not be assumed to be sufficient to effectively remove excess heat gains or provide good thermal comfort, equal to that of the pre-works conditions.

Installation of loft and cavity wall insulation changes the thermal insulation of the property, reducing heat losses. This may reduce the rate of heat gain removal, increasing the risk of overheating.

It is vital therefore that before installing acoustic insulation products, consideration should be given to whether the works increase the risk of overheating and if so, amend the proposals accordingly.

Secondary cavity heating

The cavity between the primary window and any secondary glazing leaf could be subject to excessive heat build-up, particularly when both units are well sealed. This build-up of heat could be damaging to the primary and/or secondary window frames.

Ventilation

In some properties, specific ventilation products such as trickle ventilators may not have been included at the time of construction. Consequently, natural air leakage paths through existing windows may be removed through the addition of secondary glazing and so care must be taken to ensure sufficient ventilation to provide appropriate indoor air quality post installation, whilst continuing to mitigate aircraft noise ingress.

Condensation

Without correct detailing, condensation can build up either between the primary and secondary units or on the inside (room side) face of the secondary glazing unit (Pickles, 2016). Either situation could lead to damage to the building or represent a health risk to the building occupant if left unchecked.

Conclusions from Workstream 4

The Building Regulations requirements will come into force when acoustic insulation products/packages are installed, as relevant to the product or works. It is specifically the responsibility of the person undertaking the works to demonstrate compliance with the Building Regulations, rather than the homeowner. An overview of potentially applicable requirements, relating to the installation of acoustic insulation products have been captured and summarised, as much as the review scope allows.

There is potential for a number of unintended consequences relating to installation of acoustic insulation packages. These need to be considered carefully on a project-by-project basis and liaison with competent design/ supply chain partners will be key to homeowners. Good workmanship and attention to detail by the person(s) undertaking the works is key.

In addition, albeit outside of direct Building Regulation's cover, consideration should be given to whether the works could increase the risk of overheating and if so, amend the proposals accordingly. It is likely to require the input of a specialist to determine whether the proposals are likely to increase the risk of overheating.

Workstream 5: Quality management

The aim of this workstream is to draw together the different approaches taken to quality assurance in respect of the installation of acoustic products to control aircraft noise by the UK Airports. The second aim is to consider the available competent person and quality assurance schemes that can apply to the installation of acoustic products, their relative merits and the likelihood for them controlling acoustic performance.

UK Airport approaches to quality management of acoustic insulation installation

Details quality measures were rarely found within the review of airport sound insulation schemes in the public domain.

Appointment of preferred contractors by the airports, specified products and acoustic performance requirements would goes some way to assuring quality of installation work but this was not included in all schemes reviewed.

However, quality management could well be addressed outside the public domain particularly when the airport goes through the process of selecting its preferred contractors or as part of the contractual process. We would read relatively little into its absence from the available sources.

Relevant, operating competent persons and certification schemes

The following sources have been reviewed for their relevance to airport sound insulation works and the potential benefits that an installer's membership of these associations and schemes would bring to a sound insulation scheme. The information has been obtained from gov.uk, the websites for the various schemes and organisations and websites for other organisations which refer to them. Where a website makes codes of conduct and terms and conditions available, or refers to specific British or International Standards, these have also been reviewed.

- Competent person schemes
- Trustmark
- Ombudsman schemes
- A sample of professional and trade associations

It should be noted that the websites and amount of information made available to non-members vary widely, and care should be taken not to draw negative conclusions about an organisation purely on the quality of its public domain material. Some have a substantial amount of content aimed at consumers, while others are principally designed for their member companies, with much of their content in a member-only section. For example, that one organisation has put its code of conduct for installers into the public domain does not mean that another organisation does not have such a code of conduct. With this in mind, we have drawn attention to particular examples of good practice we found but have not concluded that this indicates poor practice elsewhere. We found that guidance and good practice documents were more easily located for glazing-specific organisations.

Competent person schemes

Competent person schemes are an alternative mechanism for securing compliance with the Building Regulations without inspection by local authority building control officers. They are trade specific and linked to particular Building Regulations. Scheme providers which are approved by the UK government are listed on gov.uk. Some scheme providers specifically address a particular trade, for example FENSA for windows. Others address multiple trades, for example Blue Flame, who cover wall insulation, oil fired appliances, electrical installation, heating/hot water installations or controls, ventilation, and windows and doors.

In order to secure approval for a scheme, a provider must comply with the following conditions of authorisation, as listed in the DCLG Building Regulations: Competent person self-certification Schemes Conditions of Authorisation (Department for Communities and Local Government, 2016):

1. Achieve/maintain UKAS accreditation to standard BS EN ISO/IEC 17065:2012 and meet all the relevant requirements in the standard.
2. Have a robust and non-discriminatory management, quality and administrative system.
3. Have the technical ability to assess the competence of prospective and existing registrants to deliver compliance with the requirements of the Building Regulations.
4. Ensure that the scheme is financially viable and self-sufficient within a reasonable timescale.
5. Have an absence of, or methods for avoiding, conflicts of interest between the commercial interests of any sponsoring or parent organisations and management of the scheme.
6. Promote the development of the scheme to potential registrants and its use to consumers.
7. Scheme operator to provide annual accounts, independently audited, for the scheme itself.
8. Scheme operator to establish and publish scheme rules, including its application and certification processes and fee structure.
9. Scheme operator to assess applicants as technically competent against agreed minimum competence requirements. For applicants, this should be before registering them with the scheme. The assessment must include an on-site assessment.
10. Scheme operator to ensure that its registrants' competencies are kept up to date, for example as a result of changes to the Building Regulations and/or BS/EN standards or technical approvals.
11. Scheme operator to provide ongoing technical help and advice to registrants as required (i.e. post registration), provided such help/advice does not cause any conflicts of interest with certification schemes of the scheme operator.
12. Scheme operator to undertake surveillance of its registrants work, including carrying out periodic random assessments of a representative sample of each registrant's work, during or after completion, to check compliance with the Building Regulations.
13. Scheme operator to have effective sanctions in place for dealing with non-compliance of the Building Regulations and/or a breach of scheme rules by registrants of the scheme.
14. Scheme operator to use an agreed mechanism to make available to other competent person schemes and other interested parties (e.g. LABC & relevant Government Departments) the names of former registrants whose registration has been terminated by the scheme and the reasons for termination.
15. Scheme operator to keep and publish registration lists and the type(s) of work for which registrants have been assessed as competent.
16. Scheme operator to have a robust and publicised process for handling complaints.
17. Scheme operators to ensure consumers are provided with appropriate financial protection to put works to dwellings right, which is non-compliant with the Building Regulations, where the original installer cannot do so (because they are no longer trading).
18. Scheme operator to require its registrants to remain responsible for ensuring that all work within the scope of the scheme and carried out under a contract with the consumer is compliant with the Building Regulations.

19. Scheme operator to take measures to ensure that it is notified by registrants of all completed work within the scope of the scheme and to forward to the relevant consumers a certificate of Building Regulations compliance.
20. Scheme operator to provide the information DCLG requires in order to carry out its oversight functions, both on a regular basis or ad hoc as required.
21. Scheme operator to take measures to ensure that it is notified by registrants of all completed work within the scope of the scheme and to forward this information to the relevant local authority in the format agreed with LABC.

The types of work which have a relevant competent person scheme and would be relevant to a typical airport sound insulation scheme are:

- Replacement windows, doors, roof windows or roof lights for dwellings
- Mechanical ventilation and air conditioning systems for dwellings

Installation of loft insulation is not currently addressed as it would not require Building Regulations approval. It would be included if it was part of a roof covering replacement.

Relevance of the Building Regulations to sound insulation work for airports

The key Approved Document for sound in the Building Regulations is Approved Document E. This addresses the passage of sound between and within homes. It does not address entrance of sound from outside and would therefore not be relevant to reduction of noise from outside.

The Building Regulation requirements relevant to installing of acoustic insulation products have been discussed in detail in Workstream 4.

As discussed in Workstream 1; Approved Document F, which is concerned with ventilation, contains some limited guidance on noise but does not address the effectiveness of ventilation systems in controlling external noise intrusion.

Part L, for thermal performance, discusses sound in the context of full-filling cavity walls affecting sound transmission through party walls. It does not address the performance of roof insulation as a means of reducing the ingress of sound into a building.

Compliance with the Building Regulations therefore does not directly address sound insulation performance in a way which would be relevant to the typical scope of works of an airport sound insulation project. However, compliance may drive installation practice in a way which is relevant to ingress of sound. Paragraph 5.5 of Part L1B, for example, states that the building fabric should be constructed so that there are no reasonably avoidable thermal bridges in the insulation layers caused by gaps within the various elements, and at the edges of elements such as those around window and door openings. For a window or door to be effective at preventing transmission of sound, fit is very important; gaps around the edges of the frame will substantially compromise the overall performance of the glazing. Gaps in roof insulation will have a similar effect. Good fitting practice driven by Building Regulation compliance would therefore have a positive impact on sound insulation performance. However, infilling of gaps with lightweight material such as spray foam may be more effective thermally than it is acoustically, so compliance with thermal requirements would not automatically guarantee good acoustic performance.

Similarly, the recommendation in Approved Document F that noise generated by ventilation fans should be addressed may well drive better installation practice but would not guarantee it.

The lack of directly relevant acoustic content in the Approved Documents affects the degree to which membership of a relevant competent person scheme would certain to achieve the acoustic aims of an airport sound insulation scheme. The Conditions of Authorisation contain the following wording in reference to a competent person scheme's complaints procedure: “It must cover complaints relating to non-compliance with the Building Regulations, but may include other types of complaints from consumers (and registrants) relating to the scheme." Similarly, the insurance-backed guarantee requirement only addresses compliance with Building Requirements. Given that the Building Regulations do not directly address sound transmission into a building from outside, this means that in its strictest interpretation, an installer would not have to carry out work in a way which would address the sound insulation goals of a scheme in order to comply with the conditions of the competent person scheme they belong to.

However, membership of a scheme does bring a substantial number of other factors which increase the likelihood that a member installer would deliver a sound insulation programme in a way which would achieve its goals: a quality management programme, technical support for member installers, a requirement for minimum technical competency and continuing technical competency, regular inspection and auditing of installer's work, an insurance-backed guarantee and a robust, technically competent complaints procedure, albeit the latter two have the caveats discussed above.

Windows and doors competent person schemes

The following competent person schemes are listed for installation of windows and doors:

- Blue Flame Certification
- CERTASS
- Certsure
- Fensa
- NAPIT
- ASSURE
- Stroma

FENSA

The Fenestration Self-Assessment scheme (FENSA) is probably the most recognisable certifier for windows. It is a single competency provider specific to windows and doors.

FENSA publishes a Guide to Compliance with Building Regulations in England and Wales for Replacement Doors and Windows in Dwellings, which we have reviewed. It addresses loading, safety, means of escape from fire, and safety of replacement windows in presence of open flued devices, where it advises to bring in a Gas Safe competent person scheme for advice. It includes best practice notes. The guide doesn't address areas which would be specific to acoustic performance such as appropriate product specification or tolerances for aperture fit to ensure that sound paths are minimised, but this would not be expected given that document brief is ensuring compliance with building regulations. It references BS 8213-4:2007 Code of practice for the survey and installation of windows and external doorsets, which has been updated since publication of the guide (British Standards Institute, 2007).

CERTASS

CERTASS is another widely recognised competent person scheme for glazing installations, but is also listed for cavity and solid wall insulation. Their website indicates that the scheme scope also covers loft insulation and draught proofing. CERTASS run a skills card scheme for MTC competency which is referenced in the MTC info sheet to CERTASS Technical Handbook, CERTASS Good Practice Guide, CITB publication – 'Safe Start (GE 707) Health, Safety and Environment Handbook. Website references PAS2030 ECO Scheme for glazing, draught proofing, loft insulation, wall insulation, floor insulation (energy efficiency certification scheme run by BBA).

ASSURE

ASSURE provide a similar service as FENSA and CERTASS. Their website mentions a noise rating scheme, but does not give further information.

BLUE FLAME, Certsure, NAPIT, STROMA

The following certifiers are listed for windows on the gov.uk list of competent persons schemes, but provide more general schemes rather than being glazing specific:

- Blue Flame Certification
- Certsure
- NAPIT
- STROMA

Blue Flame specialise in gas, oil, electrical, solid fuel, building services, renewable technologies and building efficiency. Certsure (T/A ELECSA or NICEIC) specialise in electrical, ventilation, plumbing, heating & hot water, and microgeneration. NAPIT specialise in electrical, microgeneration, HVAC, plumbing and building fabric. Stroma specialise in assessment and training within this context.

Other windows and doors organisations

Double Glazing and Conservatory Ombudsman Scheme

The Double Glazing and Conservatory Ombudsman Scheme (DGCOS) is not listed on the gov.uk list of competent person schemes but covers similar issues: vetting and accreditation of contractors, the requirement to provide an insurance backed guarantee (10 years) and compliance with Building Regulations. There is an additional criterion to submit to the legal jurisdiction of DFCOS and the Ombudsman. Its Ombudsman service is provided by QASSS (Quality Assured Scheme Support Services Ltd). Membership of the scheme would confer similar assurances to those of a competent person scheme, and it lists 7 competent person schemes on its website, stating that by choosing one you will be complying with relevant Building Regulations. Installers can register with DGCOS as well as with a competent person scheme.

Double Glazing Trade Association

The web address for the Double Glazing Trade Association (DGTA) goes to Fair Trades – an organisation promoting members as responsible tradesmen and providing a searchable database for prospective customers. It is associated with Trustmark and the FENSA, CERTASS and ASSURE competent person schemes. Members sign up to Trustmark code of conduct, which covers fair dealing with customers, e.g. clear invoicing, complaints process.

Glass and Glazing Federation

The Glass and Glazing Federation (GGF) is a trade association representing companies who manufacture, supply or fit glass products and promotes best practice. It lists FENSA and the British Fenestration Ratings Council as key subsidiaries. It produces industry guidance and trade and training guides, but these are only available on its website to members and so were not available to review.

We were able to locate their 2011 Good Practice guide for the Installation of Replacement Windows and Doors. It refers to BS 6375 Part 3 for acoustic performance but doesn't provide acoustic specific guidance. BS 6375-3 states that when required, acoustic performance shall be declared in airborne insulation values tested in accordance with BS EN ISO 140-3 (superseded by the BS EN ISO 10140 series of standards, see Workstream 1) and shall be evaluated in accordance with BS EN ISO 717-1. The document provides detailed technical guidance on survey and installation and include some information on closing of cavities, good sealing and of glazing to aperture sizing (see below). The data for the latter is based on BS 8213-4 Code of practice for the survey and installation of windows and external doorsets. This would be relevant to good glazing fit for acoustic purposes.

Ventilation - competent person schemes

The following competent person schemes are listed for installation of mechanical ventilation and air conditioning:

- BESCA
- Blue Flame Certification
- Certsure
- NAPIT
- Stroma

The ventilation competent person schemes are characterised by providers offering competent person schemes for various trades and being part of wider certification businesses rather than single trade providers such as FENSA. Some of these are strongly associated with other trades, for example Certsure has two schemes, ELECSA and NICEIC, which are associated with electrical installation. Most of their technical guidance is located in member's areas, and we did not find any technical guidance associated with them in the public domain which could be reviewed for relevance to airport sound insulation schemes.

Ventilation professional associations

The following professional associations were found for ventilation manufacturers and installers:

- FETA, containing HEVAC
- BESA

We reviewed their websites for available guidance, but as heating, ventilation and air conditioning is such a broad subject, containing many individual specialisms, we did not find a key source of guidance associated with them such as the Glass and Glazing Association's guide to good practice.

Federation of Environmental Trade Associations

FETA is an umbrella organisation which contains a number of professional associations within the heating, ventilation and air conditioning trade. Its mission is stated to be to enable its members to compete on favourable terms in an improved national and international business climate. Its individual aims include participation in scientific, public and policy debates which might affect members and so influence policies, legislation, regulation and standards, and to provide members with a source of information on market issues, legislation, training, technological advances and research.

Its largest member is, HEVAC, which traditionally represents ventilation manufacturers and suppliers. One of HEVAC's subgroups is the Residential Ventilation Association (RVA), which would be most likely to cover airport noise sound insulation schemes. RVA provides a collection of links to relevant guidance and has published some commentary on post-installation performance perception and reality for domestic MVHR installations.

Building Engineering Services Association. previously the Health & Ventilating Contractors Association (HVCA)

BESA is a trade association representing building services contractors. It represents their interests and provides technical support. We did not find any guidance on their website which would be of particular relevance to airport sound insulation schemes.

Loft insulation and draught stripping competent persons schemes

There is a general consensus on installer websites that loft insulation should be at least 270mm thick and must have good thermal properties. However Approved Document L1A and L1B do not state this as a clear requirement. Approved Document L1B suggests 250mm for existing properties within the context of providing a cost-effective U-value target when undertaking renovations (Secretary of state, 2016).

For loft insulation, the Cavity Insulation Guarantee Agency (CIGA) is recognised by MHCLG as being the relevant competent persons scheme. Members installers of CIGA are assessed for competence and must follow the technical guidance for the material used and CIGA Best Practice Guidance. The membership rules include technical and financial requirements and competence requirements. CIGA also operates the Cavity Wall Insulation Self Certification Scheme.

Draught stripping installation does not appear to have a competent person scheme.

Loft insulation professional associations

National Insulation Association UK(NIA)

NIA represents the insulation industry in the UK and installers. Membership criteria for installers include product and public liability insurance, customer care and training procedures, health and safety, customer care policy registration with a manufacturer or system designed for products/systems installed, PAS2030 certification if operating in markets which require it (this is not necessarily the case if installation is for sound insulation purposes). Their code of professional practice states that all members will make sure their technicians are trained and approved by the relevant system or product supplier and products approved by relevant independent regulators and make sure that all staff are properly trained. They must follow relevant specifications and Building Regulations for cavity or solid wall insulation.

References are made to BS 5803:1985 and BS 7880:1997 for loft or draught proofing accreditation. BS 5803-2:1985 and BS 5803-3:1985 address use of the British Standard Kitemark and Safety Mark for insulation products and do not address acoustic properties.

BS 7880:1997 is a code of practice for draught stripping existing windows and doors. It addresses ventilation and fresh air supply specific to different situations. It is important for occupier safety but does not contain any specific acoustic content.

Trustmark

Trustmark is a government endorsed quality scheme covering work which a consumer chooses to have carried out in or around their home. It is not an approved contractor scheme. It covers good business practice and has a code of conduct addressing quotes, contracts, complaints, invoicing, feedback and consumer law. It does not automatically include a guarantee and it is not a source of technical advice. A number of relevant competent person schemes state they are members: FENSA, CERTASS, Blue Flame, NAPIT and Stroma. Although a positive indicator of a responsible company or organisation, membership of the Trustmark scheme would not of itself confer any particular assurance of good technical performance in an airport sound insulation scheme.

Future work

Through collaboration with one of more of the competent scheme operators or professional bodies and the airport operators it may be possible to develop quality assurance scheme around the specification and installation of acoustic insulation packages. It would be necessary to develop clear criteria in terms of critical factors that affect performance and have the organisation translate this to requirements for members of their schemes.

Some airports may already have quality requirements or guidance that they make available to their approved suppliers/contractors and this could form a basis for future discussion.

Conclusions from Workstream 5

There does not appear to be a consistent approach to quality management for airport acoustic insulation schemes in the UK, as far as has been able to be determined. This is not to say that individual schemes do not have their own quality management systems or requirements, but this information was not available for a detailed review.

There are centrally endorsed competent persons schemes covering installation of the majority of products that may be used to provide acoustic insulation to properties. The schemes are directly concerned with satisfying Building Regulation requirements, and noise ingress into a building from aircraft noise is not currently addressed by the Building Regulations. Consequently, the relevant competent persons schemes do not specifically address sound insulation.

Use of a contractor or supplier who is a member of a competent person scheme does ensure many beneficial aspects relating to quality, as would membership of a professional body or trade association, and this may include consequential benefits in terms of sound insulation. This isn’t to say that companies not part of such a scheme or body are not competent to undertake the works.

There could be an opportunity for collaboration between airport operators and schemes/professional bodies to develop and guide, code of practice or even a certification scheme relating to installation of acoustic insulation products. Due to the information available relating current approaches to quality management across the different airport schemes it is not clear whether this would be practical, or it is already addressed at a scheme level.

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Appendix A Airport schemes review, approach and summary

To examine current specification practice for sound insulation in UK airport schemes, BRE reviewed airport noise action plans for references to sound insulation actions and carried out a predominantly internet-based search for sources relevant to sound insulation schemes for UK airports. Where we were unable to locate information, we attempted to contact the airports directly but were unable to make meaningful contact within the timeframe of the project. We would gratefully acknowledge the assistance provided by Bickerdike Allen Partners and ICCAN who were able to supply a number of documents which were in the public domain, but which would have been difficult or time consuming to locate.

We used the number of properties, from each airport's published Noise action Plan, within the 63 dB $L_{Aeq,16hr}$ contour as a simple guide to the likely size of a scheme as this was information which was available for nearly all of the airports and is the stated minimum benchmark for provision of financial assistance towards sound insulation within the UK Government's Aviation Policy Framework (Secretary of State for Transport , 2013). However, the size of a sound insulation scheme may vary widely beyond this very basic measure. For example, some schemes may have completed their programme and not have any active expenditure. Others may have a more generous scheme based on a lower contour threshold than 63 dB and be a much larger scheme than the number of households within the 63 dB contour may suggest. The Aviation 2050 consultation (Department for Transport, 2018) proposed reducing the minimum benchmark to 60 dB and some airports with scheme entry criteria based on a lower noise contour have discussed this potential change in their noise action plans. This search was principally concerned with technical specifications for sound insulation measures rather than comparing the size of different schemes.

Of the thirty airports included in the search, we found seventeen active sound insulation schemes, plus three more currently in development or planned. Additionally, we located one scheme which was closed due to having achieved its goals.

It should be noted that, while the noise action plans contained harmonised data which could be compared with little difficulty, such as the estimated number of households within a particular $L_{Aeq,16hr}$ noise contour, the same could not be said for sound insulation information. The information we found varied widely depending on the sources in question. These included policy statements, airport and scheme provider web pages, individual noise reports or masterplans for airports without a current noise action plan, press releases, householder guides, scheme brochures and information provided in committee reports; our observations are based on the information which could be obtained or inferred from these. With this in mind, absence of information on a particular point for a particular scheme should not be taken as confirmation of a negative. The fact that, for example, one brochure for householders might refer to a ten year guarantee on the installation does not necessarily mean that another programme does not have such a guarantee, just that it was not outlined in the brochure for the latter scheme.

The airports which formed the basis of our review are detailed in Table A-1 which also includes summary information indicating:

1. whether we were able to locate a noise action plan,
2. the estimated number of properties affected by a 63 dB (or higher) noise contour
3. whether we were able to locate information relating to a sound insulation scheme,
4. what noise threshold(s) are used for property eligibility for sound insulation works, and
5. whether we were able to locate a specification relating to the works under the airport scheme.

Within Table A-1 we have used the following abbreviations:

Y = Yes

N = No

N/F = Not found.

Airport	Current Noise action plan found	Estimated no. of properties affected by 63 dB or more ($L_{Aeq,16hr}$)	Sound insulation scheme	Threshold	Specification available
Aberdeen (During 2011 only)	Y	<50 (65 dB)	Y N/F	66dBLAeq,16h summer. 63 proposed	N/F
Belfast International	N/F 2013-2018 version reviewed	2	Y	63dBLAeq,16h summer. Was 66	Y
Birmingham International	Y	900	Y	63dBLAeq,16h	Y
Bournemouth	Y	0	N	-	-
Bristol	Y	<50	Y	57, 60, 63dBLAeq,16h	Y
Cardiff	N	N/F	N/F	-	-
City of Derry	N/F	N/F	N/F	-	-
Doncaster Sheffield	N/F Sound Insulation scheme details found in Local Authority committee report	N/F	Y	63 LAeq,16hr day, 55 LAeq,8hr night, 90 dB SEL	N/F
Durham Tees Valley	N/F	N/F	N	-	-
East Midlands	Y	<50	Y	zone A 55 dB LAeq,8hr night and/or night single noise events 90 dB zone B 60-66 zone C 66-69 zone D >69	Y

Airport	Current Noise action plan found	Estimated no. of properties affected by 63 dB or more ($L_{Aeq,16hr}$)	Sound insulation scheme	Threshold	Specification available
Edinburgh	Y	100	Y	63 LAeq,16hr	Y
Exeter International	N/F	NK	N	-	-
Gatwick	Y	200	Y	60 LAeq,16hr	Y
George Best Belfast City	Y	0	In development	63 LAeq,16hr	
Glasgow International	Y	250	In development	63 LAeq,16hr	N
Glasgow Prestwick	N	Not Known	N/F	-	-
Heathrow (current)	Y	9100	Y	Night - 90 dBA SEL contour (2004/5) Day - 69 dBA Leq,18hr contour (1994) Day - 69 dBA Leq,16hr contour (2011)	Y
Heathrow (potential future)	-	-	Y	71 dB LAeq,16hr /66 dB LAeq,8hr 63 dB LAeq,16hr /55 dB LAeq,8hr & one additional wakening p.n. then 60 dB LAeq,16hr 57 LAeq,16hr /55 dB Lden Additional criteria for road & rail	Y
Inverness	N/F Masterplan 2007 reviewed	N/F	N/F	-	-

Airport	Current Noise action plan found	Estimated no. of properties affected by 63 dB or more ($L_{Aeq,16hr}$)	Sound insulation scheme	Threshold	Specification available
Leeds	Y	100	N Previous schemes closed	-	-
Liverpool John Lennon	Y	<50	Y	63 LAeq,16hr 59 LAeq,night reducing to 55 in future	N/F
London City	Y	1550	Y	57, 63, 66 LAeq,16hr	Y
Luton	Y	350	Y	57, 60, 63 LAeq,16hr	Y
Manchester	Y	1600	Y	63 LAeq,16hr	Y
Newcastle	Y	0 (>60)	N	-	-
Newquay Cornwall	Y	0	N	-	-
Norwich International	N/F Reviewed DEFRA Airport noise action planning data pack 2013 and 2017 Masterplan	0	N	-	-
Southampton	Y	<50	Planned	63 LAeq,16hr	N
Southend	Y	<50	Y	63 LAeq,16hr	Y
Stanstead (current)	Y	50	Y	63 LAeq,16hr	N

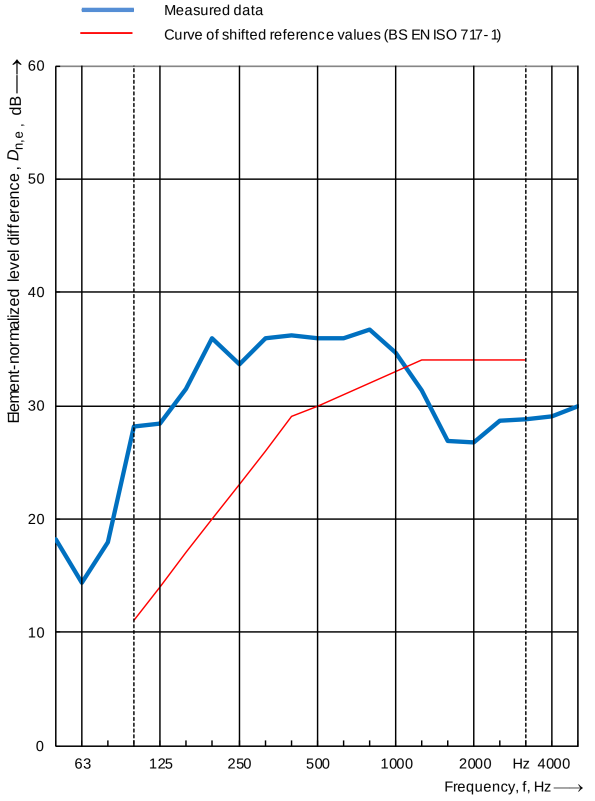
Airport	Current Noise action plan found	Estimated no. of properties affected by 63 dB or more ($L_{Aeq,16hr}$)	Sound insulation scheme	Threshold	Specification available
Stanstead (potential future)	-	-	Y	3 tiers, all LAeq,16hr Upper: 69 & 66 dB Middle: 63 & 60 dB Lower: 57 dB/N65 200 /90 dBA SEL 600m distance/55 dB LAeq,16hr ground noise	N

Table A-1: List of airports, detailing summary of information gathered during the project bre

Appendix B Example sound insulation test result

Figure B- 1 shows an example of data relating to a small technical element (10140-1 Annex E).

Frequency f [Hz]	$D_{n,e}$ 1/3 octave [dB]
50	18.2
63	14.4
80	17.9
100	28.2
125	28.4
160	31.5
200	36.0
250	33.6
315	36.0
400	36.2
500	35.9
630	36.0
800	36.7
1000	34.7
1250	31.3
1600	26.9
2000	26.7
2500	28.7
3150	28.8
4000	29.0
5000	29.9



Rating according to ISO 717-1

$D_{n,e,w}$ (C;C_{tr}) = 30 (0 ; 1) dB

Evaluation based on laboratory measurement results obtained in one-third-octave bands by an engineering method.

$C_{50-3150}$ = 0 dB $C_{50-5000}$ = 0 dB $C_{100-5000}$ = 0 dB

$C_{tr,50-3150}$ = -1 dB $C_{tr,50-5000}$ = -1 dB $C_{tr,100-5000}$ = 1 dB

Figure B- 1: Example graph showing element-normalized level difference data.

The performance of the product in tabulated form with a corresponding graph showing the sound insulation performance ($D_{n,e}$) against frequency in one-third octave bands. In the example provided, the data relating to the performance of the product is shown on the graph as a blue line, and the shifted rating curve from BS EN ISO 717-1 is presented as a red line. For airborne sound insulation, the higher the measured value the more effective the product/construction is at preventing sound transmission.

Report Ends