Ventilation Systems Installed for Road-traffic Noise Mitigation

Prepared for NZ Transport Agency

Prepared by Beca Ltd

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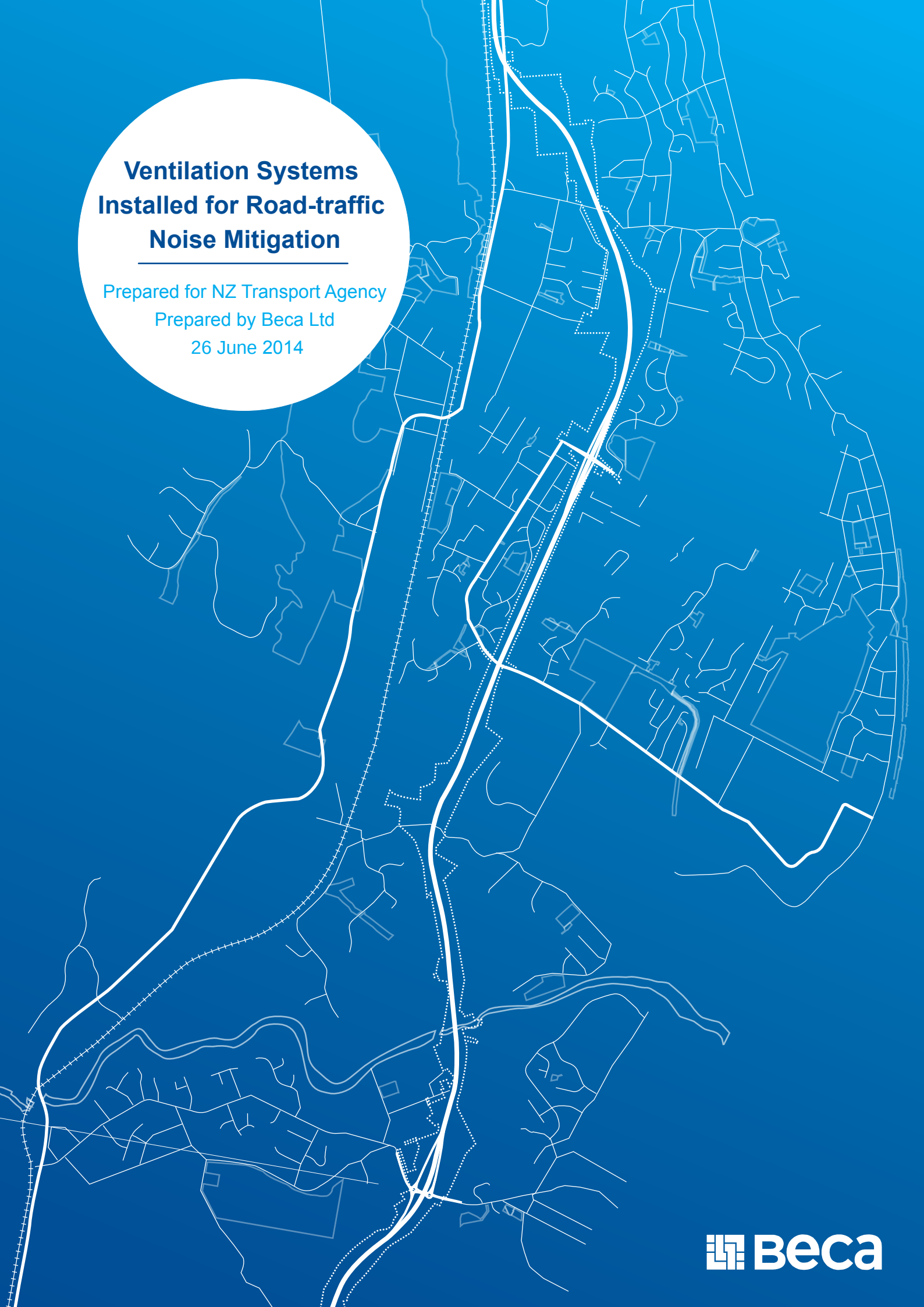

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Document Acceptance

Action	Name	Signed	Date
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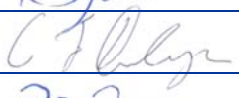
Reviewed by	**Christopher Dunlop**		26/06/2014
Approved by	**Patrick Breen**		26/06/2014
on behalf of	Beca Ltd		

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1 Introduction

1.1 Project Background

Beca recently completed a case study on behalf of the Transport Agency which provided guidance for the acoustic insulation of residential new-build homes and the associated costs for the acoustic design solutions. As part of this case study, a ventilation rate was used which complies with the Building Code and Manukau City's District Plan rules for buildings affected by airport noise. These ventilation rates were as high as 15 air-changes per hour and it was not clear how they were determined. This prompted the initial query from the client as to what would be a fair and reasonable mechanical ventilation solution for residential homes that complies with relevant legislation and provides an adequate level of occupancy comfort.

Beca has therefore been commissioned by the Transport Agency to carry out this desktop assessment in relation to the relevancy and effectiveness of the ventilation requirement for residential homes published under the relevant District Plans such as the proposed Auckland Unitary Plan (AUP). Other District Plans may be relevant but are not assessed in this report. The AUP was used as it includes several different specifications for ventilation systems installed for noise mitigation, representing the range of controls typically found in other District Plans.

There are three main objectives for the case study, namely:

- Provide context on how District Plan ventilation requirements were determined, specifically in the Auckland Unitary Plan.
- Provide recommended mechanical ventilation rates for residential homes and an associated high level specification for a system capable of achieving those rates.
- Provide clarification of mechanical cooling options as an alternative to mechanical ventilation capable of achieving similar levels of occupant comfort.

1.2 Methodology

The purpose of this case study is to investigate and recommend ventilation rates and/ or cooling for residential homes which will be sufficient for maintaining occupier comfort during peak summer periods with windows closed. These rates will comply with the Buildings Code, but may be different from the rates specified in certain District Plans.

The scope of work for the project includes:

- Research and describe how current mechanical ventilation rates have been determined.
- Recommend fair and reasonable mechanical ventilation rates, which comply with the Building Code, but also provide adequate comfort for residents. Considerations will be taken into account on the geographical location and climates in different regions.
- Clarify mechanical cooling specifications as an alternative to mechanical ventilation, considering climate conditions in different regions.
- Establish the Cooling and Ventilation Specification for implementation.

1.3 Reference Documents

The following documents were referenced when carrying out this study:

- The Proposed Auckland Unitary Plan (notified 30 September 2013)
  - 1.2 Aircraft Noise,
  - 1.3 City Centre Port Noise, and
  - 1.5 High Land Transport Noise.
- NZ Building Code Clause G4 Ventilation.
- NZS4303:1990 Ventilation for Acceptable Indoor Air Quality.
- AS/NZS1668.2:2002 The Use of Ventilation and Air Conditioning in Buildings.
- NIWA Design Temperatures for Air Conditioning (2003).

Please note the reference documents listed above are not exhaustive and other regions' plan may also be relevant.

2 Review of Auckland Unitary Plan

This section summarises the ventilation requirements stipulated under the various sub-sections of the AUP, and assumes doors and windows are shut to mitigate traffic noise.

There are clear differences on ventilation requirements between Ardmore Airport and Auckland Airport, i.e. a blanket requirement identical to the sub sections 2.1.1and 2.1.2 below for all types of building. There is no added requirement on the minimum ACH to other type of building use similar to the sub sections from 2.1.3 and onwards.

2.1 Published Requirement under AUP 1.2 Aircraft Noise

(Sub section 3.1 Acoustic insulation and ventilation for ASAN in the ANB, ICB and OCB)

1. New ASAN in ICB and OCB

- Ventilation to NZBC Clause G4 with all external doors of the building and all windows.

2. Additions and alterations of existing buildings accommodating ASAN

- Comply NZ Building Code Clause G4 where all external windows and doors are closed.
- Max 40 dB LAeq (1 min) in principal living room and hallway; max 30 dB LAeq (1 min) in other habitable rooms, all measured at 1m from any diffuser.

(Sub section 4.1 Acoustic insulation and ventilation)

3. In buildings within ASAN, except care centres and educational facilities

a. Mechanical kitchen extract directly to outside.

b. Mechanical system(s) to provide:

- 15 ACH in the principal living room and 5 ACH in other habitable spaces where doors and windows are closed except windows in a non-habitable rooms that need to be ajar to provide air relief paths.
- Air flow control from max air flow down to 0.5 ACH (+/- 0.1).
- Internal pressure differential no greater than 30Pa above the ambient.
- User controllable system ON/OFF.
- Max 40 dB LAeq (1 min) in principal living room and hallway; max 30 dB LAeq (1 min) in other habitable rooms, all measured at 1m from any diffuser.

c. Air conditioning plus mechanical outdoor air ventilation

- Providing internal temperature no greater than 25 degree C.
- Providing 0.5 ACH (+/- 0.1) of outdoor air to all habitable rooms.
- Max 40 dB LAeq (1 min) in principal living room and hallway; max 30 dB LAeq (1 min) in other habitable rooms, all measured at 1m from any diffuse.

4. For Care Centre within ASAN (achieving the acoustic requirement of Ldn 40 dB)

a. Mechanical ventilation system(s) to each learning space shall:

- Provide indoor temperature not less than 16^{o}C.
- Provide ventilation rate no less than 15L/s/m^2 for the first 50m^2 and 7.5L/s/m^2 thereafter when windows and doors are to be shut.
- Provide with control the air flow across the range from maximum (rated occupancy in the space) down to 8L/s/person.
- Comply withNZBC-G4 and NZS4303:1990
- User controllable system ON/OFF of each system.
- Max 35 dB LAeq (1 min) in each learning area; max 40 dB LAeq (1 min) in hallway or corridor, all measured at 1m from any diffuser.

b. Air conditioning system(s) with outdoor air ventilation to each space shall:

- Provide a minimum of 8L/s/person.
- Provide indoor temperature not greater than 27^{o}C in each learning area.
- Max 35 dB LAeq (1 min) in each learning area; max 40 dB LAeq (1 min) in hallway or corridor, all measured at 1m from any diffuser.
- Comply withNZBC-G4 and NZS4303:1990

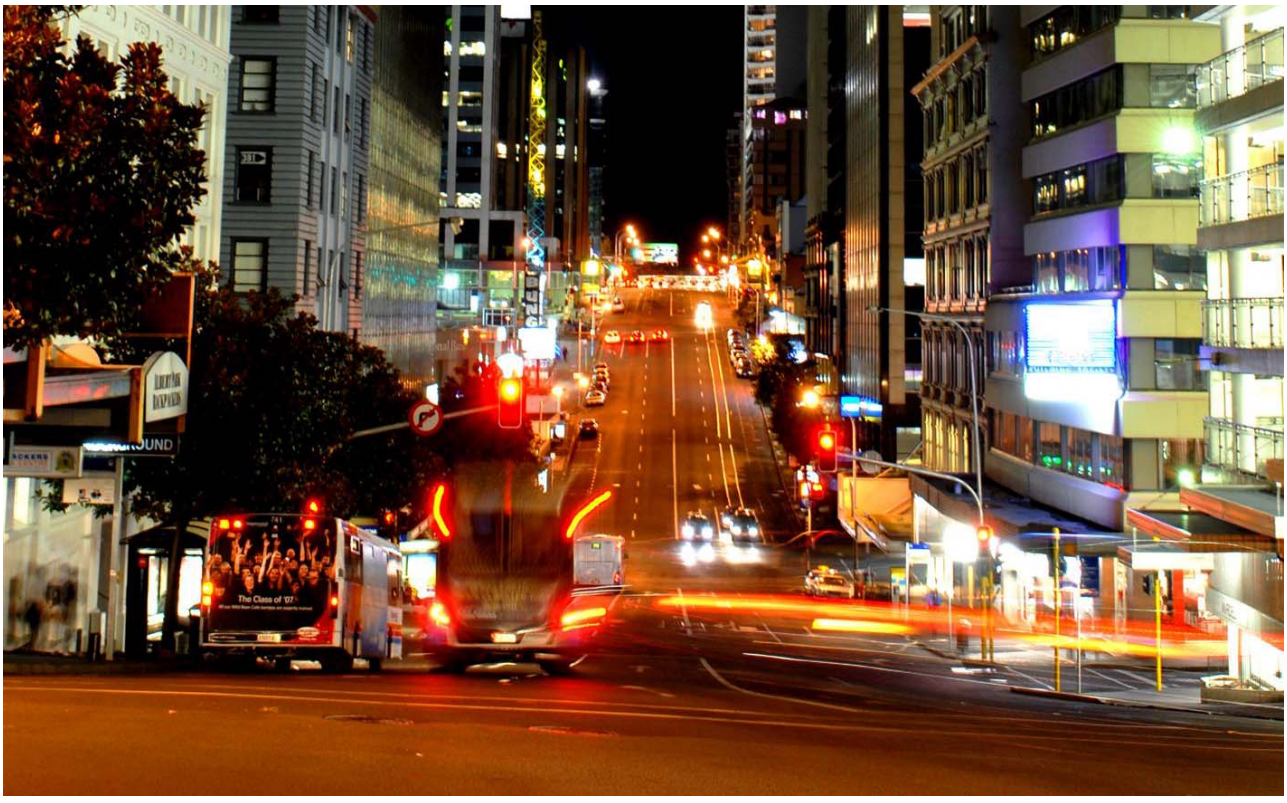
5. For Educational Facilities within ASAN

a. Mechanical ventilation and air conditioning system(s) to classrooms and libraries and halls shall:

- Provide indoor temperature not less than 16°C in winter and greater than 27°C in summer.
- Provide a minimum of 8L/s/person.
- Provide with control the air flow across the range from maximum (rated occupancy in the space) down to 8L/s/person.
- Comply withNZBC-G4 and NZS4303:1990.
- Max 35 dB LAeq (1 min) in each classroom; max 40 dB LAeq (1 min) in library, hallway or corridor, all measured at 1m from any diffuser.

b. In halls the mechanical ventilation system(s) shall:

- Provide a minimum of 12L/s/m^2 where doors and windows are to be shut.
- Provide with control the air flow across the range from maximum (rated occupancy in the space) down to 8L/s/person.
- Max 35 dB LAeq (1 min) in each hall; max 40 dB LAeq (1 min) in hallway or corridor, all measured at 1m from any diffuser.
- Comply withNZBC-G4 and NZS4303:1990.
- When the outdoor air rate is at 8L/s/person, provide indoor temperature no greater than 27°C. Max noise level 35 dB LAeq (1 min) or below in each hall; max 40 dB LAeq (1 min) in library, hallway or corridor, all measured at 1m from any diffuser.



2.2 Published Requirement under AUP 1.3 City Centre Port Noise

(Sub section 1. Land use controls)

The requirement is identical to High Land Transport Noise stated below.

2.3 Published Requirement under AUP 1.5 High Land Transport Noise

Section 1.5 High Land Transport Noise under the Auckland Unitary Plan (AUP) is reasonably relevant to this assessment and the summary of the ventilation requirement is provided below:

2.3.1 Sub section 2.2 Ventilation

a. Mechanical kitchen extract of 50L/s directly to outside and, if necessary, toilet extract of 25L/s to outside.

b. Mechanical system(s) to provide:

- 6 ACH to sleeping and habitable rooms (10 ACH for classrooms).
- Air flow control in the increment of approx. 0.15 m/s from a min of 0.5 ACH to the max air flow capacity.
- User controllable system ON/OFF.
- Operating noise <35dB LAeq(1 min) in bedrooms and <40dB LAeq(1 min) in other habitable spaces and classrooms, measured at 1m from any diffuser.

c. Air conditioning plus mechanical outdoor air ventilation

- Providing internal temperature no greater than 25 degree C.
- 6 ACH (air changes per hour) to sleeping and habitable rooms (10 ACH for classrooms).
- User controllable individual system ON/OFF.
- Operating noise <35dB LAeq(1 min) in bedrooms and <40dB LAeq(1 min) in other habitable spaces and classrooms, measured at 1m from any diffuser.

2.4 Discussion and Recommendations

The requirement of a mechanical kitchen extract (under High Land Transport Noise) could mean a dedicated extract system such as cooking range hoods or a ceiling mounted fan to be used. The 50L/s rate is low compared to normal domestic kitchen hoods that will normally deliver close to or above 100L/s. Higher extract rates shall be considered when evaluating the supply and extract air balancing.

The toilet extract rate at 25L/s (per fixture) is identical to the Building Code requirement. However, care shall be take when determining the require extract rate for a bathroom suite with shower, bath tub and toilet pan in it.

Overall, providing 5ACH as the lower end of the requirement stated above is much higher than the Building Code requirement. However, the NZBC is primarily written as to safeguard the building occupants from illness or loss of amenity due to lack of fresh air. Refer Section 3 for further details.

The required ventilation rate is somewhat consistent with what is commercially called “internal condensation control” systems such as “DVS” and “HRV” brand. Outdoor air is drawn into the ceiling space from outside and discharged to the warmer internal space. This supply air will become dryer when it gets warmer inside the building, hence dries the internal space. The surplus air with higher moisture content will be driven out of the building through the building gaps such as door and window gaps.

The air flow control requirement could be impractical to adopt as normal fans can be turned down to only about 30-40% of the full capacity using variable speed drives. Specially designed ventilators may be required to achieve this specific requirement, hence possible higher implementation costs could result. There are around 7-10 speeds (model dependent) in the commercial systems such as “DVS” and “HRV” mentioned above that can be used as an alternative.

When the ventilation rate or motor speed is high, e.g. 15ACH, the acoustic requirement on mechanical system noise may be difficult to achieve. Some form of acoustic treatment such as sound wrapping to the fan casing and/or attenuator on the supply air ducting may be required.

3 Relevant NZ Building Code and Standards

3.1 G4 – Ventilation

Performance Requirement

G4.3.1 – Spaces within buildings shall have means of ventilation with outdoor air that will provide an adequate number of air changes to maintain air purity.

G4.3.2 – Mechanical air handling systems shall be constructed and maintained in a manner that prevents harmful bacteria, pathogens and allergens from multiplying with them.

G4.3.3 – Buildings shall have a means of collecting or otherwise removing the following products from the spaces in which they are generated:

- Cooking fume and odours
- Moisture from laundering
- Utensil washing
- Bathing and showering
- Odours from sanitary and waste storage spaces
- Gaseous by-products and excessive moisture from commercial and industrial processes
- Poisonous fumes and gases
- Flammable fumes and gases
- Airborne particles
- Bacteria, viruses or other pathogens
- Products of combustion

3.1.1 Discussion and Recommendations

The key objective of NZBC Clause G4 Ventilation is to safeguard people from illness or loss of amenity due to lack of fresh air. The thermal comfort of occupants is not a requirement under NZBC-G4.

The sub clause G4.3.2 implies that the ventilation system shall be maintained. Work shall include replacement of filters and cleaning of louvres, grilles, air diffusers and ductwork.

The sub clause G4.3.2 lists out a number of activities within a domestic dwelling that shall be provided with extract ventilation in order to remove contaminants. The underlined activities on the above lists are reasonably common in a normal household environment but they are not specifically covered under the AUP. Mechanical ventilation will be required to control and remove these contaminants in place of opening windows.

3.2 NZS4303:1990 Ventilation for Acceptable Indoor Air Quality

Table 2.3 Outdoor Requirement for Ventilation of Residential Facilities:

- Living areas – 0.35 ACH but not less than 7.5 L/s/person.
- Consideration shall be made to supply air to fuel burning appliances

3.2.1 Discussion and Recommendations

The Building Code G4 does not specify outdoor air rates but refers to NZS4303:1990 as the Acceptable Solution (AS).

The outdoor air requirement under NZS4303:1990 is the minimum quantity required. These ventilation rates are identical to commercial office space.

For an indoor environment with closed windows, supply air with active cooling and compliant extracts will be necessary.

Consideration must be taken for fuel burning appliances such as open fire places, gas fire places, gas cooking, etc. According to AS/NZS5601, interlocking mechanism may be required between the fuel burning appliances (such as open fire equipment) and the ventilation system. Newer equipment that has flame failure device, Oxygen depletion detection or equipped with forced draught/balanced flues are exempted from this requirement.

3.3 AS/NZS1668.2:2002 – The Use of Ventilation and Air Conditioning in Buildings Part 2 - Ventilation design for indoor air contaminant control

The Building Code G4 also does not specify extract air rates but refers to Table B1 in AS/NZS1668.2:2002 as the Acceptable Solution.

3.3.1 Discussion and Recommendations

Extract ventilation, in order to remove the listed contaminants (refer the list above), shall be in accordance with AS/NZS1668.2:2002. Please note extract to laundry tub where steam can be generated will require extract ventilation to comply with the Code.

3.4 Summary of the Code Requirement

- Building ventilation must comply with NZBC Clause G4. Where mechanical system is used in place of naturally ventilation the outdoor air and extract rates must comply with NZS4303:1990 and AS/NZS1668.2:2002.
- Ventilation system must take into account fire places, laundry dryers, etc. When fire place is installed the fuel supply (e.g. natural gas) may need to be interlocked with the mechanical ventilation system in order to comply with the Gas Code NZS5601.
- Filtration system must be installed in order to be compliant. High quantity of air means high maintenance on filters, and high on-going running cost.

4 Discussion of Specific Requirements

4.1 Assessment based on Air Change per Hour

The following discussions have assumed that all windows and doors are closed.

In typical air conditioning applications and in cooling mode, an air supply rate of 8 ACH, inclusive of minimum outdoor air rate in compliant with NZBC (based on the temperature differential of 10^{o}C) will normally be required to provide adequate cooling to the space it serves. At this supply air rate the building occupants may feel slight air movement (draughts) when staying close to the air vents. This issue would become much more profound when supply diffusers are installed low (low ceiling height, e.g. less than 2.7m high in domestic dwellings). Careful air distribution and good selection of diffusers can effectively mitigate this.

In contrast, in ventilation only application using ambient air, the rise of supply air temperature is normally in the range of 5-6^{o}C. To allow the temperature to rise higher will heavily compromise the cooling effect as a layer of warm air will accumulate within the occupied zone under the ceiling (i.e. a stratification effect). This 5-6^{o}C narrower temperature range in the ventilation mode means the cooling effect is nearly halved that from a full cooling environment mentioned above. Compared to cold air from the air conditioning units, the ambient temperature from outside will also make the occupants feel hotter before the cooling process takes effect.

To simulate a full cooling effect by temperature rise, the amount of supply air for cooling shall theoretically be doubled, i.e. around 15-16ACH. This is in-line with the identified ventilation rates published in the AUP as well as the proprietary systems indicated in the previous Case Study. However, it will not be as effective as full air conditioning due to the direct use of the ambient air.

It would be worth highlighting that for extreme weather conditions in warmer regions or in higher population residential development, the higher ventilation rate at around 15-16ACH may not satisfy the thermal comfort requirements.

Addiotionally, this high level of air supplied to the space creates a number of issues:

- High initial capital cost (due to a larger bigger system being required),
- Higher running costs (due to the larger fan size)
- Higher filter maintenance costs (required every 3-6 months).
- Very noticeable draughts.
- The requirement for purge air paths throughout the house*.
- Higher machine and air noise.
- Risk of imbalance of air as a result of the dynamic of system operation*.

*Can be mitigated if balanced type heat recovery systems are used

4.2 Assessment based on Geographical Consideration

Cooler climates such as in the lower North Island and the coastal and southern parts of the South Island where the peak temperature generally falls below 23°C (5% of the NIWA weather data) is unlikely to require active cooling. The expected peak indoor temperature for domestic dwellings in this scenario and condition is between 25°C and 27°C.

4.2.1 Geographical Considerations

The following regions will require outdoor air supply, extracts and cooling:

- Northland – warm and humid.
- Auckland – warm and humid.
- Central Plateau, NI – warm and humid.
- Christchurch – warm and dry.
- Highland, SI – warm and dry.

The following regions may require outdoor air supply and extracts:

- Wellington – temperate summer and most of the time dry.
- Southland – Cooler summer ambient air.

For these cooler regions the ventilation only rate may be reduced down to 4 to 6 ACH. This is in line with the AUP requirement and the commercial ventilation systems such as DVS and HRV. The concerns for this ventilation rate are:

- Medium initial capital cost.
- Medium filter maintenance cost (to be replaced every 2 to 3 years).
- Medium machine and air noise.
- Unpleasant cold draughts during cold weather.

4.3 Discussion and Recommendations

Full system (OA + cooling) is likely to be the standard solution with the exception that in certain cooler regions active cooling may be omitted.

Due to multiple habitable spaces in a domestic dwelling and different architectural designs, there is no one-size-fits-all solution for providing mechanical cooling. An in-ceiling ducted air conditioning system would be a preferred solution as a single unit can serve multiple rooms and there is greater flexibility to mitigate the machine noise problem. However, in multiple storey dwellings where there is no ceiling space, other options such as hi-wall or floor console of underfloor ducted units could be considered.

5 Recommended Cooling and Ventilation Specification

Provided below is the recommended space cooling and ventilation specification:

Provide NZBC G4 compliant ventilation (outdoor and extract air) to the domestic dwelling with reverse cycle heat pump(s).

Supply air shall be filtered and ducted to all habitable spaces including but not limited to lounges, kitchens, hallways, bedrooms, study rooms, rumpuses, etc. Supply fan on/off and speed control shall be controllable by the occupiers. The ventilation rate shall be at least 6 ACH (air changes per hour) or 7.5L/s, whichever high, supplied to all sleeping and habitable rooms. The supply air system and its operation could either be individual to each space, or of a centralised system supplying multiple spaces. An air flow control in the increment of approx. 0.15 m/s from a min of 0.5 ACH to the max air flow capacity shall be provided.

Extract shall be provided to kitchens (cooking hoods), laundry cupboards, toilets, bathrooms. Provide fan on/off switch that can be operated by the occupiers. A minimum of 50L/s to kitchen extract shall be maintained. Toilet and laundry extract shall be no less than 25L/s per fixture (i.e. toilet pan, laundry sink, shower, etc.).

The supply and extract air system and their operation could either be individual to each space, or of a centralised system supplying multiple spaces.

Space cooling shall be provided by reverse-cycle heat pump(s) that are capable of maintaining the indoor temperature at no greater than 25^{o}C. Heat pumps shall ideally be ducted in-ceiling type. Any identified regions of cooler climate may not require a cooling system.

All machine noise shall be <35dB LAeq (1 min) in bedrooms and <40dB LAeq (1 min) in other habitable spaces, measured at 1m from any diffuser

Where gas-burning appliances such as cooking ranges, ovens, fire places, heaters, etc. do not equip with flame failure devices or Oxygen depletion sensors, the gas supply to these appliances shall be interlocked with mechanical ventilation system. The gas supply shall be shut when the mechanical ventilation system in not in operation or failed.

6 Glossary of Acronyms

ACH	Air Change per Hour
AUP	Auckland Unitary Plan
ASAN	Activities Sensitive to Aircraft Noise
ANB	Air Noise Boundary
ICB	Inner Control Boundary
OCB	Outer Control Boundary
NZBC	New Zealand Building Codes
NZS	New Zealand Standards
AS	Acceptable Solutions
AS/NZS	Joint Australia New Zealand Standards
OA	Outdoor Air

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