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MISCELLANEOUS MECHANICAL VENTILATION SYSTEMS IN BUILDINGS

Fire and Security Consulting Services (FSCS) is frequently consulted regarding mechanical ventilation systems in buildings that are associated with the performance of fire safety systems.

The mechanical ventilation systems associated with smoke hazard management as required under the Building Code of Australia (BCA) are addressed in detail in Part 2 of the BCA and its associated Specifications E2.2a, E2.2b and E2.2c.

FSCS advises that there are other mechanical and natural ventilation systems that are required under Part F4.5 of the BCA, reproduced below.

F4.5 Ventilation of rooms

A *habitable room*, office, shop, factory, workroom, *sanitary compartment*, bathroom, shower room, laundry and any other room occupied by a person for any purpose must have—

(a) natural ventilation complying with **F4.6**; or

(b) a mechanical ventilation or air-conditioning system complying with AS 1668.2 and AS/NZS 3666.1.

This paper does not address systems or equipment for "smoke hazard management" including pressurisation of fire isolated stairs, passageways, ramps and Fire Control Rooms; smoke exhaust systems; smoke and heat vents; and natural buoyancy driven smoke venting. These are adequately addressed in BCA Specifications E2.2b, E2.2c, G3.8 (for atria), AS1668.1§ and AS1668.3 #.

FSCS has also prepared the paper "*Smoke Hazard Management and Testing – V3*" which also provides advice regarding the acceptance testing of these systems, including those associated with natural ventilation.

§ *AS 1668.1 – The use of ventilation and airconditioning in buildings – Part 1 – Fire and smoke control in multi-compartment buildings*

AS 1668.3 – The use of ventilation and airconditioning in buildings – Part 3 – Smoke control systems for large single compartments or smoke reservoirs.

Introduction

This paper concentrates on ventilation of the following spaces, all of which will have an impact on the fire safety systems in a building.

1. Ventilation of enclosures used by vehicles with combustion engines – e.g. car parks. The requirements for this are detailed in Sections 4 and 7 of *Australian Standard (AS) 1668.2 The use of ventilation and airconditioning in buildings / Part 2 Ventilation design for indoor air contaminant control*.

   For enclosed car parks, the mechanical ventilation in association with a required fore sprinkler system provides occupant tenability during egress and fire fighter tenability for access.

2. Mechanical ventilation of commercial kitchen exhaust hoods. The requirements for this are detailed in Section 5 of AS 1668.2 and in Appendix C thereof.

   This mechanical ventilation provides a degree of smoke extract for the kitchen ensuring occupant safety.

3. Where battery charging facilities are provided in a building, ventilation is required under Table B1 in Appendix B of AS 1668.2. *This also refers to AS2676 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings – Part 1 – Vented cells and Part 2 – Sealed cells.*

   Mechanical ventilation in battery rooms provides for dilution of hydrogen evolved by batteries during charging thus providing for occupant safety and the prevention of explosions.

4. Where fire hydrant and / of fire sprinkler systems are installed in accordance with Parts E3 and E5 of the BCA and an enclosed pump room is provided and the fire pump(s) are driven by compression ignition (diesel) engines; the pump room is required to be provided with ventilation. The referenced Australian Standards are: - *AS2118.1 – Automatic Fire Sprinkler Systems, AS2419.1 – Fire Hydrant Installations and AS2941 – Fixed fire protection installations / pumpset systems*.

   Ventilation of fire pump rooms provides for occupant safety during inspection, testing and operation of fire pumps.

5. For laundries in Class 2, 3 and Class 4 parts in other buildings, BCA F4.5 requires either natural ventilation or mechanical ventilation in accordance with *Australian Standard (AS) 1668.2- The use of ventilation and airconditioning in buildings / Part 2 Ventilation design for indoor air contaminant control*.

   Ventilation of laundries provides for extract of hot air, lint and fluff and humidity which, if no addressed, can cause unwanted alarms from smoke detectors and smoke alarms.

6. For bathrooms in Class 2, 3 and Class 4 parts in other buildings, BCA F4.5 requires either natural ventilation or mechanical ventilation in accordance with *Australian Standard (AS) 1668.2- The use of ventilation and airconditioning in buildings / Part 2 Ventilation design for indoor air contaminant control*.

   Ventilation of laundries provides for extract of hot air, lint and fluff and humidity which, if no addressed, can cause unwanted alarms from smoke detectors and smoke alarms.

Appendix B to Australian Standard (AS) 1668.2 includes Table B1 which lists the mechanical ventilation requirements in various occupancies including battery rooms, laundries and bathrooms. This Table is reproduced in Appendix A to this paper.

FSCS considers that building owners and managers, developers, Certifiers Fire Engineers and QFES Building Approval Officers familiarise themselves with the requirements for the mechanical ventilation systems and that ownership of appropriate instruments will allow them to not only understand the process but also to be confident that the installation and / or service contractor is conducting the test properly but is also providing accurate and reliable results.

FSCS has included building owners and managers in this list because under Building Fire Safety Regulation 2008, they have the duty of providing the annual “Occupier’s Statement” to QFES

Appendix F in AS1668.1 provides general advice as to what instruments are required for testing mechanical ventilation systems. FSCS has conducted and witnessed many tests and has developed a slightly different methodology to that in the Standard, which still satisfies the requirements.

Figure 1 – Stair Pressurisation Instruments

A Force meter to measure the force required to open a door to a pressurised fire isolated stair, passageway, ramp or Fire Control Room. This is a Berkley 0 -20kg fish weighing device (from BCF) where I have replaced the hook (shown to the left) with a stainless rod and plastic ball; within the device, I have reversed the load sensor position so that it is under tension instead of compression thus measuring the "push" force.

A useful feature on this instrument is the"hold' button so that the maximum force is recorded both on screen and in one of nine memories.

B A piece of aluminium strip bent into a "Z" section so that for a door opening into a pressurised fire isolated stair, passageway, ramp or Fire Control Room. It fits within the door leaf and frame rebate thus holding the latch tongue depressed. This allows the door opening force to be measure accurately without the impediment of a person holding the lever down. The maximum force allowable is 110 Newtons.

C Sound level meter with both "slow", dB (A) and "max hold" features. This measures the sound pressure level within the fire isolated stair lobby and the fire isolated stair itself. The maximum allowable levels are 80dB (A) and 65dB (A) respectively.

The requirement is so that occupants can hear occupant warning alarms and public address announcements.

D Air flow meter with both m/s and ft/s settings. This measures the air velocity across doorways into fire isolated stairs; the minimum required being 1.0m/s.

It is also used to measure the air velocity from mechanical ventilation supply and return air registers.

A useful feature on this instrument is the"hold' button so that the maximum force is recorded on screen.

<u>Assessment</u>

1. **Item 1** - car parks. Refer to the FSCS technical paper "***Emergency Lighting and Exit Signs V3***" which addresses the effectiveness of EXIT signs and emergency lighting when obscured by smoke. Car park ventilation may need to be designed to provide additional ventilation over and above the Standard in order to allow emergency lighting to be effective and EXIT signs to be seen.

2. **Item 2** - Mechanical ventilation of kitchen exhaust hoods. Where automatic fire suppression systems are installed in accordance with AS 3772—2008 Australian Standard for Pre-engineered fire protection systems for cooking equipment, the "listed" system may require the hood exhaust fan to be kept running to ensure that the extinguishant is drawn into the ducting.

3. **Item 3** – Battery rooms. AS1668.2 Appendix B Table B1 (attached) refers to AS2676, being *AS 2676.1 - Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Vented cells* and *AS 2676.2 - Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Sealed cells*.

Refer also to the FSCS Paper "***Battery Charging Facilities in Buildings – a Fire Engineer's Perspective***". This paper addresses both AS2676 and the Workplace Health and Safety requirements and provides examples of compliance.

4. **Item 4** – Fire pump rooms - Refer to the FSCS technical paper "***The Design of Fire Pump Rooms – V1***" which, amongst other issues, provides information on how mechanical ventilation systems should be designed.

5. **Item 5** – Laundries. BCA F4.5 requires either natural ventilation or mechanical ventilation in accordance AS1668.2. Appendix B Table B1 (attached) of that Standard lists varying exhaust ventilation requirements dependant on the laundry use. For residential occupancies, the requirement is 20l/s per room.

Figure 2 below shows a compact laundry "cupboard" which is representative of the smaller apartments now being built in city locations.

Figure 2 shows what appears to be an exhaust register and if so, it should have an exhaust capacity of 20l/s. However there appears to be no “make up” air inlet grille with the performance being entirely reliant on undercutting the door leaf. It is not acceptable to design to have the door being left ajar, there being no reliability in the design.

Where the exhaust system exhausts multiple laundries such as shown in Figure 3, the fan capacity shall be the total of all laundries being served, in that case for 3 storeys, a total of 60l/s.

It would be interesting to know how the Australian Building Codes Board and Building Certifiers will assess this “cupboard”. AS1668.2 does not give a definition of a “room”. If it is a “room”, then the exhaust requirement applies, if it is seen as part of the open space of a kitchen then it is part of the residential kitchen for which there are no requirements in Table B1 of I AS1668.2.

Figure 2 – Typical Apartment “Laundry”

6. **Item 6** – Bathrooms. BCA F4.5 requires either natural ventilation or mechanical ventilation in accordance AS1668.2. Appendix B Table B1 (attached) of that Standard lists varying exhaust ventilation requirements dependant on the laundry use. For private residential occupancies, the requirement is 25l/s per room.

Figure 3 shows a typical arrangement for a three storey building where “n” is 25l/s per bathroom or ensuite and the total fan capacity is then 75l/s.

Where there are also ensuites at each of the three levels served by the same exhaust fan then an additional 3 x 25l/s needs to be added making the exhaust fan capacity 150l/s.

If one laundry on each of the three levels is also served by the same exhaust fan as the bathrooms and ensuites, then a further 3 x 20l/s needs to be added making the exhaust fan capacity 210l/s.

Figure 3 also shows the required dampers at each floor slab.

Figure 3 also shows some issues that FSCS considers being responsible for unwanted (false) alarms in residential occupancies. Where a QFES monitored n AS1670.1 fire detection and occupant warning system is used, such unwanted alarms can result in charges from QFES for attendance, and FSCS understands that in most Australian States and Territories, such charges can exceed $1000.

Accordingly the design of the laundry and bathroom exhaust systems should make provision for “make up” air at low level in the door. Figure 3 above shows three design of which only one is satisfactory.

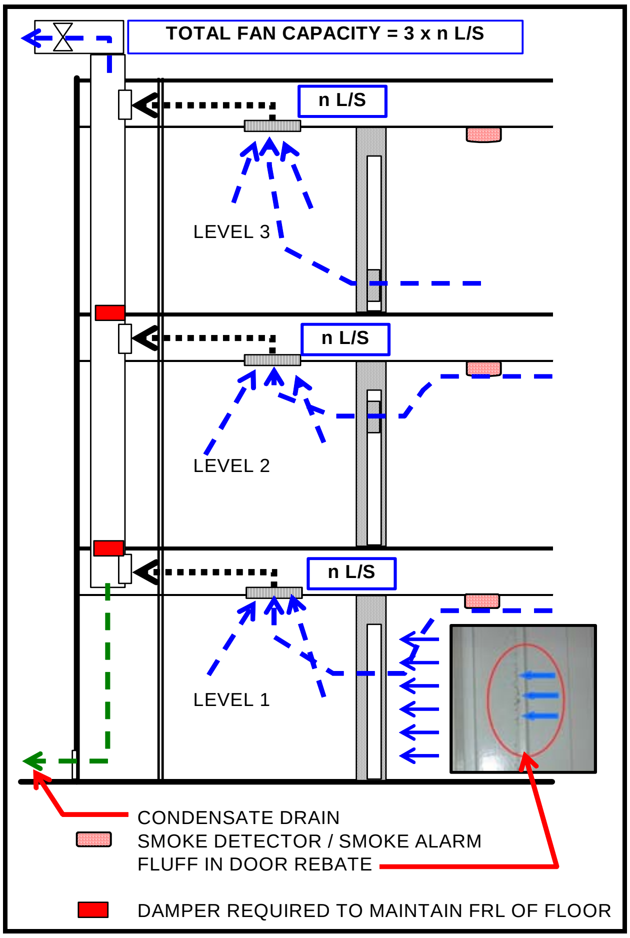

Figure 3 – Typical Apartment "Laundry"

Level 1 in Figure 3 shows how no make up air can affect the design. With the door shut the exhaust fan will draw air from wherever there is a suitable gap. In this instance the gaps between the door leaf and frame are usually sufficient for air to be drawn through. With a smoke detector or smoke alarm located in the common hallway for the bedrooms and bathroom (a common compliant location), air can be drawn across the smoke detector / smoke alarm and where, as commonly is with bedrooms nearby, lint or fluff will contaminate the detector / smoke alarm. This was one of the causes of more than 100 unwanted alarms where FSCS provided design advice for remedial works.

Figure 4 below is an enlargement of the inserted picture showing this fluff.

Figure 4 – Fluff in Bathroom Door Rebate

Level 2 in Figure 3 shows how the incorrect fitment of an air grille at the top of the door can result in smoke detector / smoke alarm contamination.

Figure 5 below is a composite picture of a laundry" cupboard" on the right with a grille at the top of the door and on the left, the door shown on the right with a smoke detector to the left. this arrangement caused a number of unwanted alarms.

Figure 5 – Laundry with door top air grille

Level 3 in Figure 3 shows the correct location of the air grille. Many may ask why not just "undercut" the door leaf. That would be acceptable for solid core doors but current interior doors have a cardboard honeycomb core with narrow timber edges. The required undercut would destroy the door.

Some Selected Examples

The following photographs are from a selection of buildings that FSCS has inspected and are included to demonstrate both acceptable and unacceptable ventilation designs, and exhaust duct penetrations. They are from two apartments buildings constructed in the late 1970s.

Figure 6 – Bathroom exhaust fan located in basement car park for the gymnasium in the same area. The makeup air was through a grille opening into the basement car park!

The riser duct went up through three floors without any fire dampers.

Figure 7 - From the same project. On the left in a bedroom showing an innocuous corner feature. On the right showing the bathroom exhaust duct with no dampers, openings up into the bedroom on the floor above and in to the bedroom lobby on the right. No fire stopping of penetrations.

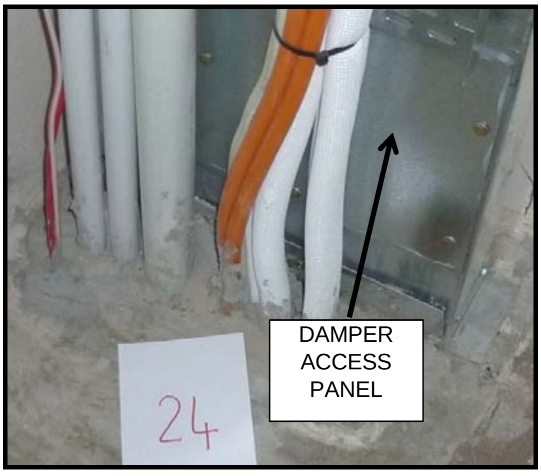

Figure 8 – again from the same project and after refurbishment. It shows the bathroom exhaust duct with its access panel for the damper and the surrounding penetration acceptably fire stopped.

Figure 9 – From another project showing how the bathroom exhaust and services were accommodated in a masonry duct. This is looking upwards from the top floor through to the roof where the exhaust fan was located. An opening covered with a mirror mounted on plywood protected the opening to the bathroom! A grille through the brick wall to the bathroom served as the required ventilation.

The same mirror / plywood arrangement was on the opposite side of the duct!

Figure 10 – From the same project as Figure 9 but this time looking down through the masonry duct through the floor slab to the levels below; with the steel flap damper, normally held open by a fusible link now disconnected but useless anyway.

The building had the original cast iron waste pipes retrofitted with cPVC. Note how the cPVC pipe was routed through the original damper location!

Measuring air flow

This section of the paper provides a series of graphs demonstrating how the air exhaust or supply rates can be measured

They cover both circular and square grilles / registers of varying sizes as shown in Figure 11. The curves allow for a suitable coefficient of discharge of ~0.85.

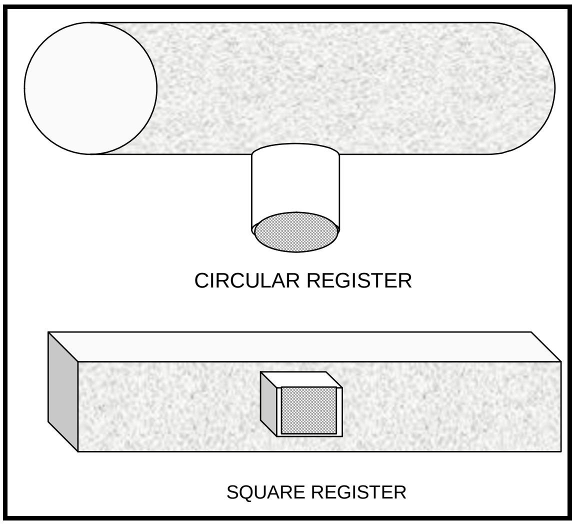

Figure 11 – Register shapes

For rectangular registers, calculate the area (l x d) in mm and from the table below select the nearest listed size. For example if the register is rectangular with measurements of 175mm wide and 100mm deep, being 17,500 mm^2, use a 150mm square register curve, the area being sufficiently equivalent to the table size of 17,674mm^2.

Where there are more than one air supply or air return registers, measure each one and summate them.

REGISTER SIZE - mm	SQUARE REGISTER AREA mm2	CIRCULAR REGISTER AREA mm2
100	7,855	10,000
150	17,674	22,500
200	31,420	40,000
250	49,094	62,500
300	70,695	90,000
400	125,680	160,000
500	196,375	
600	282,780	

Figure 12 – Table of Areas

Square Register Curves

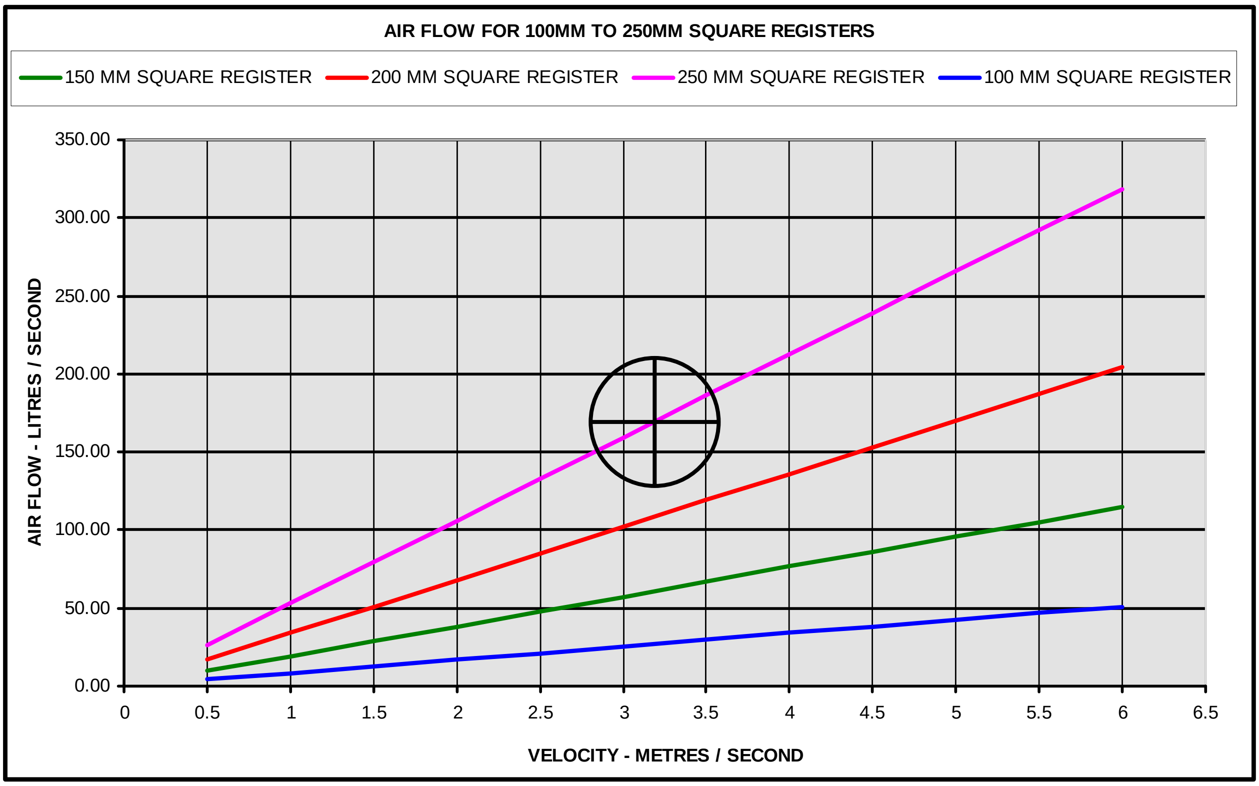

Figure 13 – 100mm to 250mm Square Registers

Example – if the measured air velocity is 3.2m/s from a 250mm square register, from Figure 13, the air flow is ~170l/s.

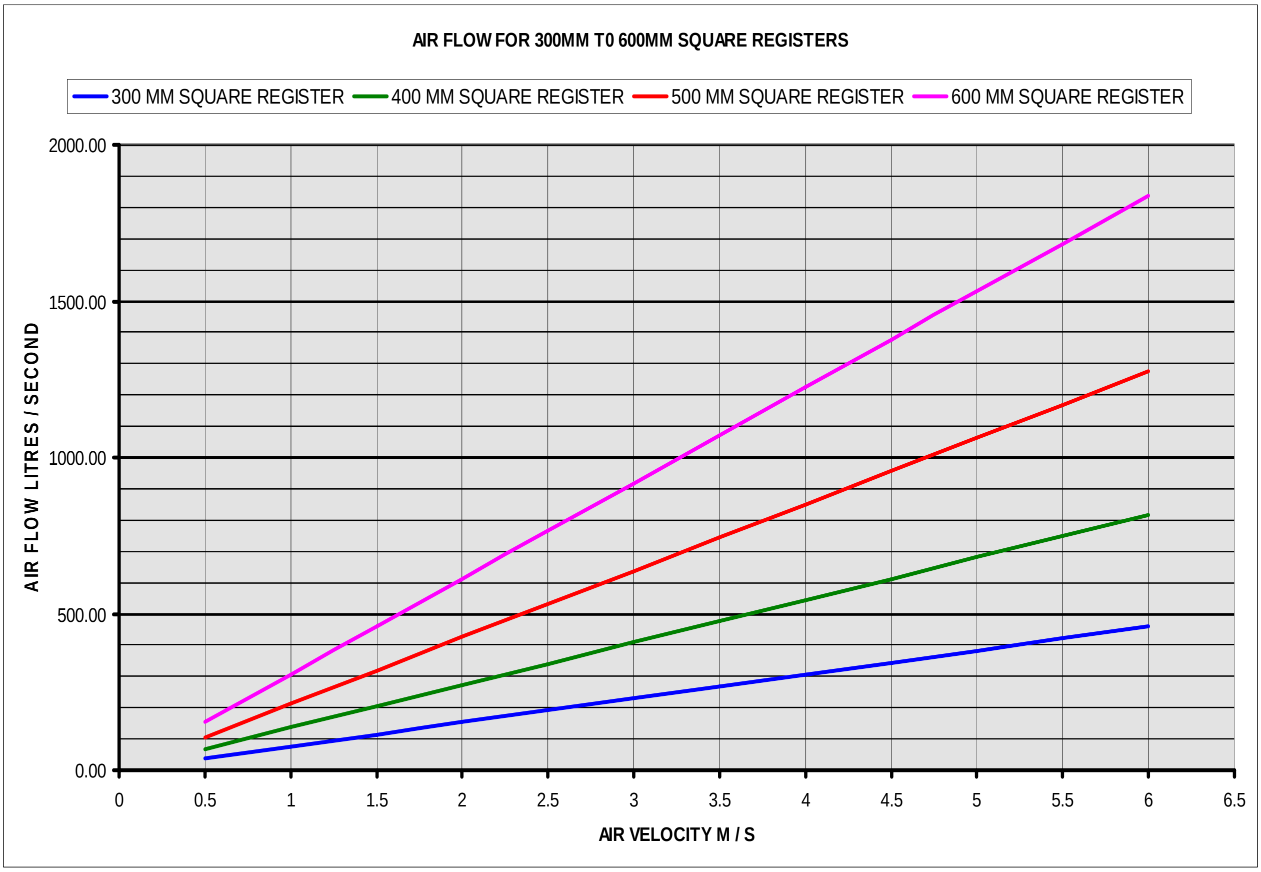

Figure 14 – 300mm to 600mm Square Registers

Circular Register Curves

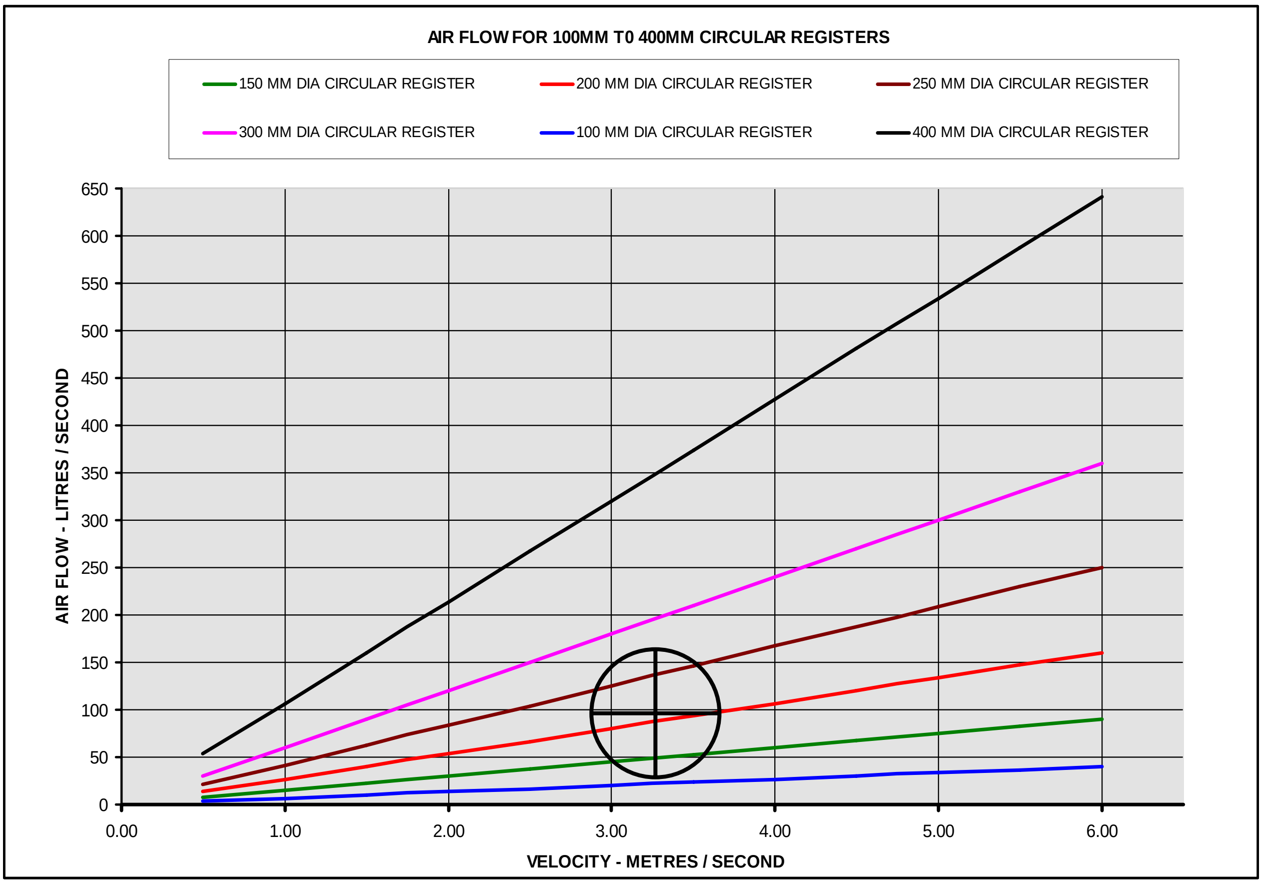

Figure 15 – 100mm to 400mm Circular Registers

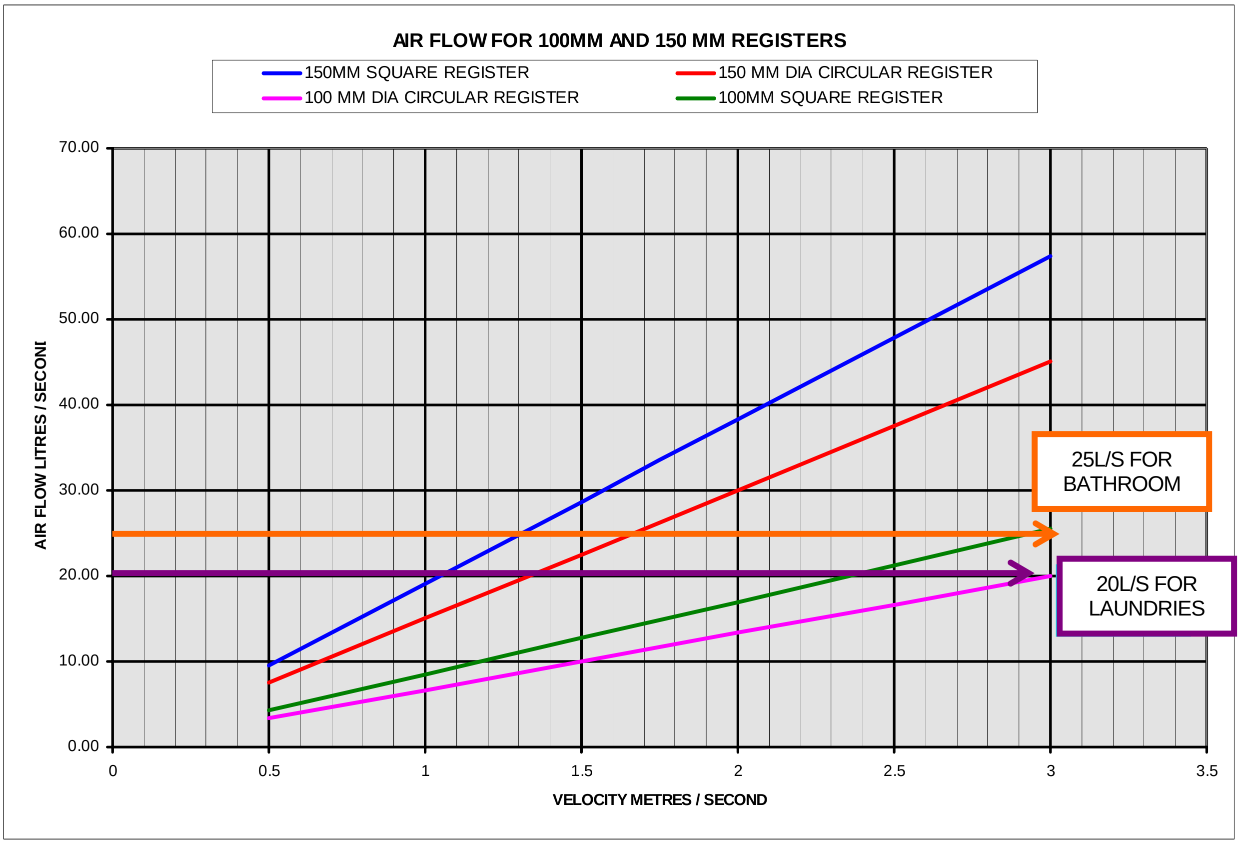

Figure 16 – Air Flow for 100mm & 150mm Square and Circular Registers

Figure 16 above shows differently structured curves providing a simpler method of checking the required air flows into bathrooms (25l/s) or laundries (20l/s) from single 100mm or 150mm registers, there are the most usual sizes found.

Figure 17 below is reading air velocity from a 300mm circular register. Because of the extensive grille, it would be appropriate to use it as a 250mm diameter circular register, in that case, from Figure 15, the velocity of 2.5m/s would indicate an air flow of ~100l/s.

Figure 17 – Measuring air velocity.

I trust that this paper will provide valuable information regarding mechanical ventilation systems.

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APPENDIX A

Table B1 from Appendix B to *Australian Standard (AS) 1668.2 The use of ventilation and airconditioning in buildings / Part 2 Ventilation design for indoor air contaminant control*.

TABLE B1
MINIMUM EXHAUST VENTILATION FLOW RATES

Enclosure type	Quantity	Unit	Comments
Automotive vehicle			See Section 7
Battery charging			See AS 2676
Document copying process that emits obnoxious effluent	5	$L/s.m^2$ floor	
Drycleaning (solvent)	20	$L/s.m^2$ floor	
Garages			See Section 7
Garbage room and service compartment	5	$L/s.m^2$ floor	100 L/s min.
Gas meter	5	$L/s.m^2$ floor	
Grease arrester	5	$L/s.m^2$ floor	100 L/s min.
Hospital sterilizing	20	$L/s.m^2$ floor	May be 5 $L/s.m^2$ of floor when local exhaust provided over sterilizers (see Clause 5.3)
Kitchen			
Commercial	5	$L/s.m^2$ floor	
Laundry			
Commercial	15	$L/s.m^2$ floor	
Hospital	15	$L/s.m^2$ floor	
Residential	20	L/s. room	Rate is independent of enclosure size. Operation of the system may be intermittent
Sanitary compartment			
Bath, Shower, Urinal, Water closet	10 *or* 25	$L/s.m^2$ floor / L/s per listed fixture	Greater value shall be taken. For calculation purposes; floor area per fixture shall be no greater than 2.5 m^2; 0.6 m length of urinal shall be equivalent to one fixture Sanitary compartments subject to high level of use, e.g., airports, entertainment venues, and similar, may require an increased ventilation rate Where privacy locks or airlocks are included, provision should be made for their ventilation at 5 L/s per square metre of floor area (e.g., via make-up air)
Bathroom, Toilet — Private dwellings and attached to bedroom of hotels, motels resorts, private hospital rooms and the like	25	L/s per room	May include bath, shower, water closet and handbasin in one compartment. Rate is independent of room size (see Note 2)
Sewage ejection	100	L/s	Minimum
Spa pools	5	$L/s.m^2$ floor	Includes water surface area
Swimming pools	2.5	$L/s.m^2$ floor	Includes water surface area
Plant room/storage room	5	$L/s.m^2$ floor	Enclosures used for storage of equipment, plant or materials likely to contaminate the air will need special consideration, see Paragraph B2
Lifts			Lift car and motor room ventilation, see AS 1735
Refrigeration			See AS/NZS 1677.2