COMMISSIONING SMOKE HAZARD MANAGEMENT SYSTEMS

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ABSTRACT

Smoke hazard management systems range from the fundamentally simple fire and smoke dampers to the complex zoned smoke control arrangements. They all require commissioning.

The first part of this paper discusses those systems that comprise fire and smoke control features of heating, ventilating and air conditioning (HVAC) systems. The number of components in such systems and the different methods of application, give rise to a discussion on the inverse relationship between system complexity and system reliability. The very direct relationship between system complexity and commissioning hours is also mentioned; leading to the conclusion that minimisation of complexity should be a major driver of smoke control system design. The designer's key role in developing the commissioning procedures is also highlighted.

From this philosophical high ground, the remainder of the paper addresses the specific commissioning needs of smoke control systems in Australian buildings. Various points are discussed, including the requirements of Australian Standards and the difference between testing of system functionality and system performance.

The paper concludes with several methods, checklists and spreadsheets that should be of assistance to commissioning personnel in resolving the conflict between verification of every aspect of a smoke control system's operation — and doing this all in the last week of construction!

1. Introduction

The objective of this paper is to raise the reader's awareness of the fire and smoke control features of HVAC systems and the necessity of commissioning them. The topic is introduced with the question "What are these features?" Then some notes on "Why commission?" with a discussion on complexity vs reliability. Finally some guides, checklists and standard forms on "How to commission", to assist the practitioner achieve complete commissioning, correctly recorded in the minimum time.

The following section lists all of the separate systems grouped under the heading fire and smoke control features of HVAC systems within the context of Australian regulations, as defined by the Building Code of Australia (BCA) [1].

2. What are the fire and smoke control features of hvac systems?

a) Fire dampers

b) Smoke dampers

c) Exit pressurisation systems

d) Smoke control systems – multi-compartment buildings

e) Smoke exhaust systems – large single compartments. Eg. shopping centres.

f) Smoke and heat vent systems

g) Smoke curtains

There are many more HVAC components applied in smoke control systems, however, these components are all employed within one or more of the systems noted above.

To assist the reader who is not familiar with all of these systems, the following notes give a brief outline of the main elements of each system and highlight the important areas related to commissioning:

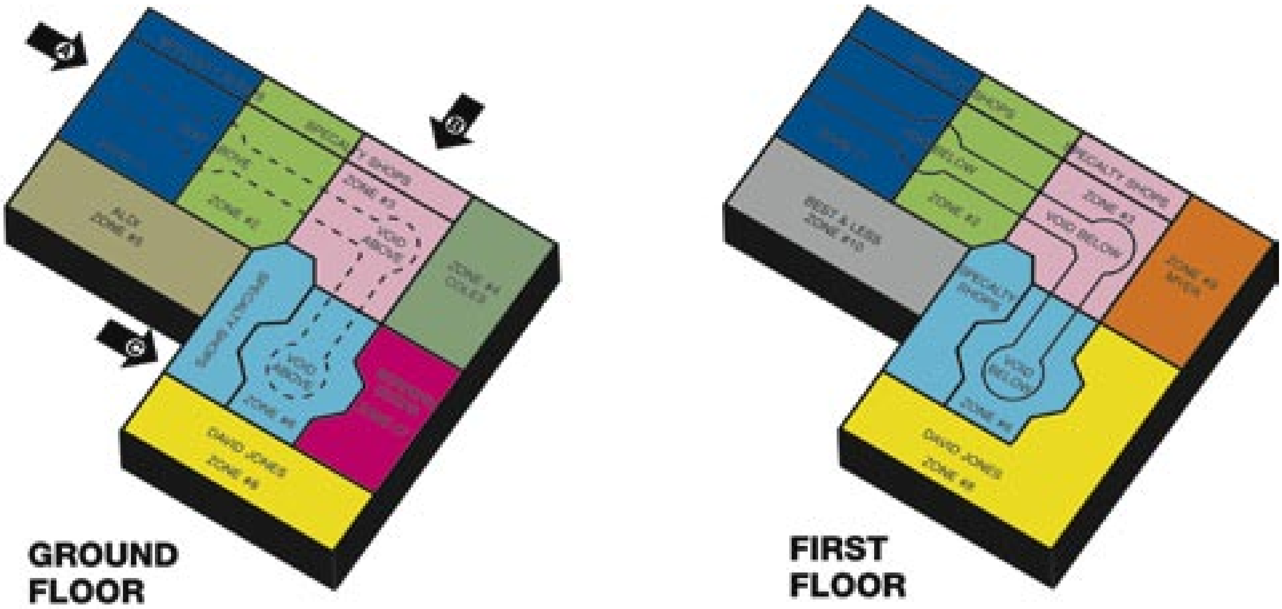
a) **Fire dampers**
Devices installed where air-conditioning or ventilation ducts penetrate fire resistant walls or floors. They close on exposure to fire, to maintain the integrity of the fire compartment boundary.

These are generally simple devices, the commissioning of which involves verification that they actually operate when released, and verification that they can be accessed for test/maintenance as required by State legislation. Problems occur due to poor coordination between building trades and HVAC trades as well as mutual ignorance of the installation requirements. These problems can be avoided by keeping good records of installation inspections and commissioning checks, supported by manufacturer's literature and fire test results.

b) **Smoke dampers**- Devices installed where air-conditioning or ventilation ducts penetrate smoke-resistant walls or floors. They close on activation of a smoke detector, to maintain the integrity of the smoke-compartment boundary. Typically applied in hospitals, nursing homes and occasionally in sole occupancy units where required by Clause E2.2 (b) (ii) of the BCA. [1]

They are required to be constructed and installed as for fire dampers, but with a motor for remote activation and other features specific to smoke control duty. Hence, commissioning involves verification that they actually drive fully open and closed, and that the detector interface is correct. It is also necessary to verify that they can be accessed for test/maintenance as required by State legislation. Problems occur due to poor coordination between building trades and HVAC trades as well as mutual ignorance of the installation requirements. These problems can be avoided by keeping good records of installation inspections and commissioning checks, supported by manufacturer's literature and fire test results.

c) **Fire-isolated exit pressurisation systems** - Are required by the BCA [1] in buildings according to size and usage of the premises, to prevent contamination of fire exits during fires. They are activated by a fire alarm in the building, but shut down if smoke is detected entering the fire exit. These systems must develop a positive pressure within the exit to prevent smoke entering while doors are closed, and when doors are open they must deliver an airflow velocity of 1 m/sec across every open doorway(s) to the fire-affected compartment.



SMOKE ZONE	a) Make-up from adjacent zones	b) Make-up from all non-smoke zones	c) Make-up from common mall	d) Make-up from main entrances
1	2, 5, 10	2-10	2, 3, 6	A + B + C
2	1, 3, 5, 6, 10	1 + 3-10	1, 3, 6	A + B + C
3	2, 4, 6, 9	1-2 + 4-10	1, 2, 6	A + B + C
4	3	1-3 + 5-10	1, 2, 3, 6	A + B + C
5	1, 2	1-4 + 6-10	1, 2, 3, 6	A + B + C
6	2, 3, 7, 8	1-5 + 7-10	1, 2, 3	A + B + C
7	6	1-6 + 8-10	1, 2, 3, 6	A + B + C
8	6	1-7 + 9-10	1, 2, 3, 6	A + B + C
9	3	1-8 + 10	1, 2, 3, 6	A + B + C
10	1, 2	1-9	1, 2, 3, 6	A + B + C

Table 1 - smoke exhaust make-up air options

The performance of these systems is highly dependent on the integrity of construction of the fire exit boundaries as well as effective relief of airflow from open doorways. Final commissioning therefore cannot commence until all builders' work affecting fire exit walls and airflow relief paths is completed for final occupation.

The other critical issue affecting commissioning of exit pressurisation systems is the performance criteria, governed by the Australian Standard AS/NZS 1668.1-1998 [2]. These criteria are dependent on the relief airflow system imposed upon the installation or selected by the designer. Commissioning cannot start without knowledge of the performance criteria.

As well as these pre-commissioning conditions of builders' work and performance criteria, exit pressurisation commissioning requires comprehensive testing at every exit door and verification of the interface with the fire/smoke detection system, which must activate and shut down the pressurisation fan(s).

d) **Smoke control systems** – multi-compartment buildings
Are required by the BCA [1] in buildings according to size and usage of the premises, to prevent spread of smoke beyond the initially fire-affected compartment during a fire. They are known as zone smoke control systems, and are activated by smoke detectors in the building. These systems exhaust air and smoke from the fire-affected compartment while pressurising all of the non-fire-affected compartments. They are required to achieve a differential pressure of at least 20 Pa between the fire-affected compartment and all other compartments.

As with exit pressurisation systems, the performance of zone smoke control systems is highly dependent on the integrity of construction of compartment boundaries and external walls and windows. Final commissioning therefore cannot commence until all work affecting internal fire-resistant boundaries and the external envelope is complete and ready for final occupation.

The performance criteria for zone smoke control systems are reasonably well defined in AS/NZS 1668.1 [2]; however, there is some scope for the designer to create building-specific performance parameters, especially in regard to the datum against which differential pressures are assessed. Commissioning cannot start without knowledge of the performance criteria.

As well as these pre-commissioning conditions of builders' work and performance criteria, zone smoke control system commissioning requires simulation of a fire alarm in each fire compartment and testing of differential pressure in each case, as well as verification of the interface with the smoke detection system for Smoke Control activation in each compartment.

e) **Smoke exhaust systems** – large, single compartments
Are required by the BCA [1] in buildings such as shopping centres, exhibition halls, theatres, atriums etc, according to size and usage, to minimise smoke spread from the fire source and maintain a tenable atmosphere

for escaping occupants. They are initiated by smoke detectors and/or sprinklers, and act to exhaust air and smoke from high-level reservoirs in the fire-affected zone while admitting uncontaminated make-up air to the occupied levels.

As with other smoke control systems, the performance of these smoke exhaust systems is highly dependent on the integrity of construction of the external walls and windows, as well as the high-level smoke reservoirs. Final commissioning therefore cannot commence until all work affecting internal smoke reservoirs and the external envelope is complete, and ready for final occupation.

The performance criteria for these smoke exhaust systems are well defined in Specification E2.2b of the BCA [1], but because they are built to suit the geometry of the space, no two smoke exhaust systems will be the same. A further complication is the scope for the designer to select size of smoke zones and the source of make-up airflow; via natural ventilation or mechanical supply. It is therefore critical that the designer defines the functional performance and airflow performance of these smoke exhaust systems, because commissioning cannot start without knowledge of the performance criteria.

As well as these pre-commissioning conditions of builders' work and performance criteria, the commissioning of smoke exhaust systems complying with Specification E2.2b of the BCA [1] requires:

- simulation of a fire alarm in each smoke zone,
- testing of fan start/stop operation in each case,
- verification of interface with smoke detection system for each zone, and
- measurement of smoke exhaust airflow rates.

f) **Smoke and heat vent systems -** Are required by the BCA [1] in buildings such as shopping centres and assembly buildings, according to size and usage (generally single-level buildings). Their purpose is to minimise smoke spread from the fire source, to remove the intense heat of the fire and to maintain a tenable atmosphere for escaping occupants. They are initiated by thermal links or smoke detectors, and act to exhaust hot air and smoke from high-level reservoirs in the fire-affected zone while allowing natural ventilation make-up of uncontaminated air to the occupied levels.

They are generally simple devices; the commissioning of which involves verification that they actually operate when smoke is detected or the thermal link is released. It is also critical that they can be accessed for test/maintenance as required by State legislation. Problems occur due to poor installation, usually as a result of mutual ignorance of the manufacturer's requirements by both builder and vent installer. These problems can be avoided by keeping good records of installation inspections and commissioning checks, supported by manufacturer's literature and fire test results.

g) **Smoke curtains** - Are used in conjunction with smoke and heat vents or smoke exhaust systems, to create smoke reservoirs. Typically used at escalator wells and at balconies in atriums, where aesthetic considerations prevent the use of fixed panel smoke reservoirs. They are activated by smoke detectors, to contain smoke in the reservoir of the fire-affected zone. Commissioning involves verification that they actually drop when required and the detector interface is correct. It is also necessary to verify that they have been installed as per the manufacturer's instructions and can be accessed for test/maintenance

3. Why commission?

Smoke control systems — complex or simple — depend on every element operating correctly and in the right sequence. Unless every possible function of the smoke control system has been demonstrated to function correctly — at least once during commissioning — then there is a real possibility that the system will not work when required to perform during fire alarm. **Proving system functionality is one of the purposes of commissioning.**

When everything is functioning correctly, the system can then be tested to demonstrate that it meets the performance criteria of the Standard. After all, it is not much use having a fully functioning stair pressurisation system that starts on fire alarm, operates correctly on smoke detection and fire fan control panel (FFCP) override, etc., but cannot achieve the airflow velocity to prevent smoke entering the stairs! **Proving system performance is the other purpose of commissioning.**

After the fully functioning, fully performing system has been tested to show that it meets the commissioning criteria, the results of all functionality and performance tests must be recorded so that:

- The owner and the authorities know that the system works correctly,
- There are performance benchmarks for the maintenance contractor to match during each year's annual certification tests and
- There is a document — which we hope will never be needed — to produce in court to say the system did work correctly when installed.

Appendix F of Australian Standard AS/NZS 1668.1 [2] provides detailed "informative" guidance for the practitioner who is carrying out the commissioning of exit pressurisation systems and smoke control systems in multi-compartment buildings. This Appendix covers the testing and recording requirements of the mandatory Clauses 4.16, 4.17, 4.18 and 4.19 in the Standard. It is a very comprehensive guide, which should be the basis of all technicians' training in smoke control system commissioning.

If you have any doubts about the need for extremely thorough commissioning and recording results, the following questions should be asked:

- Immediately after installation, but before commissioning, what might not work correctly?
- Does it really matter if it is only 99% right?

What might not work correctly?

- Motor fuses may not be installed.
- Motors may be rotating backwards.
- Dampers may be opening instead of closing.
- Holes in plenum chambers may prevent design airflow being achieved.
- Holes in fire rated walls or ducts may breach the integrity of a fire resistant barrier.
- Smoke detectors may be activating fans rather than shutting them down.
- Fire dampers may be installed upside down or sideways.
- TPS cable may have been used in lieu of Radox for a motor that runs in fire mode.

- The programmable logic controller (PLC) in the FFCP may be wrongly programmed.
- The smoke exhaust fan, selected for 200°C may overload with ambient air at 20°C.

Does it matter if it is only 99% right?

Consider a building of 25 storeys, with a zone smoke control system operating on two supply risers and two return/smoke exhaust risers:

- At least 100 air control dampers are operating in fire mode.
- At least 100 damper motors are operating in fire mode.
- There are at least 200 smoke detectors, zoned according to each compartment.

99% right would leave us with perhaps:

- One wrongly stroked damper blade that opened instead of closing.
- One damper motor that did not operate on alarm signal.
- Two smoke detectors connected to the wrong zone.

This 99% scenario, could leave us with a building in which the zone smoke control system might pressurise the fire affected floor and potentially exhaust a non-fire-affected floor, leading to the potentially disastrous situation of transferring smoke rapidly from the fire compartment to another compartment, where perhaps this time the system would respond correctly — and compound the failure!

And this disaster scenario only relates to functionality. It does not address incorrect fan blade pitch, excessive system resistance, the wrong fan speed, etc., which will all result in less than adequate airflow or pressure performance.

Discussion on smoke hazard management philosophy

The list in the previous Section 2 is quite formidable. At least six of the seven systems described as smoke control features must interface with fire alarm and detector systems — and it gets more difficult when you consider that in many projects, each one of these "features" comprises multiple different elements. The following examples, perhaps demonstrate the types of difficulty involved:

- The sheer man-hours of work involved in commissioning say 1000 fire dampers (even without complicating interfaces), or
- A seriously interdependent zoned smoke control system with say 50 air-handlers plus 150 motorised dampers all responding to 200 plus, zoned smoke detectors.

The number of components and their interdependence makes commissioning time-consuming — these numbers also reduce the reliability of the smoke hazard management system! There is a brief note in Appendix D of AS/NZS 1668.1 [2] stating that the reliability of smoke control systems decreases as the number of system components increases. This concept is explored in greater detail in Design of Smoke Management Systems [3].

This paper is on commissioning, at the completion of construction, however, it is usually in the design phase of a project that the number of components and their fire mode operation is defined, so why discuss design issues here? Two reasons:

- The designer is responsible for nominating the system's fire mode operation and hence defining commissioning criteria (both functionality and performance). The designer is also responsible for maximising smoke control reliability.
- Even at the completion of the project, with all equipment in place, there are opportunities to simplify fire mode operation, and thus increase system reliability.

The following example is intended to show some of the tangible benefits of simplified design, on both commissioning time and system reliability.

A two level shopping centre with a common mall has been designed with a total of 10 smoke control zones, to meet the requirements of Specification E2.2b of the BCA [1]. These zones are shown in the sketch overleaf. The common mall areas have large voids between ground and first floor, and the David Jones store has a large internal atrium combined with the escalator well, so the smoke exhaust fans for the mall and for David Jones, are in the ceiling of the first floor, but all other major stores have their smoke exhaust within the store. For the sake of simplicity in this example, there is one smoke exhaust fan and one air conditioning unit serving each smoke control zone.

The BCA [1] is fairly rigid in terms of its requirements for capacity and location of smoke exhaust fans, but there is some scope for variation in sourcing make-up air to balance the smoke exhaust airflow. Four options have been considered for this example. These make-up air options are described below, and are shown in Table 1 on page 25:

a) On activation of a detector in the smoke-affected zone (the smoke zone), the smoke exhaust fan in that zone commences running, and make-up air is supplied only from zones immediately adjacent to the smoke zone. In these adjacent zones, the air conditioning units operate on 100% outdoor air to introduce sufficient make-up airflow. All other air conditioning units in the shopping centre, including the smoke zone, shut down.

b) On activation of a detector in the smoke zone, the smoke exhaust fan in that zone commences running, and make-up air is supplied from ALL non-smoke zones. In these zones, the air conditioning units operate on 100% outdoor air, to introduce sufficient make-up airflow. Only the air conditioning unit in the smoke zone shuts down.

c) On activation of a detector in the smoke zone, the smoke exhaust fan in that zone commences running, and make-up air is supplied only from the four common mall zones. In these mall zones, the air conditioning units operate on 100% outdoor air to introduce sufficient make-up airflow. All other air conditioning units in the shopping centre, including the smoke zone, shut down. In the event of fire or smoke detection in one of the mall zones, then make-up air is supplied from the other three mall zones only.

d) On activation of a detector in the smoke zone, the smoke exhaust fan in that zone commences running and make-up air is supplied from the main entrance doorways A, B and C or outdoor air louvres adjacent to these doorways. All air conditioning units in the shopping centre, including the smoke zone, shut down.

Without analysis of the detailed geometry of the space, these four options do not appear to offer any particular advantage over each other in terms of smoke control, however, option d) requires significantly fewer tests to verify fan operation (run/stop) and has about three times the reliability of option a). (See page 25)

NOTE: The reader may notice in Table 1, some apparent anomalies in the allocation of sources of make-up air to certain smoke zones. These anomalies are probably due to the author's less than adequate drawing skills rather than incorrect allocation of make-up air zones.

The following assumptions have been applied in the calculations used to generate the comparison of systems in Table 2 (page 28).

- At least one detector simulation test must be carried out for each of the 10 smoke zones, and in each case, the operation (run/stop) of every fan must be confirmed.
- For those fans or groups of fans that shut down under ALL alarm conditions, analysis of the wiring diagrams should show only one test is necessary to verify such shut down.
- 10 smoke exhaust fans and 10 air-conditioning unit fans serve the shopping centre. These fans constitute 20 components in the reliability analysis, and for the calculation, are each deemed to have a failure rate of 1 in 10^6 hours.
- For each air-conditioner and smoke exhaust fan there is one electrical contactor (total of 20), there are 2 motorised damper sets per conditioner (20 in total) and there are 10 smoke detector zones. These constitute a total of 50 components, and for the calculation, are each deemed to have a failure rate of 1 in 10^5 hours.
- In its simplest configuration, Option a) requires a relay logic system involving 11 relays to activate each different combination of smoke exhaust fans and air-conditioner units.
- Because of their simpler arrangements or fewer fans actually used in fire mode, the other options b), c) and d) require progressively fewer components.

No.	Source of make-up airflow	Number of fan verification tests	Mean time between system failures
a)	Adjacent smoke zones only	200 (no short cuts)	22 weeks
b)	All non-smoke zones	200 (options for short cuts)	27 weeks
c)	Common mall zones only	146	45 weeks
d)	Main entrance doorways only	103	59 weeks

Table 2 — Commissioning tests and reliability for different make-up air options

NOTE: The component reliability data for this comparison is subject to significant variation depending on the manufacturer and the maintenance level. The important point is the relative reliability of different systems.

4. How to commission

Commissioning is always a project-specific task, so it is perhaps gratuitous and rather too optimistic to give this section such an all-encompassing title. There is, however, some useful material in this section, which will at least assist you to develop commissioning procedures for your smoke hazard management systems.

4.1 Develop a "culture" of commissioning smoke hazard management systems

Read and understand the various publications that are specific to commissioning of smoke hazard management systems. The following are recommended, however, there are considerably more.

a) Clauses 4, 5 and 6 of AS 1682.2 – 1990 [4] (only two pages) to get the full list of installation and commissioning requirements for fire dampers.

b) Appendix F of AS/NZS 1668.1 [2]. This applies to commissioning of exit pressurisation systems and smoke control systems in multi-compartment buildings (purge systems and zoned smoke control systems).

c) An August 2000 publication by the Victorian Chapter of NEBB, prepared by Paul Chasteauneuf and entitled A guide to testing stairwell and passage pressurisation systems to AS/NZS 1668.1-1998 [5] (also published in the September 2002 edition of EcoLibrium® and downloadable from www.airah.org.au).

d) Chapter 11, Design of Smoke Management Systems. [3]

There are many industry publications on commissioning of HVAC systems, which provide a useful basis for developing your commissioning plan. Examples are:

- ASB027, HVAC Commissioning Manual, published by SMACNA [6].
- ASHRAE Guideline 1-1996, The HVAC Commissioning Process [7].
- CIBSE, Commissioning Code M [8].
- NEBB008 Procedural Standards for Building Systems Commissioning [9].

4.2 General requirements

While not in any way a substitute for the publications mentioned above, the following steps provide a short checklist for planning smoke control commissioning and testing.

- Designer must prepare a document describing how the system operates in fire mode (functionality) and the physical parameters required to achieve smoke control (performance).
- Prepare a test schedule outlining procedures and all operating sequences. This can be the essential services section of the project's commissioning manual.
- Test each component.
- Test each sub-system.
- Complete all building work.
- Complete all work on associated building services. eg. electrical power, fire alarm interfaces, etc.
- Complete all installation work on all components of the smoke control system.
- Test each smoke control system, with smoke to activate the detectors.
- Test smoke control system's response to smoke detection in every single zone.
- Measure airflow rates and pressure differentials for all fire zone combinations.
- Measure all required noise levels.
- Record all results, so that they can be easily reviewed and re-tested in the future.

4.3 Builder's work

The fire and smoke control features of HVAC systems only exist within buildings. They are supported by the building structure and their capacity to contain smoke or prevent its spread is ENTIRELY DEPENDENT on the integrity of the building's external envelope, reservoirs and internal barriers. If these barriers and enclosures change, as a result of fitout and finishing trades' work between the time of commissioning and final occupation of the building, then the performance of these fire and smoke control features WILL

ALSO CHANGE. Such changes can often result in non-compliance of these features, requiring re-commissioning and/or extensive modifications to the building or HVAC systems or both — all at that critical contractual time prior to practical completion and handover of the building.

While it is generally possible to verify equipment functionality and installation quality before the builder's work is complete, the following items affecting integrity must be finalised before commencing commissioning tests on smoke hazard management systems. These should be brought to the builder's attention early in the construction program, so that they can be addressed in a timely manner when required.

a) Fire-resistant walls and floors of all fire-isolated stair shafts and passageways must be completed, with fire-stopping applied where necessary at structural joints and temporary openings sealed up. This requires particularly diligent inspection when masonry or lightweight shafts are used for pressurisation airflow.

b) All fire-isolated exit doors must be fitted, and door-closers adjusted.

c) Final finishes under fire-isolated exit doors must be completed. Carpet or tiled finishes extending under the door and applied after testing, will result in significantly different rates of air leakage from the fire-isolated exit, so that subsequent tests WILL NOT achieve the same performance as that achieved during commissioning.

d) Installation of windows and sealing of any temporary openings in the external walls must be completed. Unsealed building envelopes will affect zone pressurisation performance and relief airflow from fire-isolated exit pressurisation systems.

e) Where ceiling plenum spaces are used for return airflow or fire-isolated exit pressurisation relief airflow, all tiles, grilles, return air slots and light fittings must be in place.

f) Plant rooms or building enclosures serving as plenums for make-up airflow or exhaust airflow, must be completed and sealed.

g) Fire-resistant barriers in which fire or smoke dampers are installed, must be complete and certified to be capable of maintaining their intended fire resistance level (FRL), without depending on the fire or smoke damper for support.

4.4 Work by other trades

Many of the fire and smoke control features of HVAC systems depend on essential services electrical power supply to operate in fire mode, and are activated by smoke or fire alarm signal(s) from the fire indicator panel. It is therefore not possible to verify equipment functionality without having permanent essential services power and a completed, operational fire indicator panel.

4.5 Fire and smoke dampers

a) Show all fire and smoke dampers on the relevant mechanical services drawing(s) and prepare a schedule of fire and smoke dampers for recording installation and commissioning checks (Refer Tables 3 and 4 – these tables could not be reproduced here for space reasons, but can be downloaded from the EcoLibrium® section of www.airah.org.au).

b) Follow the manufacturer's requirements for installation and commissioning of the fire or smoke dampers.

c) In conjunction with the installer of the fire-resistant walls and floors, develop procedures for coordinating and recording the commissioning/verification of these fire-resistant barriers.

d) Follow the prescriptive requirements of Clause 5 in AS 1682.2 [4], and Clause 3.4 (b) in AS/NZS 1668.1 [2].

e) Follow the requirements listed below, of Clause 6 in AS 1682.2 [4].

- Check whether the damper label, in accordance with AS 1682.1 [4], is fitted.
- Check whether the type of construction in which the fire or smoke damper is installed is identical to the one used in prototype testing or whether the type of construction, in the opinion of the testing laboratory, would have achieved the listed FRL if so tested.
- Check the damper orientation against that marked on the label.
- Check whether damper is installed in a fully open position.
- Check the damper installation with respect to the direction of airflow marked on the label.
- Check whether the clearance between the damper and penetration is as specified in Clause 5.2 of AS 1682.2 [4].
- Check to ensure that the damper closure is not impeded.
- Check whether the damper assumes a fully closed position in fire mode.

f) In the case of smoke dampers, verify closure in response to activation of smoke detectors. This may require testing for a general fire alarm as well as a local smoke alarm.

g) In the case of smoke dampers, verify operation (open and close) in response to manual override of smoke zones on the fire indicator panel (FFCP) or equivalent central controller.

4.6 Exit pressurisation systems

a) Prepare a document showing the specific operational requirements for exit pressurisation in this building. Note the applicable clauses of AS/NZS 1668.1 [2].

- Is the exit installed in a building with a purge system of smoke control?
- Is the exit installed in a building with a zone pressurisation system?
- How many doors must be open for doorway airflow velocity tests?
- Do all doors have to be closed for door-opening force tests?
- Is the exit installed in a building with no specified system of smoke control? (e.g. residential building complying with Table E2.2a of the BCA [1].)
- Is there a system of natural or mechanically powered airflow relief system?

b) Prepare schedules for recording tests and installation quality of pressurisation systems in the building (Refer to Figures F4 and F5 in Appendix F of AS/NZS 1668.1).

c) Follow the procedures recommended in Appendix F of AS/NZS 1668.1 [2]. Do not forget the noise level tests and restoration time tests.

d) Carry out tests to verify correct activation in response to a general fire alarm and local smoke detectors if applicable.

e) Carry out tests to verify shut down of all fans in response to smoke detection at the exit pressurisation intake. Verify restoration of fan operation after the smoke clears.

f) Verify manual override ON and OFF as well as indicator lamp operation FAN ON, FAN FAULT and FAN OFF on the FFCP.

g) Consider applying the recommendations of Paul Chasteauneuf's guide [5].

4.7 Smoke control systems – multi-compartment buildings

a) Prepare a document showing the specific operational requirements for smoke control in this building. Note the applicable clauses of AS/NZS 1668.1 [2].

- Does it have a supply and exhaust system?
- Does it depend on supply air only?
- Does it depend on exhaust airflow only?
- What are the target pressure differentials?
- Are there any special features related to operation of major ventilation or air conditioning systems that run or stop in fire mode?
- Are there any back-up or stand-by systems that reduce the risk of failure of the primary smoke control system?

b) Prepare schedules for recording tests of the smoke control system(s) in the building (Refer Figure F6 in Appendix F of AS/NZS 1668.1 [2] and Clause 18.2.7 and Fig. 18.2.7(A) in AS 1851-2005 [10]).

c) Describe the method used to measure differential pressure between the fire-affected compartment and all non-fire-affected compartments in the building. Prepare a job specific schedule for recording:

- fire-affected compartment,
- differential pressure, and
- smoke detector "address" for each zone of the building.

d) Follow the procedures recommended in Appendix F of AS/NZS 1668.1 [2].

e) Carry out tests to verify correct activation in response to local zone smoke detectors, and if applicable, the response to a general fire alarm (Refer Clause 4.11 of AS/NZS 1668.1 [2]).

f) Verify shut down of all supply air fans in response to smoke detection at the air intake. Verify restoration of fan operation after the smoke clears.

g) Verify manual override ON and OFF of all essential supply and exhaust fans as well as indicator lamp operation FAN ON, FAN FAULT and FAN OFF on the FFCP.

h) Verify manual override operation of zone control dampers for each smoke zone.

4.8 Smoke exhaust systems – large, single compartments

a) Prepare a document showing the specific operational requirements of the HVAC design, for smoke exhaust in this building. If relevant, note the applicable clauses of Specification E2.2 b of the BCA [1]. (Clause 18.2.7

and Fig. 18.2.7(A) of AS 1851-2005 [10] may provide a suitable format for recording fire mode operation).

- Does it have a mechanical make-up air system?
- Does it have motorised dampers, motorised doors or motorised windows to allow make-up airflow via natural ventilation?
- Are there any separate fire compartments in addition to the smoke zones required by Specification E2.2 b of the BCA [1]?
- Are there any special features related to the operation of major ventilation or air conditioning systems that run or stop in fire mode?
- Do any of the non-required air-conditioning or ventilation systems continue operating in fire alarm?

b) Prepare schedules for recording functionality tests of the smoke exhaust system(s) in the building (refer Clause 18.2.7 and Fig. 18.2.7(A) in AS 1851-2005 [10]).

c) Prepare a job specific schedule for recording exhaust airflow rates for each smoke exhaust fan, and refer to this schedule on the functionality test chart, AND where necessary for the purpose of minimising personnel risk, disruption of trading or cost of future annual certification tests, record:

- differential pressure across each smoke exhaust fan, and
- motor current for each smoke exhaust fan, and
- status of any dampers that may change airflow conditions in future tests.

d) Carry out tests to verify correct activation of smoke exhaust fans in response to local zone smoke detectors, and if applicable, response to a general fire alarm.

e) Carry out tests to verify correct activation of motorised make-up air control devices in response to local zone smoke detectors, and if applicable, their response to a general fire alarm. eg. dampers, motorised doors or motorised windows, etc.

f) Verify correct operation of any smoke curtains installed and required to operate as part of the smoke exhaust system.

g) Verify shut down of all fans not required to run under the conditions of smoke detection in each specific smoke zone.

h) Verify continuing operation of each fan permitted or required to run under the conditions of smoke detection in each specific smoke zone. Verify shut down of all supply air fans in response to smoke detection at the air intake. Verify restoration of fan operation after smoke clears.

i) Verify manual override ON and OFF of all essential supply and exhaust fans as well as indicator lamp operation FAN ON, FAN FAULT and FAN OFF on the FFCP.

4.9 Smoke vents, heat vents and smoke curtains

a) Show all smoke vents, heat vents and smoke curtains on the appropriate roof (or ceiling) layout drawing(s) and prepare a schedule of smoke vents, heat vents and smoke curtains for recording installation and commissioning checks.

b) Follow the manufacturer's requirements for installation and commissioning of the smoke vents, heat vents and smoke curtains.

c) Prepare schedules for recording operational tests of the smoke vents, heat vents and smoke curtains in the building.

d) Operate each vent or smoke curtain manually and confirm satisfactory operation.

e) Verify automatic operation (where applicable) of each smoke vent, heat vent and smoke curtain in response to remote smoke detection or fire alarm.

4.10 Commissioning short cuts?

The following very short list of unrelated points may be of benefit to practitioners preparing essential services commissioning manuals or commissioning procedures.

a) Think of the future. Retain in a usable format, any information that is recorded during commissioning and which may be useful or necessary for the annual certification of the essential fire safety measures:

- Tables 3 and 4 of this paper (downloadable from www.airah.org.au), Figure F4 and F6 in Appendix F of AS/NZS 1668.1 [2] and Clause 18.2.7 and Fig. 18.2.7(A) in AS 1851-2005 [10] should be retained as master documents for future comparison.
- The schedules suggested previously in 4.7 c), 4.8 c) and 4.9 c).
- Photographs of dampers, fan intakes or discharges may be useful to confirm damper or fan status as suggested previously in 4.8 c)

b) Understand the control systems and wiring diagrams, so that you know when each circuit has been tested and verified. With the knowledge that a particular circuit's or control loop's operation has been confirmed, it is often practicable to carry out further equipment verification tests, simply by observation of indicator lamps rather than visual inspection of the controlled device (See Item 6 in the "Notes Applying to Functionality Test Chart" attached to Clause 18.2.7 and Fig. 18.2.7(A) of AS 1851-2005 [10]).

c) Testing of pressure differentials in zone smoke control systems can be expedited if a length of copper or polyethylene pipe, about 6mm Ø, is installed in a riser shaft, and accessible at every fire compartment.

In each fire compartment, install a tee-branch that is connected to the occupied space or is unambiguously capable of sensing pressure in the occupied space. If all tee-branches are open, then the pressure in the riser pipe is effectively the average pressure of all fire compartments.

During testing, connect one port of the pressure gauge to the tee-branch on the fire-affected compartment and leave the other port open in the fire-affected compartment. The resulting reading will be the difference between the pressure in the fire-affected compartment and the average pressure in all non-fire-affected compartments. Confirm with your designer, that this value reflects the requirements of the Standard for the specific building in question. ■

References

[1] "Building Code of Australia", Australian Building Codes Board, (Various editions)

[2] Australian/New Zealand Standard AS/NZS 1668.1-1998, "The use of ventilation and air-conditioning in buildings Part 1: Fire and Smoke control in multi-compartment buildings", Standards Australia, November 1998.

[3] J. H. Klote & J. A. Milke, "Design of Smoke Management Systems", ASHRAE, 1992

[4] Australian Standard AS 1682 - 1990, "Fire Dampers Part 1: Specification" and "Part 2: Installation", Standards Australia, November 1990.

[5] P. Chasteauneuf, " A guide to testing stairwell and passage pressurization systems to AS 1668 Pt. 1 – 1998", Victorian Chapter of NEBB, August 2000.

[6] ASB 027 "HVAC Systems Commissioning Manual", SMACNA, 1994.

[7] "ASHRAE Guideline - The HVAC Commissioning Process", ASHRAE, 1996.

[8] "CIBSE - Commissioning Code M", CIBSE, 2003.

[9] NEBB 003 "Procedural Standards for Building Systems Commissioning", NEBB, 1993.

[10] Australian Standard AS 1851 - 2005, "Maintenance of Fire Protection Systems and Equipment", Standards Australia, September 2005.

About the author

Simon Hill holds a degree in mechanical engineering from the University of Sydney, is a fellow of AIRAH and a member of the Institution of Engineers Australia and ASHRAE. He has over 30 years' experience in mechanical services design, installation, commissioning and maintenance, with particular expertise in smoke control of multi-compartment buildings.
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