SINGAPORE STANDARD
SS 553 : 2009
(ICS 91.140.30)

CODE OF PRACTICE FOR

Air-conditioning and mechanical ventilation in buildings

(Formerly CP 13)

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Building and Construction Authority
Institution of Engineers Singapore
Nanyang Technological University
National University of Singapore
Singapore Civil Defence Force
Sustainable Energy Association of Singapore

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Foreword

This Singapore Standard Code of Practice was prepared by the Working Group under the direction of the Technical Committee on Building Maintenance and Management. The Technical Committee is under the purview of the Building and Construction Standards Committee. This code is a revision of CP 13 : 1999 and has been re-numbered as SS 553 : 2009.

The purpose of this revision is to keep abreast of international standards in the design, construction, installation, testing and commissioning, operation and maintenance of air-conditioning and mechanical ventilation systems (ACMV) in all commercial, office and institutional buildings except hospitals.

This code represents a standard of good practice for air-conditioning and mechanical ventilation systems with particular emphasis on indoor air quality, energy efficiency, fire safety and maintainability. Some graphical symbols relating to ACMV are given in Annex A.

The changes include:

a) Grouping of clauses into the main sections of air-conditioning system, mechanical ventilation system, auxiliary equipment, and operation and maintenance.

b) Aligning general guidance on energy efficiency requirements for ACMV systems with national and international standards. In particular, a new clause on general guidance in energy recovery for ACMV systems (Clause 12) has been introduced.

c) Expanding the requirements for maintenance

This code is intended to complement Singapore Standard 'Code of practice for indoor air quality for air-conditioned buildings (SS 554)'.

The values in Tables 1 to 13 of this Singapore Standard are based on the following ASHRAE standards:

a) ANSI/ASHRAE/IESNA Standard 90.1 : 2007 'Energy standard for buildings except low-rise residential buildings (SI Edition)',

b) ANSI/ASHRAE 62.1 : 2007 'Ventilation for acceptable indoor air quality',

c) BSR/ASHRAE//USGBC/IESNA Standard 189P 'Proposed standard for the design of high-performance green buildings except low-rise residential buildings'.

Attention is drawn to the possibility that some of the elements of this Singapore Standard may be the subject of patent rights. SPRING Singapore shall not be held responsible for identifying any or all of such patent rights.

NOTE

1. *Singapore Standards are subject to periodic review to keep abreast of technological changes and new technical developments. The revisions of Singapore Standards are announced through the issue of either amendment slips or revised editions.*

2. *Compliance with a Singapore Standard does not exempt users from legal obligations.*

Code of practice for air-conditioning and mechanical ventilation in buildings

Section One – General

1 Scope

1.1 This code of practice provides general guidance in the design, construction, installation, testing and commissioning, operation and maintenance of air-conditioning and mechanical ventilation systems in all commercial, office, and institutional buildings except hospitals. The purpose of this code is to establish minimum requirements in mechanical ventilation and air-conditioning engineering practice such that an acceptable indoor thermal environment can be attained in an energy efficient manner with general consideration for the indoor air quality (IAQ), and maintainability of the equipment.

1.2 This code does not address specific indoor air quality concerns for minimizing potential health hazards. Users should refer to the SS 554 for specific / more complete IAQ requirement guidelines.

1.3 This code does not address the design requirements of fire protection. Users should refer to the Code of Practice for Fire Precautions in Buildings for the purpose of design requirements of fire protections, including smoke purging system.

1.4 This code does not address heating installations as the majority of mechanical ventilation and air-conditioning systems in Singapore do not require any form of heating.

1.5 This code does not apply to industrial ventilation in control of specific air contaminants inside workplace as such requirements are separately covered by a different set of regulations.

NOTE 1 – It is not intended that this code should impose unnecessary restrictions on design and installations of systems, nor on the development and use of new improved or unusual materials, design or methods of constructions or installation not covered by this code. However, in the event that this code is applied as a requirement by regulations of regulatory authorities, any departure from this code will require the specific approval of the regulatory authority. It is good practice that all parties involved in the project are informed through a process of exchange of information. The recommended procedure can be found in Annex B.

NOTE 2 – Neither this code nor Singapore Standard SS 554 prescribes specific ventilation rate requirements for zones that include smoking. ASHRAE 62.1: 2007 may be referred to if smoking zones are present or if there are zones that do not meet the requirements for separation from zones that include smoking.

2 Normative references

The following documents are referenced for the application of this code. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

1.	ARI Standard 1060	Rating air-to-air energy recovery ventilation heat exchangers
2.	ASHRAE 55 : 2004	Thermal environmental conditions for human occupancy
3.	ASHRAE 62.1 : 2007	Ventilation for acceptable indoor air quality
4.	ASHRAE 90.1 : 2007	Energy standard for buildings except low-rise residential buildings

5.	ASHRAE 111 : 2008	Practices for measurement, testing, adjusting, and balancing of buildings, heating, ventilation, air-conditioning and refrigeration systems
6.	ASHRAE 189P	Proposed standard for the design of high-performance green buildings except low-rise residential buildings
7.	ASHRAE 15	Safety standard for refrigeration systems
8.	ASHRAE Guideline 0 : 2005	The commissioning process
9.	ASHRAE Guideline 1.1 : 2007	The HVAC commissioning process
10.	BS 476 : Part 5 : 1989	Method of test for ignitability
11.	SS CP 5	Code of practice for electrical installations
12.	SS 212 : 2007	Specifications for aluminium alloy windows
13.	SS 299	Fire resistant cables: Performance requirements for cables required to maintain circuit integrity under fire conditions
14.	SS 530 : 2006	Code of Practice for energy efficiency standard for building services and equipment
15.	SS 554 : 2009	Indoor air quality for air-conditioned buildings

16. Code of practice for fire precautions in buildings
17. Guide to setting up a childcare centre 2008
18. Code of practice on environmental health 2009

3 Definitions

For the purpose of this code, the following definitions apply:

3.1 Activated carbon

A form of carbon made porous by special treatment by which it is capable of adsorbing various odours, anesthetics and other vapours.

3.2 Air, ambient

Generally speaking, the air surrounding an object.

3.3 Air changes

A method of expressing the rate of air entering or leaving a space by natural or mechanical means in terms of the number of volume of the space.

3.4 Air-conditioning

The process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space.

3.5 Air diffuser

A circular, square or rectangular air-distribution outlet, generally located in the ceiling and consisting of deflecting members discharging supply air in various directions and planes, and arranged to promote mixing of supply air with room air.

3.6 Air, exhaust

Air other than recycled air, removed from an enclosure and discharged to atmosphere.

3.7 Air-handling system

A system for the purpose of providing air in a controlled manner to specific enclosures by means of one or more air-handling plants, ducts, plenums, air distribution devices and automatic controls.

3.8 Air, outdoor

Ambient air entering the system or opening from outdoors before any air treatment.

3.9 Air, recirculated

Enclosure air that passes through a local air cleaning unit and returns to the same or other enclosures.

3.10 Air, return

Air returned from conditioned or refrigerated space.

3.11 Air, supply

The quantity of air delivered to each or any space in the system, or the total delivered to all spaces in the system.

3.12 Air, transfer

Air moved from one indoor space to another.

3.13 Comfort, thermal

Condition of mind derived from satisfaction with the thermal environment. Thermal comfort is the combined thermal effect of environmental parameters including air temperature, relative humidity, air movement, mean radiant temperature (fixed factors) and clothing and activity level of occupants.

3.14 Condensate

The liquid formed by the condensation of a vapour, such as water which is extracted from moist air as it flows across the cooling coil of an air-conditioner.

3.15 Condenser

A vessel or arrangement of pipes or tubings in which vapour is liquefied by removal of heat.

3.16 Contaminant, airborne

An unwanted airborne constituent that may reduce acceptability of the indoor air quality.

3.17 Control

Any device for the regulation of a system or component in normal operation, manual or automatic. If automatic, the implication is that it is responsive to changes of pressure, temperature or other property whose magnitude is to be regulated.

3.18 Cooling tower, water

An enclosed device for the evaporative cooling of water by contact with air.

3.19 Covering, duct

Duct covering includes materials such as adhesives, insulation, banding, coating(s), film and jacket used to cover the outside of a duct, fan casing or duct plenum.

3.20 Damper

A device used to vary the volume of air passing through an air outlet, inlet or duct.

3.21 Direct digital control (DDC)

The use of microcomputer to directly perform the control logic for control loops.

3.22 Duct

A passageway made of sheet metal or other suitable materials, used for conveying air.

3.23 Evaporator

That part of a refrigeration system in which the refrigerant is vapourised to produce refrigeration.

3.24 Exfiltration

Air that flows outward through a wall, door, window, crack, etc.

3.25 Exhaust opening

Any opening through which air is removed from a space which is being air-conditioned or ventilated.

3.26 Exit

A means of egress from the interior of the building to an exterior space which is provided by the use of the following either singly or in combination: exterior door openings, exit staircases, exit ramps or exit passageways but not including access stairs, aisles, corridor doors or corridors.

3.27 Grille

A louvered or perforated covering for an air passage opening which can be located in the side-wall, ceiling or floor.

3.28 Humidity, relative

The ratio of the mole fraction of water vapour present in moist air to the mole fraction of water vapour in saturated air at the same temperature and pressure.

3.29 Infiltration

Air that flows inward through a wall, door, window crack, etc.

3.30 Insulation, thermal

A material having a relatively high resistance to heat flow and used principally to retard the flow of heat.

3.31 Kilowatt

The kilowatt is the unit of measure of power. It can be used to quantify power (electrical) or rate of energy transfer (thermal).

3.32 Lining, duct

Duct lining includes materials such as adhesives, insulation, coating and film used to line the inside surface of a duct, fan casing, or duct plenum.

3.33 Plenum chamber

An air compartment connected to one or more distributing ducts.

3.34 Register

A grille and damper assembly covering an air opening.

3.35 Service agency

An agency capable of providing calibre testing, or manufacture of equipment, instrumentation, metering, or control apparatus, such as contractor, laboratory, or manufacturer.

3.36 Smoke

An air suspension (aerosol) of particles, usually but not necessarily solid, often originating in a solid nucleus, formed from combustion or sublimation. Also defined as carbon or soot particles less than 0.1 micron in size which results from the incomplete combustion of carbonaceous materials such as coal, oil, tar and tobacco.

3.37 Temperature, dry-bulb

The temperature of a gas or mixture of gases indicated by an accurate thermometer shielded from effects of radiation.

3.38 Temperature, mean radiant

The temperature of a uniform black enclosure in which a solid body or occupant would exchange the same amount of radiant heat as in the existing non-uniform environment.

3.39 Temperature, operative

Arbitrary index that combines into a single number the effects of dry-bulb temperature, radiant temperature and air motion on the sensation of warmth or cold felt by the human body. The operative temperature can be taken as average of mean radiant temperature and dry- bulb temperature.

3.40 Temperature, wet-bulb

Thermodynamic wet-bulb temperature is the temperature at which water (liquid or solid state) by evaporating into air can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer, constructed and used according to specification

3.41 Vapour barrier

A moisture-impervious layer applied to the surfaces enclosing a humid space to prevent moisture travel to a point where it may condense due to low temperature.

3.42 Ventilation

The process of supplying or removing air, by natural or mechanical means, to or from any space. Such air may or may not have been conditioned.

3.43 Zone

A space or group of spaces within a building with sufficiently similar cooling requirement.

4 Rules and regulations

The ACMV system shall be designed and carried out to comply with all relevant acts, regulations and by laws, and all amendments thereof, in particular the following:

a) Building Control Act (Chapter 29)
Building Control Regulations

b) Fire Safety Act (Chapter 109A)
Fire Safety (Building Fire Safety) Regulations

c) Public Utilities Act (Chapter 261)
Public Utilities (Water Supply) Regulations

d) Electricity Act (Chapter 89A)
Electricity (Electrical Installation) Regulations

e) Environmental Public Health Act (Chapter 95)

f) Environmental Protection & Management Act (Chapter 94A)

g) Workplace Safety and Health Act (Act 7 of 2006)

Section Two – Air-conditioning system

5 Design considerations

An air-conditioning system should be designed such that it can maintain a comfortable and healthy environment under all the operating conditions that can be expected, in an energy-efficient manner.

5.1 General requirements

5.1.1 All rooms and occupied spaces which are not naturally ventilated or mechanically ventilated shall be clearly designated in the architectural drawings to be air-conditioned.

5.1.2 There shall be no smoking in air-conditioned spaces, except in designated areas.

5.1.3 In designated areas where smoking is allowed, these areas shall be in compliance with requirements in SS 554.

5.1.4 In designing a central air-conditioning system for a building, the cooling load of the building, both sensible and latent, and the ventilation load should be calculated.

5.1.5 An air-conditioning system should be designed to meet the indoor temperature and humidity requirements of the space it serves, when the cooling load is at full load as well as when it is at part-load. The ability of the system to maintain the indoor conditions at part-load should be checked at the design stage.

5.1.6 Documentation on the design of an air-conditioning system should be kept for future reference.

6 Ventilation rates

6.1 Outdoor air intakes

6.1.1 The location of outdoor air intakes for air-handling systems shall take due account of any other intake openings for ventilation or exhaust. The intakes of outdoor air to all air-conditioning systems, including those for the ventilation and pressurisation of stairshafts, shall be located at external walls or at roof level, arranged so as to pick up outdoor air free of contamination or odours.

6.1.2 Outdoor air intakes shall be covered with an insect screen and protected from rain entrainment.

6.1.3 Outdoor air intakes shall not be within 5 m of exhaust discharges from any buildings, kitchens, toilets, car parks, cooling towers, laundries, rubbish dumps or plant rooms. The distance from an air intake to a cooling tower is measured from the base of the cooling tower.

6.1.4 Outdoor air intakes should be protected from the water droplets emitted by cooling towers, such that no water droplet can enter the ventilation air stream.

6.1.5 For air-conditioned spaces, the bottom of the outdoor air intakes shall not be less than 2.1 m above the outside floor level, when the air intakes are adjacent to car parks or busy thorough fares.

6.2 Air classification and recirculation

Air (return, transfer or exhaust) shall be classified and recirculated in accordance with 6.2.1 and 6.2.2.

6.2.1 Classification

Air (return, transfer or exhaust) leaving each space shall be designated at air-quality classification based on relative contaminant concentration using the following subjective criteria:

a) Class 1 – Air with low contaminant concentration, low sensory-irritation intensity and inoffensive odour.

b) Class 2 – Air with moderate contaminant concentration, mild sensory-irritation intensity or mildly offensive odour. Class 2 air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.

c) Class 3 – Air with significant contaminant concentration, significant sensory-irritation intensity or offensive odour.

d) Class 4 – Air with highly objectionable fumes or gases or with potentially dangerous particles, bioaerosols, or gases, at concentrations high enough to be considered harmful.

6.2.2 Recirculation

Recirculation of air shall be limited in accordance with the following requirements:

a) Class 1 air may be recirculated or transferred to any space.

b) Class 2 air may be recirculated within the space of origin. It may be transferred to other Class 2 or Class 3 spaces utilised for the same or similar purpose involving the same or similar pollutant sources. It may also be recirculated or transferred to Class 4 spaces. Class 2 air shall not be recirculated or transferred to Class 1 spaces.

c) Class 3 air may be recirculated within the space of origin. Class 3 air shall not be recirculated or transferred to any other space.

d) Class 4 air shall not be recirculated or transferred to any space or recirculated within the space of origin.

6.2.3 Outdoor air for ventilation and indoor air that is to be recirculated should be filtered for particulates.

6.2.4 Air from any of the following rooms or spaces shall not be recirculated:

a) Bathrooms and toilets; and

b) Any space where there is present or likely to be present flammable vapour, dust, odours or noxious gases in such quantity as to be a danger to life or public health.

6.3 Outdoor air supply

6.3.1 Outdoor fresh air supplied to air-conditioned space must be filtered, cooled and de-humidified, if total cooling to the space is above 35 kW capacity.

6.3.2 For comfort air-conditioning design purposes, the minimum quantity of outdoor air supply at full load for any occupiable space(s) of any zone(s) in a building shall be based on the floor area and determined according to the rates given in Table 1. The quantities of outdoor air stated in the table have taken into consideration the occupancy load given in the Code of Practice for Fire Precautions in Buildings, the requirement for diluting the odour caused by people and their activities, and the requirement for diluting the pollutants caused by the interior furnishing.

6.3.3 The values of the air quantity given in Table 1 can be deemed to have satisfied the minimum requirement for the outdoor air at the breathing zone level. When the air distribution makes use of floor supply and ceiling return to have a low velocity displacement flow in the space, a reduction in the air quantity is allowed, if unidirectional flow and thermal stratification can be achieved. Reference can be made to ASHRAE Standard 62.1:2007.

6.3.4 The rates of ventilation given in Table 1 apply to normal types of buildings with normal heat gains from occupants and activities and no-smoking in air-conditioned spaces. When abnormal conditions prevail, the ventilation rate may be increased to prevent undue concentration of body odours, bacteria-carrying particles, gas, vapour or dust and to prevent undue accumulation of carbon dioxide and to remove products of combustion.

6.3.5 For any type of room or floor space not specified in this section, the ventilation rate shall be determined by the qualified person subject to the approval of the relevant authority.

6.3.6 In air-conditioned office premises, classrooms and theatres, the supply of outdoor air can be varied according to occupancy if the requirements given in SS 554 can still be met.

6.3.7 Unless there is monitoring and control of the concentration of carbon dioxide indoors, the design outdoor air quantity should be maintained during the air-conditioning operation.

6.3.8 In existing buildings where the air-conditioning systems have been designed for a lower ventilation rate, the indoor air quality can be improved by using suitable filters for the particulates or gases.

Table 1 – Outdoor air supply requirement for comfort air-conditioning

Type of building/ Occupancy	Minimum outdoor air supply			
	l/s per m^2 floor area	m^3 /h per m^2 floor area	l/s per person	Air class [1]
Restaurants	3.4	12.2	5.1	2
(i) Dance halls	7.0	25.0	10.5	1
Offices	0.6	2.0	5.5	1
(ii) Shops, supermarkets and department stores	1.1	3.8	5.5	1 or 2
Theatres and cinemas seating area	2.0	7.3	3.0	1
Lobbies and corridors	0.3	1.1	3.3	1
Concourses	1.1	4.0	3.3	1
(iii) Hotel guest rooms	15.0 l/s per room	54.0 m^3 /h per room	5.5	1
(iv) Classrooms				
Primary school children and above	2.8	10.0	4.2	1
Childcare centres	2.8	10.0	8.4	1

NOTE:

i) Dance halls refer to night clubs. The outdoor air supply in discotheques requires 50% more than that in dance halls.

ii) Air classification in occupancy with generation of internal contaminants such as barbershops, beauty and nail salons and pet shops is Class 2 and should be exhausted so that the spaces are maintained at negative pressure relative to the surrounding spaces.

iii) The use of higher outdoor air supply in hotel guest rooms stipulated in Table 1 should take precedence.

iv) The occupancy load for primary school children and above is 1.5 m^2 per person referred to in the Code of Practice for Fire Precautions in Buildings. The occupancy load for childcare centres is based on 3 m^2 per person referred to in the *"Guide to setting up a childcare centre"*, the Ministry of Community Development, Youth & Sports.

7 Calculation of cooling load and ventilation load

7.1 Design and calculation requirements

7.1.1 Equipment used in air-conditioning shall have minimum performance in accordance with Singapore Standard SS 530.

7.1.2 Cooling systems design loads for the purpose of sizing systems and equipment shall be determined in accordance with generally accepted engineering standards and handbooks acceptable to the relevant authority.

[1] Refer to 6.2.1 (See also SS 554 for more information on air classification)

7.1.3 The normal design dry-bulb temperature for comfort air-conditioning can vary from 23 °C to 25 °C, with the lower temperature applicable to zones with solar load and the higher value in all other zones. To meet the indoor air quality requirement, the design relative humidity should be selected such that if the solar load is assumed to be zero, while the rest of the load components remain at their design values, the resulting relative humidity can be predicted not to exceed 65%. The air speed within the occupied space for sedentary occupants should be designed not to exceed 0.30 m/s.

7.1.4 When a space has a significant sensible equipment load, care should be taken for situations when the equipment is operating at part-load.

7.1.5 The specification of indoor conditions shall take into consideration the anticipated mean radiant temperature and air movement.

7.1.6 The design outdoor air conditions can be taken at 32 °C dry-bulb and 26 °C wet-bulb with a daily range of 8 °C. The dry-bulb temperature value is not exceeded more than 2% of the total hours during the months of June to September and the wet-bulb value is the average of the coincident wet-bulb temperature occurring at the design dry-bulb temperature.

7.1.7 The load contribution from the outdoor air introduced into a building for ventilation shall be calculated. The ventilation rates for specific places are given in Table 1.

7.1.8 The load contribution from outdoor air infiltrating into a building shall be calculated by the procedures in ASHRAE Handbook of Fundamentals or equivalent computation procedures. The maximum rate of outdoor air infiltration for aluminium casement and sliding windows is given in Singapore Standard SS 212 to be 12 m^3/h per metre length of opening joint.

7.2 Indoor thermal environment

When the air-conditioning system is in operation, the operative temperature should be maintained within 24 °C and 26 °C and the air movement should not exceed 0.30 m/s, measured at the occupants' level 1500 mm from the floor, and the average relative humidity should not exceed 65% for new buildings and 70% for existing buildings. The operative temperature can be taken as average of mean radiant temperature and dry- bulb temperature.

7.3 Indoor supply air

7.3.1 The cool supply air should be directed away from the fenestration glazing or the glazing adjacent to a non air-conditioned area to prevent moisture condensing on the outside surface.

7.3.2 The cool air leaving the supply diffuser should be designed at a temperature less than 2 °C below the room dew point to prevent moisture condensing on the diffuser surface.

7.4 Purging of indoor air

In the event that the indoor air quality becomes unacceptable, because of renovation or other reasons, it should be possible to purge the contaminants from the affected floor without affecting the rest of the building.

7.4.1 For air-conditioned buildings, an air purging system should be provided at each floor so that contaminated air can be exhausted when necessary to improve the indoor air quality.

7.4.2 The air purging system should be able to introduce outdoor air into the space and then discharge the indoor air to outside the building at a minimum rate of 2 air-changes per hour.

7.4.3 The capacity of the exhaust fans shall be higher than the flow rate of the outdoor air introduced into the space.

7.4.4 For buildings with fixed windows, the outdoor air for purging can be supplied by the fan for air-conditioning or others.

7.4.5 The exhaust discharge shall be at least 5m away from the outdoor air intake of another system.

7.5 Air filtration

The particulate contaminants in the air in an air-conditioned space should be continuously removed in order to maintain the cleanliness of the air.

7.5.1 Outdoor air for ventilation and indoor air that is to be recirculated should be filtered for particulate.

7.5.2 An air filter should be placed specifically for cleaning the outdoor air only. The Minimum Efficiency Reporting Value (MERV) of the pre-filter for cleaning the outdoor air should be MERV 1 or better.

7.5.3 The Minimum Efficiency Reporting Value (MERV) of the primary filter for cleaning the recirculated air or mixed air should be MERV 5 or better.

7.5.4 Air filters should be installed such that no unfiltered air can bypass the filters and enter the air handling system.

7.5.5 It should be possible to assess at any time the condition of the air filter and the pressure drop across it.

7.5.6 For a better indoor air quality, it is recommended that a filter of 80% dust spot efficiency or better be used as the secondary filter for cleaning the recirculated air or mixed air in places for continuous occupancy. The use of such filter can be helpful when the quality of outdoor air is poor. It can also reduce the need to clean the air ducts of dust cake that will form with time which can support the growth of micro-organisms.

7.5.7 Where no secondary filter is used, it is recommended that the recirculated air or mixed air or outdoor air is further cleaned of fine particles whenever the pollution standard index of the outdoor air exceeds 100 based on PM10 over 24 hours.

7.5.8 To meet the requirement stated in 7.5.7, an air filter of 80% dust spot efficiency or better can be inserted into the stream of recirculated air or mixed air after the primary filter. For this purpose the fan motor needs to have been sized accordingly such that the required air flow rate can be maintained.

7.5.9 The requirement of 7.5.7 can similarly be met, if an air filter of 80% dust spot efficiency or better is used to filter the intake outdoor air further after the pre-filter.

7.5.10 The requirement stated in 7.5.7 or 7.5.8 can also be met by other types of air cleaning devices of similar performance.

8 Control

8.1 The design of the control system shall allow operation to utilise energy efficiently while maintaining the desired indoor conditions.

8.2 When an air-conditioning system has to serve areas with different cooling requirements, sufficient number of zones shall be provided.

8.3 At least one thermostat of suitable operating range shall be provided to each separate air-handling system and zone for the regulation of space temperature.

8.4 A readily accessible manual or automatic means shall be provided to partially restrict or shut off the cooling to each zone.

8.5 Air-conditioning systems shall be equipped with at least one of the following to enable them to shutdown automatically:

a) Controls that can start and stop the system under different time schedules for seven different days per week with manual override, or equivalent function that allows temporary operation of the system for up to two hours.

b) An occupant sensor that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes.

c) An interlock to a security system that shuts the system off when the security system is activated.

8.6 The following systems are exempted from automatic shutdown requirement given in 8.5:

a) Systems serving hotel guestrooms;

b) Systems intended to operate continuously; and

c) Systems having cooling capacity less than 4.4 kW that are equipped with readily accessible manual on/off controls.

8.7 Air handlers supplying 5 m^3/s or more of air should have an optimum start control. The control algorithm should at least take into account the difference between the temperature of the space and its setpoint and the length of time prior to the scheduled occupancy.

8.8 Zones that are intended to operate or be occupied non-simultaneously should be grouped into isolation areas, with each isolation area not exceeding 2300 m^2 of floor area or one floor provided that:

a) Central systems and plants serving these zones are provided with controls and devices that enable a stable system and equipment operation for any length of time while serving only the smallest isolation area; and

b) The systems serving each isolation area, besides meeting the requirements of 8.5 for automatic shutdown, are also equipped with isolation devices and controls that can isolate them from the supply of outdoor air and the exhaust system.

8.9 The following are exempted from isolation devices and controls requirements given in 8.8(b):

a) Exhaust air and outdoor air connections to isolation zones when the fan system to which they are connected is 2.4 m^3/s and smaller;

b) Exhaust airflow from a single isolation zone of less than 10% of the design airflow of the exhaust system to which they connect; and

c) Zone intended to operate continuously or intended to be operated only when all other zones are inoperative.

8.10 The dampers used in all outdoor supply air and exhaust systems serving air-conditioned spaces should shutoff automatically when the spaces are not in use.

8.11 During the pre-occupancy building cool-down, the outdoor air dampers should shutoff automatically.

8.12 The air dampers shall have a maximum leakage rate of 100 $l/s/m^2$ damper area at 250 Pa.

8.13 Fans with motors greater than 0.5 kW used in the systems should have automatic controls, which comply with 8.5, to shut them off when their services are not required.

8.14 Systems with design outdoor air intake greater than 1.4 m^3/s serving areas with an average design occupancy density exceeding 1 person/m^2 shall include means to automatically reduce outdoor air intake below the design rate, when spaces are partially occupied. Ventilation controls shall be in compliance with SS 554.

8.15 Control of indoor thermal environment by reheating the air shall not be allowed except for energy source from site-recovered energy (including condenser heat) or site-solar energy.

8.16 A minimum of one of the following control technologies shall be required in hotel guest rooms with over 50 guest rooms such that all the power to the lights and switched outlets in a hotel guest room would be turned off when the occupant is not in the room and the space temperature would automatically set up by no less than 3 °C:

a) Controls that are activated by the room occupant via the primary room access method-key, card, deadbolt;

b) Occupancy sensor controls that are activated by the occupant's presence in the room.

9 Air handling units

9.1.1 Air handlers should be equipped with control devices that are appropriate for the intended control of indoor thermal environment.

9.1.2 Finned coils used in an air handler should not be more than 8-row deep. When more number of rows are required in the air treatment process, more than one cooling coil can be used, each separated by a distance sufficient for cleaning.

9.1.3 The condensate from the cooling coil shall be provided with a U-bend on leaving the air handler and there should be an air break between the condensate drain pipe and the floor trap.

9.1.4 An air handler should be constructed and installed such that the condensate from the cooling coil can be completely drained after the fan is switched off.

9.1.5 No chilled water should continue to be supplied to the cooling coil after the fan is switched off.

9.1.6 The inner surfaces of air-handling units shall be easy to clean and abrasion resistant.

9.1.7 Air-handling unit rooms shall not be used for storage and shall not house installations not associated with the air-conditioning system.

9.1.8 Design and operations of air handling units associated with fire safety requirements shall comply with the requirements of the Code of Practice for Fire Precautions in Buildings.

9.2 Fan system design criteria

9.2.1 Air-conditioning systems having a total fan system power exceeding 4 kW shall comply with 9.2.1.1.

9.2.1.1 Fan power limitations

The ratio of the fan system power to the supply fan air flow rate (main fan) of each air-conditioning system at design conditions shall not exceed the allowable fan system power shown in Table 2.

Table 2 – Fan power limitation in air-conditioning systems

Allowable nameplate motor power	
Constant volume	**Variable volume**
1.7 kW/m³/s	2.4 kW/m³/s

9.2.2 Variable air volume fan control

Variable air volume (VAV) fan control, including systems using series fan power boxes shall comply with 9.2.2.1, 9.2.2.2 and 9.2.2.3.

9.2.2.1 Part load fan power limitation

Individual VAV fans with motors 11 kW and larger shall meet one of the following requirements:

a) Be driven by a mechanical or electrical variable speed drive or the fan shall be a vane-axial fan with variable pitch blades;

b) Have other controls and devices for the fan that will result in fan motor demand of less than 30% of design wattage at 50% of design air volume when static pressure setpoint equals one-third of the total design static pressure based on manufacturer's certified fan data.

9.2.2.2 Static pressure sensor location

Except for systems with zone reset control complying with 9.2.2.3, static pressure sensors used to control variable air volume fans shall be placed in a position such that the controller setpoint is no greater than one-third the total design fan static pressure. If this results in the sensor being located downstream of major duct splits, multiple sensors shall be installed in each major branch to ensure that static pressure can be maintained in each.

9.2.2.3 Setpoint reset

For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure setpoint shall be reset based on the zone requiring the most pressure, for e.g. the setpoint is reset lower until one zone damper is nearly wide open.

10 Plants

10.1 Equipment used in air-conditioning and ventilation shall have minimum performance in accordance with Singapore Standard SS 530.

10.2 The design of the chilled water system should ensure that the chillers will be able to operate properly over the full range of cooling demand that can be expected and supply chilled water to the building at the required temperature. The surging or frequent starting and stopping of the compressors should be avoided.

10.3 The refrigerant used in chillers should be non-CFC.

10.4 The safety requirements on the use of refrigerant in a plant room can be referred to in ASHRAE Standard 15.

10.5 Pumping system design criteria

10.5.1 Hydronic System Design and Control

Air-conditioning hydronic systems having a total pump system power exceeding 7.5 kW shall comply with 10.5.1.1, 10.5.1.2, 10.5.1.3 and 10.5.1.4.

10.5.1.1 Hydronic Variable Flow Systems

The pump power limitation for chilled water systems shall be 349 kW/m^3/s. The pump power limitation for condensing water systems is 301 kW/m^3/s.

Motors exceeding 15 kW shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

10.5.1.2 Pump isolation

When a chilled water plant includes more than one chiller, provisions shall be made so that the flow in the chiller plant can be automatically reduced correspondingly, when a chiller is shut down. Chillers referred to in this clause when connected in series for the purpose of increased temperature differential shall be considered as one chiller.

10.5.1.3 Chilled water temperature reset controls

Chilled water systems with design capacity exceeding 88 kW supplying chilled water to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature.

10.5.1.4 The following systems are exempted from the requirements given in 10.5.1.3.

a) Where the supply temperature reset controls cannot be implemented without causing improper operation of cooling, dehumidifying systems; and

b) Hydronic systems such as those that use variable flow to reduce pumping energy.

10.6 Hot gas by-pass limitation

Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as in Table 3 with the exception of unitary packaged systems with cooling capacities not greater than 26.4 kW.

Table 3 – Hot gas by-pass limitation

Rated capacity	Maximum hot gas bypass capacity (% total capacity)
≤ 70 kW	50%
> 70 kW	25%

11 Noise and vibration

Noise and vibration in mechanical ventilation and air-conditioning systems arise from mechanical and electrical equipment, and from the flow of water through pipes and the flow of air through ducts and grilles. Table 4 gives the recommended design criteria (for guidance only) to assist designers in providing acoustical environment within occupied spaces in buildings compatible with the activities and areas mentioned, and is intended for use in the selection of the air-conditioning and ventilation plant and equipment to be used in these spaces.

Table 4 – Recommended ambient sound level

Area	Low dBA	Average dBA	High dBA
Cinemas, Theatres	-	35	40
Private executive type offices	35	40	45
General offices, other private or semi-private offices	40	45	50
Conference rooms	35	40	45
Air-conditioned classrooms	40	45	50
Hotel bedrooms	35	40	45
Places of public resort e.g. shops	40	50	55
Circulation areas e.g. staircases, lobbies, car parks	50	55	60

12 Energy recovery

12.1 Energy recovery from conditioned space exhaust air

Exhaust air of 2.5 m^3/s or greater from conditioned space in a single location shall have energy recovery system with at least 60% recovery effectiveness. 60% recovery effectiveness shall mean a change of enthalpy of the outdoor air supply equal to 60% of the difference between the outdoor air and return air at design conditions when tested under ARI Standard 1060.

12.1.1 The following systems are exempted from the energy recovery requirements given in 12.1:

a) Laboratory systems;

b) Systems exhausting toxic, flammable, paint or corrosive fumes and dust;

12.2 Exhaust hoods

12.2.1 Kitchen hoods

Individual kitchen exhaust hoods larger than 2.5 m^3/s shall be provided with makeup air sized at least 50% of exhaust air volume that has not been cooled mechanically except when exhaust ventilation air that would have otherwise exfiltrated or been exhausted by other fan systems.

12.2.2 Fume hoods

Buildings with fume hood systems having a total exhaust rate greater than 7.5 m^3/s shall include at least one of the following features:

a) Variable air volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50% or less of design values.

b) Direct makeup air supply equal to at least 75% of the exhaust rate that is cooled to no lower than 2 °C above room setpoint and that no re-heating for this air supply.

c) Heat recovery systems to precondition makeup air from fume hoods exhaust in accordance with 12.1.

Section Three – Mechanical ventilation system

13 Ventilation rates

13.1 Design considerations

The purpose of providing ventilation to a room or occupied space within a building is to remove heat from the space and also possible contaminants, such as the products of respiration, bacteria, odours, product of combustion etc, so that an acceptable indoor air quality can be maintained. The air from the space should be continuously withdrawn and replaced by outdoor air drawn from external sources.

13.2 General requirements

13.2.1 All rooms and occupied spaces which are not naturally ventilated or air-conditioned shall be clearly designated in the architectural drawings to be mechanically ventilated.

13.2.2 There shall be no smoking in mechanically ventilated spaces, except in designated areas.

13.3 Outdoor air supply

13.3.1 The quantity of outdoor air supply for mechanical ventilation for any room or floor space in a building shall be based on its volume and determined according to the rates given in Table 5.

13.3.2 The rates of ventilation given in Table 5 apply to normal types of buildings with normal heat gains from occupants and activities. When abnormal conditions prevail, the ventilation rate may be increased to prevent undue concentration of body odours, bacteria-carrying particles, gas, vapour or dust and to prevent undue accumulation of carbon dioxide and to remove products of combustion.

13.3.3 A refrigeration machinery room under normal operation should be ventilated when occupied with a least 2.5 litres per second of air per square metre of machine room area.

13.3.4 If necessary for operator comfort, the ventilation rate should be such that the heat-producing machinery in the room does not raise the temperature beyond 5 °C above the ambient.

13.3.5 For any type of room or floor space not specified in this section, the ventilation rate shall be determined by the qualified person subject to the approval of the relevant authority.

Table 5 – Outdoor air supply for mechanical ventilation in non air-conditioned buildings or parts of buildings with no natural ventilation

Type of building/ Occupancy	Minimum outdoor air supply air-change/h
Offices	6
Restaurants, canteens	10
Shops	6
Workshops, factories	6
Classrooms	8
(i) Car parks	6
(ii) Toilets, bathrooms	10
(iii) Lobbies , concourse, corridors, staircases and exits	4
Kitchens (commercial, institutional and industrial)	(iv) 20

NOTE:

i) Where the ceiling height exceeds 2.5 m, the air change rate will be calculated based on 2.5 m ceiling height.

ii) For heavily used public toilets, refer to "*Code of Practice on Environmental Health*", National Environment Agency

iii) Lobbies of area of 10 m^2 or less are exempted from being mechanically ventilated

iv) The air supply may be reduced to 10 air-change/h when the kitchen hood exhaust system is not in operation.

14 Fan systems

14.1 Car parks

It is required to ventilate the car parking areas in a building in order to remove carbon monoxide and other combustion products from the areas.

14.1.1 Except where natural ventilation is available as described in 14.1.7, a mechanical ventilation system incorporating a supply part and an exhaust part, and capable of providing six air changes per hour is required for car parking areas in a building.

14.1.2 The mechanical ventilation system in commercial carparks may be operated at a lower rate at times of low occupancy subject to the condition that the carbon monoxide concentration is maintained below the permitted level of approximately 25 ppm averaged over a one-hour period.

14.1.3 The mechanical ventilation system in residential car parking areas may be switched off if the carbon monoxide concentration is below 25 ppm averaged over an hour period.

14.1.4 For the exhaust part of the ventilation system, at least 50% of the exhaust air shall be extracted at low level not exceeding 650 mm above the finished floor, as measured from the top of the grille to the finished floor.

14.1.5 The supply air shall be drawn directly from the exterior and its intake shall not be less than 5m from any exhaust discharge openings. Outlets for the supply air shall be adequately distributed over the car park area.

14.1.6 The discharge points of the exhaust ventilation system:

a) Shall be arranged to discharge directly to the exterior and shall not be less than 5 m away from any intake openings, doorways or apertures to prevent the re-entry of objectionable odours or flammable vapour into the premises; and

b) Shall not face or discharge in the direction of any adjacent residential building.

14.1.7 Aboveground car park

14.1.7.1 For aboveground car park, no mechanical ventilation is required for any part of the car park where natural ventilation opening of not less than 15% of the floor area served is provided. The naturally ventilated part of the car park shall be within 12 m from the ventilation opening except where cross-ventilation is provided.

When smoke purging system for aboveground car parks is required, it shall comply with the requirements of the Code of Practice for Fire Precautions in Buildings.

14.1.7.2 For aboveground car park without cross ventilation, where additional natural ventilation opening of not less than 15% of the areas beyond 12 m of the opening is provided, a reduced mechanical ventilation system in the form of fume extract may be provided to these areas as follows:

a) The extract system shall be able to provide 1.2 air changes per hour;

b) The supply part can be omitted; and

c) The extract points shall be wholly located at low level not exceeding 650 mm above the finished floor, as measured from the top of the grille to the finished floor.

14.1.7.3 Where natural ventilation opening equivalent to not less than 2% of the mechanically ventilated area is provided, the supply part may be omitted.

14.1.7.4 In a large car park, a combination of natural and mechanical ventilation may be provided as illustrated in Table 6.

Table 6 – Mode of ventilation for aboveground car park

Size of ventilation opening (% of floor area)	Mode of ventilation to be provided (Natural 'NV', Mechanical 'MV', or fume extract)	
	Zone 'A'	Zone 'B'
15% of A + 15% of B	NV	Fume extract
15% of A + 2% of B	NV	MV without supply
15% of A	NV	MV
2% of A + 2% of B	MV without supply	MV without supply
2% of A	MV without supply	MV

Zone 'A' refers to part of car park within 12 m of natural ventilation opening
Zone 'B' refers to part of car park beyond 12 m of natural ventilation opening

14.1.8 Basement car park

14.1.8.1 For basement car park, the mechanical ventilation system shall be designed in such a way that the quantity of replacement air shall not exceed that of the exhaust air. This requirement is necessary so that the car park can be maintained under negative pressure at all times to prevent the spread of noxious gases into adjacent occupied areas. In addition, the system shall be so designed that it can be operated in two or more sections conforming to the following requirements:

a) The capacity of each section shall be such that in the event of breakdown the remaining sections should at least be able to provide half the total required air for the storey;

b) The sections may operate through a common duct work;

c) Each section of the ventilation system shall be so controlled that in the event of failure of one section, the other shall continue to operate;

d) The exhaust and supply parts of each section shall be electrically interlocked such that failure of any section of the exhaust part shall automatically shut-down the corresponding section of the supply part;

e) the exhaust and supply parts shall be such that they can continue to run automatically in the event of a failure in the principal source of electrical supply.

14.1.8.2 For basement car park exceeding one level, the supply and exhaust parts shall be designed in such a way as to minimise intermixing of air between the different levels.

14.1.8.3 For car park located on the first basement level where some degree of natural ventilation is available, the mechanical ventilation requirements as specified in 14.1.7.1 may be modified as follows:

a) Where natural ventilation opening equivalent to not less than 2% of the mechanically ventilated area is provided, the supply part may be omitted;

b) Where the natural ventilation opening provided is not less than 15% of the car park area served, a reduced mechanical ventilation system in the form of fume extract as described in 14.1.7.2 may be provided.

14.1.8.4 In a large basement car park, a combination of different modes of mechanical ventilation may be provided as shown in Table 7

Table 7 – Mode of ventilation for basement car park

Size of ventilation opening (% of floor area)	Mode of ventilation to be provided (Mechanical 'MV' or fume extract)	
	Zone 'A'	Zone 'B'
15% of A + 15% of B	Fume Extract	Fume extract
15% of A + 2% of B	Fume Extract	MV without supply
15% of A	Fume Extract	MV
2% of A + 2% of B	MV without supply	MV without supply
2% of A	MV without supply	MV

Zone 'A' refers to part of car park within 12 m of natural ventilation opening
Zone 'B' refers to part of car park beyond 12 m of natural ventilation opening

14.1.9 Smoke purging systems for basement car parks

Smoke purging systems for basement car parks shall comply with the requirements of the Code of Practice for Fire Precautions in Buildings.

14.1.10 Where cars are parked and retrieved with the engines off, the ventilation requirement shall be determined by the relevant authority.

14.2 Fan systems fan power limitations

Mechanical ventilation systems having a total fan system power exceeding 4 kW shall comply with requirements given in 14.2.1 and 14.2.2.

14.2.1 Fan power limitations

The ratio of the fan system power to the supply fan air flow rate (main fan) of each air-conditioning system at design conditions shall not exceed the allowable fan system power shown in Table 8.

Table 8 – Fan power limitation in mechanical ventilation systems

Allowable nameplate motor power	
Constant volume	**Variable volume**
1.7 $kW/m^3/s$	2.4 $kW/m^3/s$

14.2.2 Variable air volume (VAV) fan control

Variable air volume fan control shall comply with 14.2.2.1.

14.2.2.1 Part load fan power limitation

Individual VAV fans with motors 11 kW and larger shall meet one of the following requirements:

a) Be driven by a mechanical or electrical variable speed drive or the fan shall be a vane-axial fan with variable pitch blades;

b) Have other controls and devices for the fan that will result in fan motor demand of less than 30% of design wattage at 50% of design air volume when static pressure setpoint equals one-third of the total design static pressure based on manufacturer's certified fan data.

14.3 Kitchens

14.3.1 Mechanically ventilated kitchens shall be designed for a ventilation rate of not less than 20 air-changes per hour as given in Table 5. When kitchen hoods are in operation, the exhaust air through the hoods can be considered as contributing to the exhaust requirement for ventilation.

14.3.2 Kitchen exhaust

Exhausts from hoods designed to capture smoke and/or grease-laden vapour produced by a cooking process, incorporated with listed grease-removal devices and fire-suppression equipment shall be directed away from roofs and building surfaces. Exhaust discharge shall not impinge on obstacles such as parapets, overhangs and other equipment and higher parts of buildings.

14.3.3 Mechanical exhaust system for the cooking area of a kitchen in a hotel, restaurant, coffee house or the like shall be independent of those serving other parts of the building.

14.3.4 Sufficient make-up air shall be provided and negative pressure in the kitchen area shall be maintained when the kitchen hood is in operation. Whether or not the kitchen hood is in operation, the kitchen shall be provided with ventilation in accordance with Table 5.

14.3.5 Kitchen-exhaust hoods shall be installed above appliances of heating capacity greater than 8 kW and likely to generate grease vapour (e.g. ranges, fryers, barbecues). Where grease is present, kitchen hoods incorporating grease filters shall be used.

14.3.6 For appliances requiring a kitchen exhaust hood, the exhaust flow rate Q [m^3/s] shall not be less than that given in the following formula, if it is an "island" hood:

$$Q = 1.4V \times 2(L + W)H \times F$$

where:

V	=	Capture velocity which shall not be less than 0.30 m/s for commercial type kitchens
L	=	Length of cooking surface, m
W	=	Width of cooking surface, m
H	=	Distance of hood to emitting surface, m
F	=	1.0 for heavy duty high temperature, grease burning, deep-fat frying cooking with equipment such as woks, broilers, char-broilers normally associated with solid or gas fuel burning equipment
F	=	0.7 for light duty, medium and low temperature cooking with equipment such as ovens, steamers, ranges, griddles and fryers

For wall-mounted hoods, it can be considered as part of an island type hood composed of actual hood and its mirror image in the wall. Thus the above formula can also be applied and corrected.

14.3.7 Design considerations

14.3.7.1 The hood and ducts for the exhaust shall have a clearance of 500 mm from unprotected combustible materials.

14.3.7.2 The exhaust shall be discharged directly to the exterior and away from the habitable areas of the building. It shall not be less than 5 m from any air intake openings.

14.3.7.3 Where the exhaust duct runs outside the kitchen it shall either be enclosed in a structure or be constructed to give at least the same fire rating as the kitchen or that of the room through which it traverses, whichever is higher. The rating shall apply to fire exposure from both the internal and external part of the duct or structure. Where the duct riser is required to be enclosed in a masonry shaft, it shall be compartmentalised from the rest of the shaft space containing other ducts or services installations.

14.3.7.4 Fire damper shall not be fitted in kitchen exhaust ducts.

14.3.8 Ducts

14.3.8.1 Kitchen-exhaust ducts and shafts shall be sized and installed for the flow rate of air necessary to remove the effluent.

14.3.8.2 Ducts forming part of a kitchen exhaust system shall be manufactured from:

a) Mild steel of thickness not less than 1.2 mm, or

b) Stainless steel of thickness not less than 0.9 mm, or

c) Other approved materials.

14.3.8.3 Ducts shall be installed with a fall in the direction of flow of not less than 0.5%. To enable cleaning of all the ductwork, openings large enough shall be provided at suitable intervals and locations, and/or appropriate cleaning apparatus/systems shall be incorporated. A drain shall be provided at the lowest point of each run of ducting.

14.3.9 Exhaust hoods

14.3.9.1 Exhaust air flow shall be suitably distributed over the exhaust hood to capture the cooking vapour emission under still air conditions, which will be considered as room air motion not exceeding 0.15 m/s velocity.

14.3.9.2 Kitchen exhaust hoods shall be manufactured from rigid impervious hard-faced and non-combustible materials, such as mild steel, stainless steel or aluminium.

14.3.9.3 The seams shall be made liquid-tight seams and the joints made by fusion welding, lapping, riveting, soldering; or other approved methods.

14.3.9.4 Hoods shall be fitted with washable grease filters mounted in frames in positions enabling convenient removal and replacement, and installed so as to prevent significant leakage of air around the filters.

14.3.9.5 All internal surfaces of hoods shall be vertical or sloped at an angle not greater than 40° from vertical. The faces of filters shall be vertical or sloped at an angle not greater than 30° from vertical.

14.3.9.6 It should be possible to assess the pressure drop of the ventilation air as it flows across the grease filter.

14.3.9.7 Gutters shall be located beneath any protruding surface or edges such as lower edges of filters, except light fittings inside hoods. Internal gutters not greater than 50 mm or less than 35 mm wide and not less than 10 mm deep shall be located around the lower edges of hoods. Plugged drainage holes shall be provided at intervals not greater than 6 m along the gutter.

14.3.9.8 Canopy type hoods

The lower edges of canopy type exhaust hoods shall be not higher than 1.2 m above the cooking surface nor lower than 2 m above floor level; and extend not less than 150 mm outside the plan perimeter of the appliance over which the hood is installed.

14.4 Bathrooms, toilets and locker rooms

When a bathroom, toilet, locker room or similar facility is not provided with natural ventilation, it shall be mechanically ventilated as follows:

a) Air shall be supplied through a ventilation duct directly from the outdoor or from a permanently air-conditioned or naturally ventilated room through louvers in the doors or undercutting the doors or by other openings;

b) The exhaust system shall dispel the vitiated air directly to the outdoors; and

c) The quantity of replacement air shall not exceed that of exhaust air.

14.5 Exit facilities

Design and operation of mechanical ventilation systems for exit facilities shall comply with requirements of the Code of Practice for Fire Precautions in Buildings.

14.5.1 Exits staircase and internal exit passageway

The ventilation system for exits staircase and internal exit passageway shall comply with the following:

a) Mechanical ventilation systems for exit staircase and internal exit passageway shall provide ventilation at the rate of four air-changes per hour.

b) Supply air shall be drawn directly from the exterior with intake point not less than 5m from any exhaust discharge or openings for natural ventilation

14.5.2 Smoke-stop and fire fighting lobbies

The ventilation system for smoke-stop and fire fighting lobbies shall comply with the following:

a) The ventilation system shall function in supply mode only and it shall provide ventilation at the rate of four air-changes per hour. Upon activation by the building fire alarm system it shall supply at not less than ten air changes per hour

b) Supply air shall be drawn directly from the exterior with intake point not less than 5m from any exhaust discharge or openings for natural ventilation.

14.6 Ventilation systems for fire command centres, engine driven pump room, generator room, and spaces involving use of flammable and explosive substances

Design and operation of mechanical ventilation systems for fire command centres, engine driven pump room, generator room, and spaces involving use of flammable and explosive substances shall comply with requirements of the Code of Practice for Fire Precautions in Buildings.

14.7 Pressurisation systems

Design and operation of pressurisation systems for exit facilities shall comply with the requirements of the Code of Practice for Fire Precautions in Buildings.

14.8 Mechanical smoke control systems for basement occupancies (other than car parking areas)

Design and operation of mechanical smoke control systems for basement occupancies other than car parking areas shall comply with the requirements of the Code of Practice for Fire Precautions in Buildings.

Section Four – Auxiliary equipment

15 Ductwork and other air passages

This section applies to the design, construction and installation of the air duct system including fittings and accessories for mechanical ventilation or air-conditioning.

Design requirements to minimise the spread of fire and smoke via the system throughout the building in the event of a fire shall comply with the requirements in the Code of Practice for Fire Precautions in Buildings.

15.1 Design considerations

15.1.1 In designing the ductwork for an air distribution system, consideration should be given to the air velocities in ducts, choice of materials and construction of the ducts, etc.

15.1.2 Ventilation ducts should not pass through smoke-stop or fire fighting lobbies. Where unavoidable, the requirements of the Code of Practice for Fire Precautions in Buildings shall be complied with.

15.1.3 A concealed space between the ceiling and floor above it, ceiling and roof, or raised floor and structural floor of a building may be used as a plenum provided that:

a) The concealed space is free of obstructions, so as to permit free flow of air;

b) The concealed space contains only materials and services in compliance with the Code of Practice for Fire Precautions in Buildings; and

c) The supports for the ceiling membrane are of non-combustible material.

15.1.4 Air ducts shall be made substantially air tight throughout, and shall have no openings other than those required for proper operation and maintenance of the system. Access openings shall be provided where debris, paper or other combustible materials may accumulate in plenums and ducts. Removable grilles requiring only the loosening of catches or screws for removal may be considered as access openings.

15.1.5 Locations of intakes and return air openings

15.1.5.1 The location of outdoor air intakes for air-handling systems shall take due account of any other intake openings for ventilation or exhaust. The intakes of outdoor air to all air-conditioning and mechanical ventilation systems, including those for the ventilation and pressurisation of stairshafts, shall be located at external walls or at roof level, arranged so as to pick up outdoor air free of contamination or odours.

15.1.5.2 Openings for the intakes of outdoor air to all air handling systems, mechanical ventilation systems, pressurisation systems of exit staircases and internal corridors, and smoke control systems shall be no less than 5m from any exhaust discharge openings.

15.1.5.3 Outdoor air intakes shall not be within 5 m of exhaust discharges from any buildings, kitchens, toilets, car parks, cooling towers, laundries, rubbish dumps or plant rooms. The distance from an air intake to a cooling tower is measured from the base of the cooling tower.

15.1.5.4 Outdoor air intakes shall be covered with an insect screen and protected from rain entrainment. Screening shall be of corrosion resistant material not larger than 10 mm mesh.

15.1.5.5 Outdoor air intakes should be protected from the water droplets emitted by cooling towers, such that no water droplet can enter the ventilation air stream.

15.1.5.6 All return air openings and outdoor air intakes shall be so located and arranged that sources of ignition such as lighted matches and cigarette butts accidentally entering the openings and intakes shall not be deposited onto the filter media.

15.1.5.7 For air-conditioned spaces, the bottom of the outdoor air intakes shall not be less than 2.1 m above the outside floor level, when the air intakes are adjacent to car parks or busy thorough fares.

15.1.6 Exhaust ducts from toilets and domestic kitchens shall not be connected to duct systems serving other areas except at the inlet of the exhaust fan. Where such connection is made, devices shall be installed to prevent the circulation of exhaust air through the dwelling units when the fan is not operating. Exhaust ducts for industrial or commercial kitchens shall be of a separate system.

15.1.7 Exhaust ducts shall discharge directly to the outdoors. When exhaust are adjacent to pedestrians thoroughfare, the location of the exhaust air discharge shall not be less than 2.1 m above the outside floor level

15.1.8 Ducts shall not be located where they will be subject to damage or rupture. Where so located they shall be suitably protected.

15.1.9 Return air ducts should be routed away from toilets or places where odours are expected and may recirculate into the supply air stream.

15.2 Construction

15.2.1 The inner surfaces of the ducts for supply and return air should be smooth and resistant to abrasion to reduce dust accumulation.

15.2.2 Where ceiling space is used as a return air plenum, the ceiling and the side-walls should be properly plastered and painted. Masonry ducts should be finished in a similar manner where possible.

15.2.3 Rigid ducts shall be manufactured from steel, aluminium, glass-fibre batt or mineral wool or other approved materials. Ducts or duct linings where glass fibre batt or mineral wool is exposed to the air stream shall be suitably protected to prevent erosion of fibres.

15.2.4 Ducts shall be sturdily supported. Hangers and brackets for supporting ducts shall be of metal.

15.2.5 Duct covering, duct lining and flexible connection materials should be non-combustible. However, if it is necessary to use combustible material it shall comply with the following requirements:

a) When tested in accordance with the methods specified in the Code of Practice for Fire Precautions in Buildings, it should have a surface flame spread rating of not lower than Class 1. But in areas of the building where Class 0 flame spread rating is required for the ceiling construction under the said code, a Class 0 rating for the covering and lining materials shall be required; and

b) When involved in a fire, it should only generate a minimum amount of smoke and toxic gases.

15.2.6 Flexible connections at the extremity of ventilation ductwork connecting terminal units, extract units and ventilation grilles shall not exceed 2 m.

15.2.7 Flexible joints, which are normally provided to prevent and/or allow for thermal movements in the duct system, shall not exceed 250 mm in length.

15.2.8 Flexible joints shall be made of material classified as 'not easily ignitable' when tested under British Standard BS 476 : Part 5.

15.2.9 Ducts shall be installed with openings at suitable intervals and locations to enable cleaning of all the ducts.

15.2.10 The construction and support of air ducts, fittings and plenums, including joints, seams, stiffening, reinforcing and access openings shall conform to the appropriate requirements of the duct construction standards contained in ASHRAE Handbook, IHVE guide books or SMACNA Manuals.

15.2.11 Ducts and plenum sealing

Ductwork and plenums shall be sealed in accordance to Table 9 so as to meet the requirements of duct leakage test in 15.2.11.1.

Table 9 – Ductwork seal requirements

Duct location	Duct type		
	Supply	**Exhaust**	**Return**
Outdoor	A	C	A
Unconditioned space	A	B	A
Conditioned space	A	B	A

where :

A: All transverse joints, longitudinal seams and penetrations in duct wall. Pressure sensitive tape shall not be used as primary sealant.

B: All transverse joints and longitudinal seams. Pressure sensitive tape shall not be used as primary sealant.

C: Transverse joints only.

Longitudinal seams are joints in the direction of the airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow direction. Penetrations in duct walls are any openings made by screws, pipe, rod or wire.

15.2.11.1 Duct leakage test

Ductwork designed to operate at static pressures in excess of 750 Pa shall be leak tested in accordance with industry accepted test procedures. Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. Duct systems with pressure ratings in excess of 750 Pa shall be identified on the drawings. The maximum permitted duct leakage shall be in accordance to the formula:

$$L_{max} = C_L\,(P^{0.65}/1000)$$

where:

L_{max} = maximum permitted leakage in l/s·m^2 duct surface area

C_L = duct leakage class, ml/s.m^2 at 1 Pa

C_L = 8 for rectangular sheetmetal, rectangular fibrous, and round flexible ducts

C_L = 4 for round/flat oval sheetmetal or fibrous glass ducts

P = test pressure, which shall be equal to the design duct pressure rating, Pa

15.2.11.2 Tapes and sealants used for sealing joints in air ducts, plenums and other parts of air ducts systems shall be subject to the approval of the relevant authority.

15.3 Fire dampers

15.3.1 Fire damper shall have a fire resisting rating of not less than that required for the compartment wall or compartment floor through which the relevant section of the ventilation duct passes in accordance with the requirements of the Code of Practice for Fire Precautions in Buildings.

16 Pipework

This section applies to the design and installation of the piping system for air-conditioning installation.

16.1 Design considerations

16.1.1 In designing and planning the layout of the pipework, due attention should be given to the choice of material, rate of flow, accessibility, protection against damage, corrosion, avoidance of airlocks, water hammers, noise transmission, unsightly arrangement, vibration and expansion of fluid, stress and strains, etc.

16.1.2 The use of protected shafts for the passage of pipes between compartments, and the protection of openings permitted in compartment walls and compartment floors for the passage of pipes shall be in accordance with the requirements of the Code of Practice for Fire Precautions in Buildings.

16.1.3 Every pipe used shall be designed to have adequate strength and durability. Pipes shall be adequately supported. Hangers and brackets for supporting pipes shall be of metal.

16.1.4 Pipes shall not be located where they may be subject to damage or rupture. Where so located, they shall be suitably protected.

16.2 Installation

16.2.1 Materials for piping and associated fittings shall be suitable for the intended service.

16.2.2 Sufficient unions or flanged fittings and valves shall be provided for disconnecting equipment, controls, etc.

16.2.3 Standard fittings such as tees, elbows, etc, shall be used; fittings fabricated by welding together segmented pieces are not recommended.

16.2.4 The construction and support of pipes, fittings and valves shall conform to the applicable requirements of the pipe construction standards contained in the ASHRAE Handbook, IHVE Guidebooks or other recognised Piping Handbooks.

16.2.5 All installed pipework which is intended to contain/convey pressurised fluid shall be pressure tested.

16.2.6 Thermal insulation for pipework associated with air-conditioning and mechanical ventilation system shall comply with the following requirements:

a) Thermal insulation material for pipework together with vapour barrier lining and adhesives shall, when tested in accordance with the methods of specified in the Code of Practice for Fire Precautions in Buildings, have a surface flame spread of not lower than Class 1 but in areas of buildings where Class 0 flame spread is required for the ceiling construction under this said code, a Class 0 rating for the insulation material shall be required; and

b) Notwithstanding the requirements of 16.2.6(a), the use of plastic and foam rubber insulation materials of a lower classification may be permitted if:

   i) the material is the self-extinguishing type to the satisfaction of the relevant authority; or

   ii) the insulation material is covered by or encased in a metal sheath or hybrid plaster or other non-combustible cladding materials acceptable to the relevant authority;

   provided that any opening in the element of structure or other parts of the building penetrated by the pipework shall be effectively fire-stopped by replacement of the insulation material at the junction of penetration with fire resistant materials having an equal fire rating. Fire rated proprietary pipework system may be used if it is tested in the manner acceptable to the relevant authority.

16.2.7 Identification of pipeline, if required, shall be in accordance with the colour codes in Annex C.

17 Thermal insulation

17.1 General requirements

Thermal insulation shall be installed in accordance with industry accepted standards.

Thermal insulation shall be protected from damage including that due to sunlight, moisture, equipment maintenance and wind, in accordance with the following:

a) Insulation exposed to weather shall be suitable for outdoor service, protected by aluminium sheet metal. Cellular foam, where permitted under Code of Practice for Fire Precautions in Buildings, shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material; and

b) Insulation covering chilled water piping, refrigerant suction piping or cooling ducts located outside the conditioned space shall be sealed against vapour and located outside the insulation (unless the insulation is inherently vapour retardant), all penetrations and joints in the vapour seal shall be sealed.

17.2 Duct and plenum insulation

All supply and return ducts and plenums, installed as part of a conditioned air distribution system shall be thermally insulated in accordance with Table 10.

Table 10 – Minimum duct insulation R-values for cooling only supply ducts and return ducts

Duct location	R-value (m^2K/W)*
Exterior	1.06
Ventilated attic	1.41
Unvented attic above insulated ceiling	1.77
Unvented attic with roof insulation	1.06
Unconditioned space	1.06
Buried	1.06
Indirectly conditioned space	None

* NOTE:
Insulation R-values (m^2K/W) are for insulation installed and do not include film resistance. The required minimum thickness does not consider water vapour transmission and possible surface condensation

17.2.1 The following are exempted from requirements given in 17.2

a) Factory installed plenums, casings, or ductwork furnished as part of air-conditioning equipment tested and rated in accordance with the relevant standards;

b) Ducts or plenums located in conditioned space;

c) Connections less than 3 m in length to air terminals or air outlets, for which the rated insulation thickness need not exceed 0.6 m^2K/W; and

d) Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas exceeding 0.5 m^2, for which the insulation need not exceed 0.4 m^2K/W, and those 0.5 m^2 or less need not be insulated.

17.3 Piping insulation

Piping shall be thermally insulated in accordance with Table 11. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:

$$T = r[(1 + t/r)^{K/k} - 1]$$

where:

T = minimum insulation thickness, mm.

r = actual outside radius of pipe, mm.

t = insulation thickness listed in Table 11 for applicable fluid temperature and pipe size

K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature, W/(mK)

k = the upper value of the conductivity range listed in Table 11 for the applicable fluid temperature

17.3.1 The following are exempted from the requirements given in 17.3

a) Factory installed piping within air-conditioning equipment tested and rated in accordance with the relevant standards;

b) Piping that convey fluids having a design operating temperature range between 16 °C to 41 °C, inclusive; and

c) Piping that convey fluids that have not been heated or cooled such that heat gain or heat loss will not increase energy usage.

Table 11 – Minimum pipe insulation thickness for heating and cooling systems *

Fluid design operating temp range (°C)	Insulation conductivity		Nominal pipe or tube size (mm)			
	Conductivity (W/m.K)	Mean rating temp (°C)	<25	25 to <38	38 to <102	102 to 203≤
Heating systems (steam, steam condensate and hot water)						
> 176.7	0.0461 - 0.0490	121.1	76	89	89	114
121.7 - 176.7	0.0418 - 0.0461	93.3	51	76	89	89
93.9 - 121.1	0.0389 - 0.0433	65.6	51	51	63	63
60.6 - 93.3	0.0361 - 0.0418	51.7	38	38	38	51
40.6 - 60.0	0.0317 - 0.0404	37.8	25	25	25	38
Cooling systems (chilled water, brine and refrigerant)						
4.4 - 15.6	0.0317 - 0.0404	37.8	25	25	38	38
< 4.4	0.0317 - 0.0404	37.8	25	38	38	38

* NOTE:

1. These thicknesses are based on energy efficiency considerations only. Issues such as water vapour permeability or surface condensation sometimes require vapour retarders or additional insulation.

2. Considerations should be given to the possibility of condensation at the inside or outside of the duct.

18 Electrical works

18.1 General requirements

All electrical works shall comply with Singapore Standard SS CP 5.

18.2 Design considerations – General power distribution

In planning the electrical distribution system, consideration should be given to a central control of all the fans in the air handling system, such that they can be partially or completely shut down in the event of fire. A central monitoring and control system, when incorporated, can serve the same purpose.

18.3 Installations

Wiring installation in ducts, plenum chambers and concealed spaces, used to transport supply air, return air and outdoor air requires the use of specific metallic types to minimise the products of combustion or flame spread in such areas. The use of metallic systems reduces the products of combustion and fuel contribution during a fire. Where wiring installation penetrates fire compartmented walls, floor and ceiling, the opening shall be sealed with fire-stop material having the same rating as the compartment through which they penetrate.

18.3.1 No wiring system shall be installed in any duct used to transport dust, loose stock or flammable vapours, or for ventilation of commercial type cooking equipment. No wiring system shall be installed in any shaft which contains such ducts.

18.3.2 Wiring in ducts or plenum chambers

Wiring in ducts or plenum chambers shall comply with the following requirements:

a) Wiring systems to be installed in such ducts and plenum chambers shall be of fire-rated cables, aluminium-sheathed cable, or copper-sheathed cable.

b) Flexible metal conduit, rigid metal conduit and enclosed metal trunking are permitted in lengths not exceeding 1 m to connect physically adjustable equipment and devices in these ducts and plenum chambers. The connectors used with flexible metal conduit shall effectively close any opening in the connection.

c) Equipment and devices are permitted within such ducts or plenum chambers only if their functions are needed there.

d) Where equipment or devices are installed in such ducts and plenum chambers and illumination is necessary to facilitate maintenance and repair, totally enclosed type fixtures can be installed in those locations.

18.3.3 Wiring in concealed spaces

Wiring in concealed spaces shall comply with the following requirements:

a) Wiring in concealed spaces, such as spaces above the ceiling, requires the use of fire-rated cable, aluminium-sheathed cable, or copper-sheathed cable.

b) Rigid metal conduit, enclosed metal trunking, flexible metal conduit, liquid-tight flexible metal conduit in lengths not more than 2 m, or metal-clad cables can also be used.

c) Other electric equipment is permitted within the concealed spaces of such structures if the wiring materials, including fixtures, are suitable for the expected ambient temperature to which they will be subjected.

18.3.4 Wiring of integral fan systems

The wiring installation of integral fan systems, which have been specifically designed and constructed for the purpose, and the installation of motors and control equipment in air-handling ducts, where such equipment have been specifically approved and listed by recognised authorities for the particular application, shall be deemed to comply with the requirements of this section.

18.4 Secondary source of power supply

18.4.1 Power supply to essential services

Apart from the supply from normal mains, a secondary source of power supply shall be provided in accordance with the requirements of the Code of Practice for Fire Precautions in Buildings to serve the mechanical ventilation systems and equipment serving the following:

a) Exit staircases and exit passageways;

b) Smoke-stop and fire fighting lobbies;

c) Areas of refuge within the same building;

d) Basement carparks;

e) Fire command centres;

f) Flammable liquid/gas storage rooms,

g) Emergency power generator room and engine driven fire pump room;

h) Carpark smoke purging system; and

i) Powered smoke control systems.

The electrical circuit wiring from the supply source to the utilisation points of such equipment shall be of the fire-resistant type complying with Singapore Standard SS 299, or suitably protected along their entire length within fire-rated ducts, or shafts.

18.4.2 Motor and motor control

18.4.2.1 All motors and their control equipment as well as the associated wiring and accessories shall be suitable for their particular application and for the environment they are exposed to.

18.4.2.2 High Rupturing Capacity Fuses (HRC) or Moulded Case Circuit Breakers (MCCB) with magnetic release shall be installed and capable of:

a) protecting the cable connections to the motor; and

b) carrying the stalled current of the motor for a period of not less than 75% of the period which such a current would cause the motor windings to fail.

18.4.2.3 Any no-volt release mechanism shall be of the automatic resetting type such that on restoration of supply the motor can start automatically.

18.4.2.4 Thermal overload trips shall not be permitted.

18.4.2.5 Magnetic (short circuit) trips are permitted for use in motor circuits of mechanical ventilation systems serving essential services.

18.5 Start-stop control

Start-stop control and visual indication of operation shall be provided in accordance with the requirements of the Code of Practice for Fire Precautions in Buildings in the fire command centre, or in the absence of a fire command centre in the building, at the main fire indicator board, for the mechanical ventilation systems serving the following:

a) Exit staircase pressurisation;

b) Smoke-stop and fire fighting lobbies;

c) Basement carparks;

d) Carpark smoke purging system; and

e) Powered smoke control systems.

Section Five – Operation and maintenance

19 Testing and commissioning

19.1 Upon completion of installation of the system, the equipment of plants/systems are tested to check that they can function according to design. Reference can be made to ASHRAE Guideline 0 and ASHRAE Guideline 1.1.

19.2 The procedure for testing and commissioning would include but not limited to the following:

a) Objects of the tests;

b) Method and duration of the tests;

c) Type and degree of accuracy of instruments to be used;

d) The personnel carrying out the tests;

e) The state of the plant and machinery with special reference to the cleanliness of heat transfer surfaces; and

f) The conditions of outdoor air as representing the required test conditions.

19.3 Performance tests and adjustments

Appropriate sections of the plant shall be run and all necessary adjustments of valves, dampers and controls should be made to fulfil the function for which it has been designed, e.g. room temperature and humidity to be maintained, air quantity to be handled, etc. Reference can be made to an acceptable standard such as ASHRAE Standard 111.

19.4 Tests on site of individual items of plant/system

Besides tests by manufacturers for various equipment or components, the following tests on site should be considered appropriate:

a) Ductwork should be checked for tightness, the absence of vibration and the operation of all movable fittings.

b) Pipework should be hydrostatically tested.

c) Insulation and the associated vapour barrier on ducts and pipes should be checked for their integrity.

d) Air flow rate for each grille should be checked.

e) Fans should be checked for alignment, blade angles, rotational frequency, air flow rate, sound levels and operating pressures.

f) Pumps should be checked for alignment, rotational frequency, flow rate and pressure, and checked to comply with the required capacity.

g) Heat transfer coils and automatic control valves should be checked for water flow, pressure drops, as well as heat transfer on air-side and water-side to meet the required capacity.

h) All control equipment and components should be calibrated and set points adjusted. Time and control sequences should also be tested.

i) Each refrigerant compressor should be tested in accordance with manufacturer's instructions. Each water chilling unit should be checked under design conditions if practicable.

j) All electrical equipment and installation shall be tested in accordance with Singapore Standard SS CP 5.

19.5 Completion requirements

19.5.1 Drawings

Construction documents shall require that within 90 days after the date of system acceptance record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of duct and pipe distribution system including sizes, and the terminal air or water design flow rates.

19.5.2 Manuals

Construction documents shall require that an operating manual and a maintenance manual be provided to the building owner within 90 days after the date of system acceptance. These manuals shall be in accordance with industry accepted standards and shall include, as minimum, the following:

a) Data stating equipment size and selected options for each piece of equipment requiring maintenance.

b) Operation manuals and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

c) Names and addresses of at least one service agency.

d) Air-conditioning control systems maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in programming comments.

e) A complete narrative of how each system is intended to operate, including suggested setpoints.

19.5.3 System balancing

19.5.3.1 General requirements

Construction documents shall require that all air-conditioning systems shall be balanced in accordance with accepted engineering standards. Construction documents shall require that a written balance report be provided to the owner or the designated representative of the building owner for the systems serving zones with a total conditioned area exceeding 460 m^2.

19.5.3.2 Air system balancing

Air systems shall be balanced in a manner to first minimise throttling losses. For fans with fan system power greater than 0.75 kW, fan speed shall be adjusted to meet design flow conditions.

19.5.3.3 Hydronic system balancing

Hydronic systems shall be proportionately balanced in a manner to first minimise throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Pump impeller need not be trimmed nor pump speed adjusted in the following situations:

a) For pump with pump motors of 7.5kW or less.

b) When throttling results in no greater that 5% of the nameplate power draw, or 2.25 kW, whichever is greater, above that required if the impeller was trimmed.

19.6 System commissioning

Air-conditioning control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition. For projects larger than 4600 m^2 conditioned area, detailed instructions for commissioning air-conditioning systems shall be provided by the designer in plans and specifications.

20 Maintenance

Regular and proper maintenance of equipment and systems is necessary to ensure efficient operation and to sustain long usable life.

20.1 General requirements

20.1.1 Competent staff

The staff in charge of maintenance planning and execution should be competent and trained in ACMV.

20.1.2 Documentation

Shop drawings and operation manual of the plant, operation, manufacturers' instructions and maintenance manuals of the equipment and system; and electrical and control schematic diagrams should be made available for the maintenance team to perform its tasks.

20.1.3 Provisions for maintenance operation

There should be provisions during the design stage for:

a) Adequate access for inspection, maintenance and repair of all component parts of the installation;

b) Facilities for emptying the piping services;

c) Reasonable operating space, noting that air handling unit room should not be used for maintenance work; and,

d) 600mm minimum clearance with no obstruction around each air handling unit.

20.1.4 Operating log sheets

Hourly and daily records of operating conditions of all major equipment (e.g. refrigerating compressors, cooling tower) as well as records of all faults, breakdown and repairs shall be maintained, to serve as reference for operation and planned maintenance of the plant and systems.

20.2 Air-conditioning installations

20.2.1 General

Inspect the equipment and systems such as chillers, compressors, condenser coils, chilled and condenser water pumps, water tanks, air handling units, fan coil units, all motors, chemical treatment system and the associated electrical, electronic and mechanical controls, and circuit boards to ensure satisfactory operation of the equipment and systems within designed conditions.

20.2.2 Monthly maintenance

20.2.2.1 Refrigerant compressors

a) Inspect all refrigerant compressors and refrigerant systems including checking of refrigerant and oil levels, refrigerant filters, oil filters, transmission, controls, safety devices, joints, leaks, and suction and discharge pressures.

b) Check starters for abnormalities such as arcing in the starter contactors. Check and adjust tightness of terminals and connections if necessary.

c) Check and adjust all belt tension if applicable. Replace belt if it appears cracked or worn.

d) Lubricate bearings as required.

20.2.2.2 Chiller condenser

a) Check for proper operation of chiller condenser, its associated controls and control circuits.

b) Check for water inlet and outlet temperatures, operating pressure, pressure drop and flow rate.

c) Inspect the condition of joints, stop valves, covers and seals for leaks. Repair or replace if necessary.

d) Perform water treatment as required.

20.2.2.3 Air handling units

a) Check for proper operation of the air handling units, its associated controls and control circuit. Repair or replace if necessary.

b) Check unit casing, air filters and passages around coils for any air leakage. Rectify if necessary.

c) Check and clean condensate drain pan, drain pipe and floor drains. Flush drain pipe with approved chemical or vacuum if necessary.

d) Inspect and adjust all thermostats, safety cut-outs and modulating dampers.

e) Check routine operation of electrical components.

f) Check chilled water pressure drop and clean evaporator coils as required.

g) Check and adjust all belt tension if necessary. Replace belt if it appears cracked or worn.

h) Check and rectify any abnormal running noise and vibration. Replace bearings and anti-vibration rubber and springs if necessary.

i) Check condition of duct insulation. Repair or replace if necessary.

j) Clean or replace filters as required.

k) Check and clean water strainers, if applicable.

l) Check for proper operation of control valves and isolating valves. Rectify if required.

m) Check blower fan and its bearings and housing.

n) Lubricate bearings as required.

20.2.2.4 Fan coil units

a) Check for proper operation of the fan coil units and associated controls. Repair or replace if necessary.

b) Check and clean condensate drain pan, drain pipe and floor drains. Flush drain pipe with approved chemical or vacuum if necessary.

c) Inspect and adjust all thermostats, safety cut-outs and modulating dampers.

d) Check routine operation of electrical components

e) Check and clean evaporator coils.

f) Check and adjust all belt tension if necessary. Replace belt if it appears cracked or worn.

g) Check and rectify any abnormal running noise and vibration. Replace bearings and anti-vibration rubber and springs if necessary.

h) Clean the supply and return air grilles.

i) Clean or replace filters as required.

j) Check and clean water strainers if applicable.

k) Check blower fan and its bearings and housing.

l) Lubricate bearings as required.

20.2.2.5 Pumps

a) Check operating pressures and flow rate to ensure the pump is operating normally.

b) Inspect all water pumps and seals, check for abnormal running noise and vibration. Repair if necessary.

c) Check condition of glands. Replace if necessary.

d) Check for correct alignment of the motor and pump. Rectify if necessary.

20.2.2.6 Cooling towers

a) Check for proper operation of cooling tower and associated controls and control circuits.

b) Check and clean the in-fills, drift eliminators, water screens, basins and sprinklers.

c) Check for water leakage in piping circuits due to corrosion or other reasons. Repair or replace if necessary.

d) Check make-up water system and cooling tower float valve operation.

e) Check, clean and rectify fan assembly for proper operation.

f) Check on chemical treatment system.

g) Check on tower structure and condition of tower support. To clean, wire brush, touch up and paint all rusty supports including ladder, all bolts and nuts.

h) Ensure tower cleanliness.

i) Ensure that water treatment comforms to and complies with the latest edition of the *Code of Practice for the Control of Legionella Bacteria in Air-conditioning Cooling Towers in Singapore, National Environment Agency, Ministry of the Environment and Water Resources (MEWR).*

j) Check water balancing to each cooling tower to ensure balanced flow. Adjust if necessary.

20.2.2.7 Motors

a) Check motor running ampere to ensure motor is operating under normal conditions.

b) Check the motor casing. Lubricate motor bearings if necessary.

c) Check, adjust and rectify defect if necessary for circuit protective devices including starters, control gears and relays ancillary apparatus, bearings and moving parts, electric contactors and fuses.

d) Check electrical circuits. Rectify any loose connections or bad contacts.

e) Check motor drive. Adjust belt tension and pulleys if necessary. Replace belt if it appears cracked or worn.

f) Check and rectify any abnormal running noise and vibration. Replace bearings and anti-vibration rubber and springs if necessary.

20.2.2.8 Chilled water expansion tank

a) Check chilled water expansion tank, float valve position and availability of make-up water supply. Clean the water expansion tank if necessary.

20.2.3 Half-yearly maintenance

20.2.3.1 Air handling units

a) Check and balance outside air quantities.

b) Clean electrical contacts. Tighten all screws where necessary.

c) Clean, wire brush, touch up and paint all rusty parts.

20.2.3.2 Fan coil units

a) Clean electrical contacts. Tighten all screws where necessary.

b) Clean, wire brush, touch up and paint all rusty parts.

c) Check pipe insulation for deterioration and damage. Repair or replace if necessary.

20.2.3.3 Pumps

a) Inspect and clean strainers.

20.2.4 Annual maintenance

20.2.4.1 Refrigerant compressors

a) Pump down the machine and open up compressor assembly inspection cover to visually inspect for abnormalities and excessive wear on the gear package.

b) Replace refrigeration filter.

c) Dismantle oil pump for servicing. Clean up oil pump chamber. Replace oil filters and refill with new oil.

d) Check and analyse the oil and refrigerant. Replace the oil and refrigerant if necessary.

e) Perform leak test and evacuation of system.

f) Test safety controls and re-calibrate them to a specific setting to ensure proper operation.

g) For starters: inspect and service contactors, check for abnormalities and tighten connecting parts.

20.2.4.2 Chiller condenser

a) Clean condenser tubes at regular intervals. Cleaning may be carried out annually if proper water treatment is maintained.

b) Check and clean all strainers on condenser water pipework.

c) Check and balance water flow rates.

d) Use if needed for ease of maintenance, automatic tube cleaning system to keep the condenser tubes from scaling and fouling. Reference can be made to Annex D for a typical system.

20.2.4.3 Air handling units

a) Replace filter as required.

b) Test and record electrical insulation of all motors and wiring with megger.

c) Clean cooling coils with high pressure jet or steam and cleaning detergent.

20.2.4.4 Supply and return air ducts

a) Inspect the supply and return air ducts for cleanliness. Reference on ACMV system cleanliness inspection can be made to Annex F in SS 554:2009.

20.2.4.5 Fan coil units

a) Replace filter as required.

b) Test and record electrical insulation of all motors and wiring with megger.

c) Clean cooling coils.

20.2.4.6 Pumps

a) Check all associated controls. Repair or replace as required.

b) Dismantle pump casings and check condition of pump shafts, impellers, sleeves, bearings and casings for wear and corrosion. Repair or replace as necessary. Repaint the pump interior and external casings with suitable protective paint of approved colour.

c) Check pumps and motor couplings. Repair or replaced if necessary.

d) Check grease, oil and gland packing and other parts. Replace as necessary.

e) Realign the pump and motor.

20.2.4.7 Motors

a) Check winding insulation by megger test. Check cable terminals and cables for damage or deterioration. Replace motor bearings, windings, and cable terminals as necessary.

b) Check the associated circuit protection devices, electrical starter and equipment are in good working condition. Replace contacts and other worn or defective parts as required.

c) Check motor bolts and nuts. Re-tighten any loose bolt and nut.

20.2.5 Overhaul (when necessary)

a) Overhaul all refrigerant compressors if necessary, in accordance with the procedures and details described in the manufacturers' instruction manuals whenever available.

20.3 Mechanical ventilation installations

Inspect the equipment and systems, electrical, electronic and mechanical controls, and circuit boards associated with mechanical ventilation systems to ensure satisfactory operation of within designed conditions.

20.3.1 Monthly maintenance

a) Check motor running ampere to ensure motor is operating under normal conditions.

b) Inspect fan blades for wear and tear. Clean fan blades as required.

c) Check fan and motor bearings. Lubricate if necessary

d) Check electrical circuits. Rectify any loose connections or bad contacts.

e) Check motor drive. Adjust belt tension and pulleys if necessary. Replace belt if it appears cracked or worn.

f) Check flexible connections and anti-vibration mountings. Replace bearings and anti-vibration rubber inserts and springs if necessary.

g) Check for proper operation of the fan, its associated controls and control circuit. Repair or replace if necessary.

h) Clean supply and return air grilles.

i) Clean air filters. Replace air filters if necessary.

20.3.2 Half-yearly maintenance

a) Check all electrical wiring and connections, circuit protection devices and electrical starter. Rectify or replace if necessary

b) Clean the exhaust hood with suitable cleaning detergent.

20.3.3 Annual maintenance

a) Check winding insulation by megger test. Check cable terminals and cables for damage or deterioration. Replace motor bearings, windings, and cable terminals as necessary.

b) Check the associated circuit protection devices, electrical starter and equipment are in good working condition. Replace contacts and other worn or defective parts as required.

c) Check motor bolts and nuts. Re-tighten any loose bolt or nut.

d) Check alignment of fan shaft with motor. Realign the fan shaft if necessary.

e) Check fan and metal components for corrosion. Clean and repaint if necessary.

f) Clean air passages.

21 Energy audit

21.1 Requirements

All air-conditioned buildings shall have the necessary provisions for the conduct of an energy audit for improvement of energy performance. The necessary provisions should be provided for energy metering, temperature flow rate and pressure measurements. Provision should also be made for connecting those instruments with the Building Automation System (BAS) or Building Management System (BMS) or other system of similar purpose if available.

21.2 Energy metering and instrumentation

21.2.1 Meters

All buildings whose supply energy source exceeds the thresholds listed in Table 12 shall be provided with meters with remote metering capability or automatic meter reading capability to collect energy consumption data for each supply energy source such as electricity, district cooling or heating, and gas.

Table 12 – Supply energy source thresholds

Energy source	Main meter threshold
Electricity	> 200 kVA
On-site renewable energy	All systems > 1 kVA (peak)
Gas and steam service	> 300 kW

21.2.2 Sub-metering

For all buildings that exceed the threshold in Table 12, subsystem measurement devices with remote capability (including current sensors or flow meters) shall be provided and shall measure energy consumption data of each subsystem in accordance with Table 13. Subsystems that are 10% below the thresholds in Table 13 are exempt.

Table 13 – Sub-system energy use thresholds

Use (total of all loads)	Sub-systems thresholds
ACMV systems	Connected electrical loads > 100 kVA
ACMV systems	Connected gas or district services loads > 150 kW
People moving	Sum of all feeders > 50 kVA
Lighting	Connected load > 50 kVA
Process and plug loads	Connected loads > 50 kVA
Process loads	Connected gas or district services load > 75 kW

21.2.3 Meter and measured data collection

All building meters and measurement instruments shall be able to communicate energy consumption and metered data to a meter data management system. Meters shall provide a minimum of daily data and shall record a minimum of hourly consumption of energy and measured data.

21.2.4 Data storage and retrieval

The data management system shall be capable of electronically storing energy metered and measured data and creating user reports showing calculated hourly, daily, monthly and annual energy consumption for each meter and performance parameters for the plant.

21.3 Energy efficiency

The energy metering collection/storage system provided under 21.2 shall be used to collect and store meter data for each meter and sub-meter immediately upon building commissioning and issuance of Temporary Occupation Permit or Certificate of Statutory Completion, whichever is earlier.

21.3.1 Green Mark Gold Plus and Platinum Grade Buildings

Building projects awarded the Green Mark Gold Plus and Platinum Grade shall perform energy measurement and verification activities in accordance with the requirements of the award.

21.3.2 Energy simulation compliance path

21.3.2.1 Initial measurement and verification

After 12 months and no later than 18 months after commencement of meter data collection and with minimum of 80% occupancy, all measured energy consumption from the main meters and sub-meters shall be compared against the predicted energy consumption of the systems and subsystems, as obtained by an energy simulation model for the whole building. The existing building energy simulation model that has been created previously to satisfy performance requirements shall be used. Otherwise, subject to the approval of the relevant authority, a new energy simulation model shall be created using as-built construction documentation and following the modeling methodology and requirements of the Green Mark award.

21.3.2.2 Variations

Variations of 10% or more in the predicted annual energy consumption versus measured energy consumption and/or variations of 20% or more in peak demand or consumption for any individual month shall be documented. If required, short-term metering for sub-systems and process loads that do not have permanent metering provided under 21.2 shall be made in order to reconcile measured building energy meter data to the energy model predicted values.

21.3.2.3 Energy baseline update

An updated energy baseline for monthly and annual energy consumption and demand for the building shall be established. The energy simulation model shall be corrected and calibrated for each major energy consuming system by normalizing it based on actual weather and operational conditions such as use and occupancy patterns, and equipment operating schedules during the period the metered data was collected, so that it matches the energy baseline within 10% annually and within 20% for each individual month.

21.3.3 Post occupancy measurement and verification evaluation

Periodic post-occupancy evaluations of energy performance shall be conducted as follows:

a) Three years after receiving the Certificate of Occupancy or a minimum of 80% of occupancy, whichever is later; and

b) Subsequent post-occupancy evaluations of energy performance shall be performed a minimum of every three years.

21.3.3.1 Evaluations

Building energy monthly consumption and peak demand and system and subsystem performance shall be evaluated using meter and sub-meter data collected for the prior 12 months relative to baseline monthly energy consumption and peak demand data established under 21.3.2. The impact of any functional changes that might have occurred during or prior to the occupancy period shall be documented and credited or debited against the baseline monthly energy consumption and peak demand data and actual weather data for the occupancy period used to adjust baseline energy use.

21.3.3.2 Actions to be taken in the event of deviations in performance

If the measured results are not within the 10% of the established baseline annual energy use or within 20% of the established baseline monthly energy consumption and peak demand, the owner shall retain the services of a Qualified Person. The Qualified Person shall analyse systems operation and submit a written report to the owner giving reasons why deviations exceed maximums for any metered energy using system, together with recommendations for actions that would correct any documented degradation in system performance.

Where the building or the building's use changes significantly enough over time to warrant permanent adjustment to the energy baseline, a new energy baseline is allowed to be established using procedures established in 21.3.2.3 and occupancy period meter data. This new baseline energy consumption data shall be documented and used for future post-occupancy evaluations of building energy performance.

21.4 Documentation of energy efficiency

21.4.1 Initial baseline energy simulation

Reports shall be created to summarise measured meter and sub-meter data and baseline energy consumption data, with metrics summarising the baseline annual energy use intensity for the overall building and by fuel, in kWh/m^2. The reports shall be retained by the owners for future use by owners and relevant authorities that may request this information.

21.4.2 Post-occupancy energy simulation

Reports shall be created to summarise measured meter and sub-meter data relative to baseline energy consumption along with metrics of corrected baseline annual energy use for the overall building and by fuel, in kWh/m^2, for the occupancy period. These documents, along with the Qualified Person's report, shall be retained by the owners for future post-occupancy evaluations by owners and for the relevant authority that may request this information.

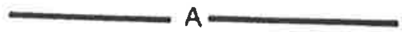
21.4.3 All collected meter and sub-meter data shall be retained for a minimum of 3 years.

Annex A

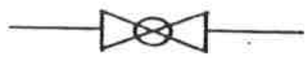
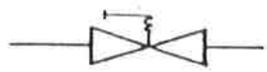
Symbols

Graphical symbols for drawings

Air-conditioning pipework

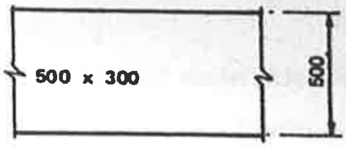
Refrigerant discharge	
Refrigerant suction	
Condenser water supply	
Condenser water return	
Chilled water supply	
Chilled water return	
Make up water	
Drain	
Compressed air	

Valves

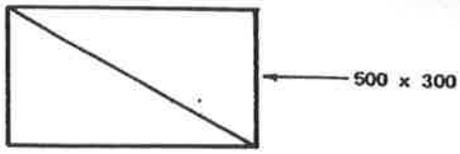
Gate valve	
Globe valve	
Ball valve	
Butterfly valve	
Non-return valve	
Relief valve	
Air valve or cock	
Drain cock	
Strainer	

Ductwork

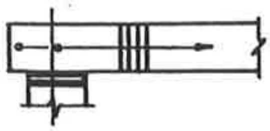
Duct, plan or elevation



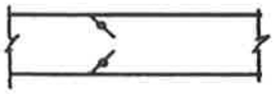
Duct, section (indicate larger dimension first)



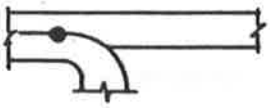
Flexible joint



Volume damper



Splitter damper



Vane

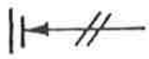
Grilles, registers, diffusers, etc.

Louvre opening

Outdoor air grille	OAG
Exhaust air grille	EAG
Supply air register	SAR
Return air grille	RAG
Supply air diffuser	SAD

Supply outlet

Exhaust inlet



Annex B

Exchange of information

B.1 Preliminary discussion

In the initial planning of a project, information should be exchanged between the client, architect and consulting engineer regarding the various aspects of the air-conditioning and ventilation installation.

The following items should be discussed and the responsibility for these items should be clearly stipulated in the contract:

a) Hoisting of equipment, tools and materials.

b) Supply and erection of scaffolding and ladders.

c) Preparation and final completion of foundations and equipment bases.

d) Cutting away and making good of every description including built-in brackets and fixtures.

e) Joinery and carpentry.

f) Plumbers' work on cold water supply pipes to cooling towers, and floor traps.

g) Electrical wiring and cabling.

h) Temporary artificial lighting and water supply for installation purposes and supply of workshop and lock-up store accommodation.

i) Fuel, power and water for testing and commissioning.

B.2 Planning

The consulting engineer for each type of installation covered by this code should be consulted at the planning stage to ensure a good and economical design. The various matters should be settled in principle, including the following:

a) Location of plant rooms, outdoor air intakes and exhaust air outlets.

b) Occupancies of buildings.

c) Restrictive conditions governing pipe and duct runs.

d) Drainage facilities for discharge of condensate and emptying installation.

e) Source and quantities of internal heat and moisture gains, e.g. people, lighting, equipment, appliances, etc.

f) Noise and air pollution to/from adjacent buildings.

B.3 Information to be provided by the architect

The following information should be provided by the architect:

a) Scale plan drawings of the premises showing orientation together with cross-sections having sufficient details based upon which a reasonable appraisal can be made of the heat transfer through the structures.

b) Scale plan drawings of the premises with all the air-conditioned, mechanically ventilated and naturally ventilated areas clearly marked.

c) Location of fire-resistance walls, partitions and floors.

d) A schedule of builders' work as a forecast during the early stages of design.

B.4 Information to be provided by consulting engineer

The following information should be provided by the consulting engineer:

a) Scale drawings indicating the layout of the inlet and extract fan sets, air filters, duct heater and duct routings, and the volume of air flow at each point of inlet and outlet of the air distribution system.

b) Drawings and/or specifications indicating full requirements for the complete installation, starting capacities, ratings and conditions of performance of each item to comply with the specific requirements.

B.5 Information to be provided by the installation contractor

The following information should be provided by the installation contractor:

a) Shop drawings relating to special fabrication of ducts and pipes, and assembly of plant items covered by his contract.

b) Work drawings relating to layout and sections of ducts, pipes and plant items superimposed on architectural drawings.

c) Builders' work drawings showing the extent of all builders' work required for installation.

d) A set of working instructions and at the conclusion of the installation work, a set of record plans on which all work "as installed" is clearly defined.

e) A set of operating and maintenance instruction manuals.

B.6 Time schedule

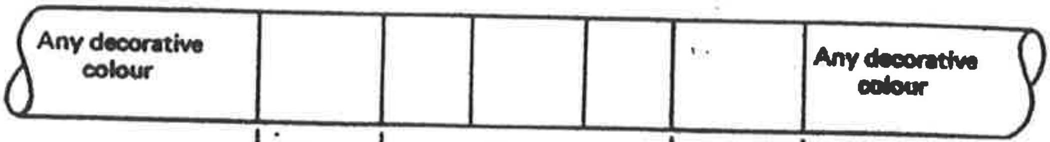
The installation contractor should be informed before the award of contract of the commencement and completion dates of the installation.

Annex C

Identification of pipelines (colour code)

To identify pipes conveying fluids in air-conditioning systems, the following colour code shall be used. They shall be placed at all junctions, at both sides of valves, near service appliances, wall/floor penetrations, and at any other place where identification is necessary.

Identification colours shall be applied as bands about 100 mm wide depending on the diameter of the pipe and illustrated as follows:



	150mm Approx.	100mm Approx.			150mm Approx.
	Basic Colour	Colour Code			Basic Colour
Chilled Water	Green	White	Emerald Green	White	Green
Condenser Water	Green	White			Green
Drainage	Black				
Compressor Air	Light Blue				

Reference colour

Colour	Colour Reference (BS 4800)
Green	12D45
Emerald Green	14B53
Light Blue	20B51

When it is necessary to know the direction of flow of the liquid, this shall be indicated by an arrow.

i) Arrow shall be painted black.

ii) Arrows shall be visible from the floor.

Annex D

Automatic tube cleaning system for shell and tube heat exchangers

D.1 Selection

During selection of an appropriate system, there should be consideration about the wear and tear posed by the components with moving parts such as pumps, diverters and compressors.

D.2 Minimal head loss

There should be negligible head loss to the cooling water system to prevent extra load on the cooling water pump.

D.3 No mixture of water

The system should not allow warm water leaving the condenser to re-enter the condenser inlet pipe without going through the cooling tower as this will increase the temperature of the cooling water entering the condenser.

D.4 Durable and corrosion resistant

The system should be made of materials that can withstand corrosion.

D.5 Easy replacement of consumables

The procedure to replace the cleaning medium passing through the condenser tubes should be simple and fast.

D.6 Little or no water wastage

The system shall not result in loss of chemically treated cooling water during its normal operation.

D.7 Able to withstand high pressure

The system shall be suitable for the operating pressure of the cooling water system.

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Technical References are transition documents developed to help meet urgent industry demand for specifications or requirements on a particular product, process or service in an area where there is an absence of reference standards. Unlike Singapore Standards, they are issued for comments over a period of two years before assessment on their suitability for approval as Singapore Standards. All comments are considered when a technical reference is reviewed at the end of two years to determine the feasibility of its transition to a Singapore Standard. Technical References can therefore become Singapore Standards after two years, continue as Technical References for further comments or be withdrawn.

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