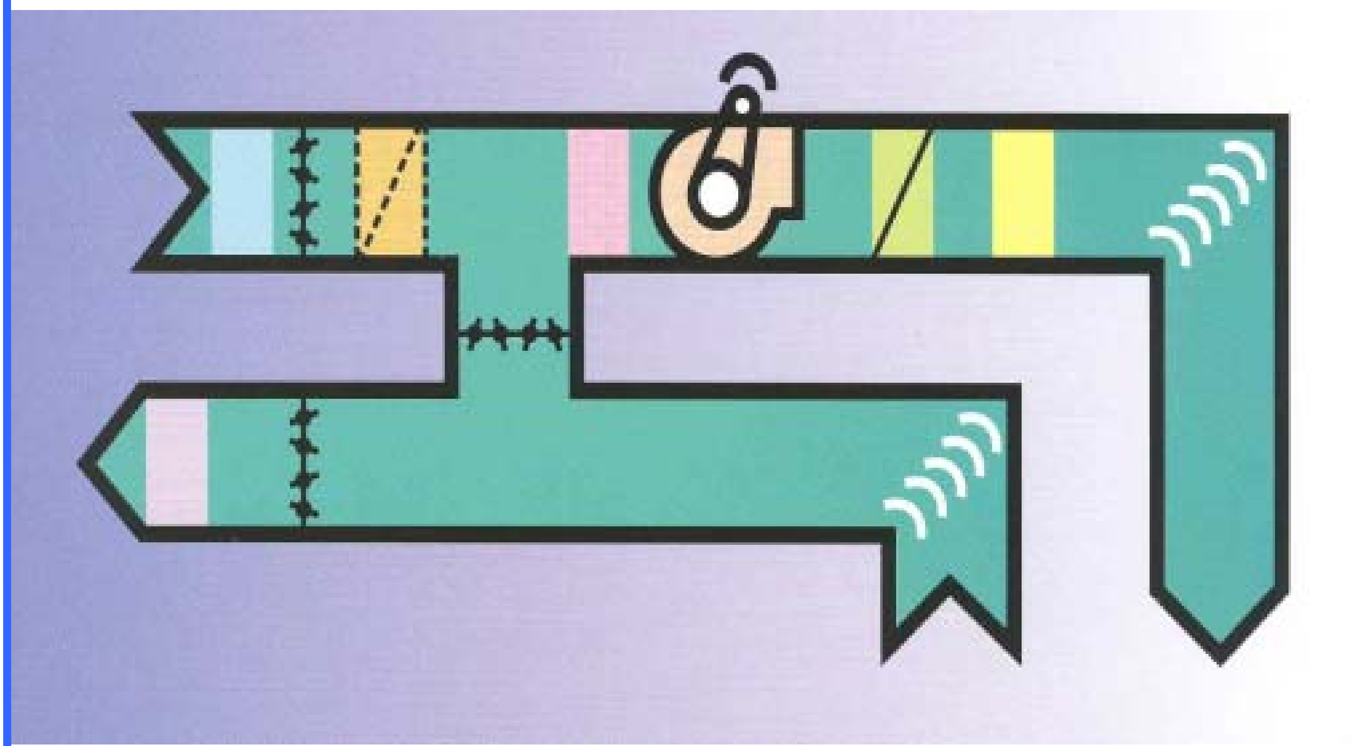
Code of Practice for Energy Efficiency of Air Conditioning Installations

2007 EDITION



EMSD

Foreword

The **Code of Practice for Energy Efficiency of Air Conditioning Installations** aims to set out the minimum design requirements on energy efficiency of air conditioning installations. It forms a part of a set of comprehensive *Building Energy Codes* that address energy efficiency requirements on building services installations. Designers are encouraged to adopt a proactive approach to exceed the minimum requirements.

The *Building Energy Codes* were developed by ad hoc task forces under the Energy Efficiency & Conservation Sub-committee of the Energy Advisory Committee. The set of comprehensive *Building Energy Codes* cover this Code, the Codes of Practice for Energy Efficiency of Lighting Installations, Electrical Installations, and Lift & Escalator Installations, and the Performance-based Building Energy Code.

To promote the adoption of the *Building Energy Codes*, the Hong Kong Energy Efficiency Registration Scheme for Buildings was also launched. The Registration Scheme provides the certification to a building complying with one or more of the *Building Energy Codes*.

To supplement and further explain the codes, corresponding Guidelines were also published.

The Building Energy Codes and Registration Scheme documents are available for free download at http://www.emsd.gov.hk/emsd/eng/pee/eersb.shtml
Enquiry: hkeersb@emsd.gov.hk

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Amendments

The Code was first published in 1998. To suit changes in technological advancement and to cope with trade practices, there have been amendments to the first published edition, which were agreed in code review task forces with members from representative organizations in the building industry including professional institutes, trade associations and the academia.

In 2003, exemption was given to fan power requirement for special design needs, such as statutory, safety & health. In 2005, the Standard Rating Conditions for Air-Cooled Water Chillers and Water-Cooled Water Chillers were slightly adjusted, and the COP requirements on unitary air conditioners were slightly tightened. In 2007, the Minimum Allowable Coefficient of Performance requirements are upgraded (Tables 9.5 to 9.12B of Code); fouling condition fixed at 0.000018m^{2} ^{0}C/W for evaporator and 0.000044m^{2} ^{0}C/W for condenser (in clause 9.1 of Code); and designers requested to provide data on Part Load Values of AC equipment and motor power of fan coil units (in Forms for submission).

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Appendix :

1. SCOPE

This Code applies to all buildings provided with air conditioning (AC) installations for **human comfort** except :

(a) domestic buildings
(b) medical buildings
(c) industrial buildings
(d) any area or any part of the building which is constructed, used or intended to be used for domestic, medical or industrial purposes.

2. DEFINITIONS

The words and terms in this Code are defined as follows :

"**Air conditioning (AC) system**" means
the equipment, distribution network and terminals that provide either collectively or individually the processes of cooling, dehumidification, heating, humidification, air distribution or air-purification or any other associated processes to a conditioned space.

"**Coefficient of performance (COP) - cooling**" means
the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete cooling system or factory assembled equipment, as tested under an internationally recognised standard and designated operating conditions.

"**Coefficient of performance (COP), heat pump - heating**" means
the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, as tested under an internationally recognised standard and designated operating conditions.

"**Dead band**" means
the range of values within which an input variable can be varied without initiating any noticeable change in the output variable.

"**Domestic building**" means
a building constructed, used or intended to be used for habitation but excluding the use of it for hotel, guest-house, boarding-house, hostel, dormitory or similar accommodation and the expression "domestic purposes" is construed accordingly.

"**Fan motor power,** (unit : Watt)" means
the actual electrical power drawn by the motor, calculated by dividing fan shaft power/fan brake power by motor efficiency and drive efficiency, which should be verified through site measurement.

"**Humidistat**" means
a regulatory device, actuated by changes in humidity, used for automatic control of relative humidity.

"**Industrial building**" means
(a) a godown; or
(b) a building in which articles are manufactured, altered, cleaned, repaired, ornamented, finished, adapted for sale, broken up or demolished, or in which materials are transformed;

and the expression "industrial purposes" is construed accordingly.

"**Maximum dry bulb temperature**" means
the dry bulb temperature which the design dry bulb temperature should not be higher than.

"**Maximum relative humidity**" means
the relative humidity which the design relative humidity should not be higher than.

"**Medical building**" means
a building constructed, used or intended to be used as clinic, infirmary or hospital and the expression "medical purposes" is construed accordingly.

"**Minimum dry bulb temperature**" means
the dry bulb temperature which the design dry bulb temperature should not be lower than.

"**Minimum relative humidity**" means
the relative humidity which the design relative humidity should not be lower than.

"**Part Load Value (PLV)**" means
a number representing the efficiency performance at prescribed operating conditions of a cooling/heating equipment at a percentage of full load capacity, the representative percentages usually respectively at 75%, 50% & 25%, the performance at full load being the COP.

"**Recooling**" means
lowering the temperature of air that has been previously heated by a heating system.

"**Reheating**" means
raising the temperature of air that has been previously cooled by a refrigeration system.

"**Surface coefficient** (symbol : h), (unit : W/m^2·^{o}C)" means
the rate of heat loss by a unit area of a given surface divided by the temperature difference in degree Celsius between the surface and the ambient air.

"**Thermal conductivity** (symbol : λ), (unit : W/m·^{o}C)" means
the quantity of heat that passes in unit time through unit area of a homogeneous flat slab of infinite extent and of unit thickness when unit difference of temperature in degree Celsius is established between its faces.

"**Variable air volume (VAV) fan system**" means
an AC installation that controls the dry-bulb temperature within a space by varying the volume of supply air to the space.

"**Zone**" means
a space or group of spaces within a building with similar heating or cooling requirements which are considered to behave as one space for the purposes of design and control of heating and cooling system.

3. GENERAL APPROACH

3.1 This Code sets out the minimum requirements for achieving energy-efficient design of AC installations in buildings. The Code specifies design parameters and control criteria of AC installations and minimum COP for AC Equipment.

3.2 As the Code sets out only the minimum standards, designers are encouraged to design AC installations with energy efficiency standards above those quoted in this Code.

3.3 Although the intake rate of outdoor air quantity contributes to a significant portion in energy consumption in AC installations, requirements on this aspect is not included in the Code. Designers are recommended to incorporate into the design of AC installations the appropriate requirements for outdoor air after taking into account of relevant international recommendations and any other relevant health requirements.

4. SYSTEM LOAD DESIGN

4.1 Load Calculation & Sizing

The cooling/heating load calculation for the purpose of sizing system and equipment should be carried out according to internationally recognised procedures and methods.

4.2 Indoor Design Conditions

The following indoor design conditions should be used for the purpose of sizing system and equipment but may or may not be the actual operating conditions.

Summer

Office and Classroom
Minimum dry bulb temperature 23^{o}C
Minimum relative humidity 50%

Other Applications except Office and Classroom
Minimum dry bulb temperature 22^{o}C
Minimum relative humidity 50%

Winter

Hotel
Maximum dry bulb temperature 24^{o}C
Maximum relative humidity 50%

Other Applications except Hotel
Maximum dry bulb temperature 22^{o}C
Maximum relative humidity 50%

4.3 Outdoor Design Conditions

The following outdoor design conditions should be used for purpose of sizing system and equipment but may or may not be the actual operating conditions.

Summer

Maximum dry bulb temperature	33.5^oC
Maximum relative humidity	68%

Winter

Minimum dry bulb temperature	7^oC
Minimum relative humidity	40%

5. AIR SIDE SYSTEM DESIGN CRITERIA

5.1 Air Distribution System

5.1.1 Separate Distribution System

If zones have special process temperature requirements and/or humidity requirements, they shall be served by air distribution systems separate from those serving the zones requiring only comfort conditions; or shall be provided with supplementary control specifically for comfort purposes only.

Exceptions :

(a) The total supply air to the comfort heating or cooling zone(s) is no more than 25% of the total system supply air primarily used for above special process purposes.

(b) The total conditioned floor area of the zones requiring comfort heating or cooling is smaller than $100m^2$.

5.1.2 Air Leakage Limit On Ductwork

At least 25% in area of ductwork which is designed to operate at operating static pressure in excess of 750 Pa shall be leakage tested in accordance with the air leakage limit set on table(5.1) :

Table(5.1) : Air Leakage Limit On Ductwork

Leakage Class	Operating Static Pressure (Pa)	Air Leakage Limit (L/s per m^2 of duct surface)
I	above 750 to 1000	$0.009 \times p^{0.65}$
II	above 1000 to 2000	$0.003 \times p^{0.65}$
III	above 2000	$0.001 \times p^{0.65}$

Note : where p is the operating static pressure in Pascal

5.2 Fan System

5.2.1 General

The total fan motor power of a fan system is the sum of the fan motor power of all fans which are required, at design conditions, to intake outdoor air, circulate air between the heating or cooling source and the conditioned space(s) and, where applicable, exhaust it to the outdoors and shall satisfy clause (5.2.2) or clause (5.2.3).

Exceptions :

(a) System with total fan motor power less than 5 kW.

(b) System with only fan-coil unit(s) of individual fan motor power less than 5 kW.

in which case the fan motor efficiency values shall also be indicated (FORM AC-F1).

Additional fan motor power required by air treatment or filtering systems with clean pressure drop over 250 Pa need not be included. It can be calculated by using the following equation and be deducted from the total fan motor power.

$$P_f = V \times (P_d - 250)/(\eta_m \times \eta_f \times \eta_d)$$

where P_f = Fan motor power for air treatment/filtering - W

V = Air volume flow rate - m^3/s

P_d = Clean air pressure drop of the filtering system - Pa

η_m = Motor efficiency

η_f = Fan efficiency

η_d = Drive/belt efficiency

5.2.2 Constant Air Volume(CAV) Fan System

The total fan motor power required for a CAV fan system supplying constant air volume at design conditions shall not exceed 1.6 W per L/s of supply air quantity.

The requirement will be considered as having complied with if the total fan motor power has to exceed 1.6 W per L/s of supply air quantity in order to meet special design needs, such as statutory, safety and health requirements. In such cases, applicants shall state in the "Fan Motor Power Worksheet" (FORM AC-F1) in their submissions that the limit is exceeded and provide the justifications.

5.2.3 Variable Air Volume(VAV) Fan System

5.2.3.1 The total fan motor power required for a VAV fan system of being able to vary system air volume automatically as a function of load at design conditions shall not exceed 2.1 W per L/s of supply air quantity.

The requirement will be considered as having complied with if the total fan motor power has to exceed 2.1 W per L/s of supply air quantity in order to meet special design needs, such as statutory, safety and health requirements. In such cases, applicants shall state in the "Fan Motor Power Worksheet" (FORM AC-F1) in their submissions that the limit is exceeded and provide the justifications.

5.2.3.2 Any individual supply fan with a fan motor power of 5 kW or greater shall incorporate controls and devices such that the fan motor demands no more than 55 % of design wattage at 50% of design air volume.

6. WATER SIDE SYSTEM DESIGN CRITERIA

6.1 Pumping System

Variable Flow

Pumping systems shall be designed for variable flow if control valves of the system are designed to modulate or step open and closed as a function of load. The system shall be capable of reducing system flow to 50% of design flow or less.

Exceptions:

(a) Systems where a minimum flow greater than 50% of the design flow is required for the proper operation of equipment served by the system, such as chillers.

(b) Systems that serve no more than one control valve.

(c) Systems that include supply water temperature reset controls.

6.2 Friction Loss

The friction loss of a piping system shall not exceed 400 Pa/m. The designer shall also consider lower friction loss for noise or erosion control.

7. CONTROL

7.1 Temperature Control

7.1.1 Each AC system shall be provided with at least one automatic control device for regulation of temperature.

7.1.2 Thermostatic controls for comfort cooling should be capable of adjusting the set point temperature of the space they serve up to 29°C or higher.

7.1.3 Thermostatic controls for comfort heating should be capable of adjusting the set point temperature of the space they serve down to 16°C or lower.

7.1.4 Thermostatic controls for both comfort cooling and heating shall be capable of providing a temperature range or dead band of at least 2.0°C within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

Exception : Thermostats that require manual changeover between heating and cooling modes.

7.2 Humidity Control

If a system is equipped with a means for adding or removing moisture to maintain specific humidity levels in a zone or zones, a humidistat shall be provided. For comfort purpose, the humidistat should be capable of preventing the use of energy to increase relative humidity above 30% during humidification or to decrease relative humidity below 60% during dehumidification.

7.3 Zone Control

7.3.1 Each air-conditioned zone shall be controlled by individual thermostatic control corresponding to temperature within the zone. As a minimum each floor of a building shall be considered as a separate zone.

Exceptions : Independent perimeter systems that are designed to offset only envelope heat losses or gains, or both, may be used to serve one or more zones which are also served by an interior system with the following limitations :

(a) the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for contiguous distance of 15 m or more, and

(b) the perimeter system heating and cooling supply are controlled by thermostat(s) located within the zone(s) served by the system.

7.3.2 Where both heating and cooling energy are provided to a zone, the controls shall not permit :

a) heating previously cooled air

b) cooling previously heated air

c) both heating and cooling operating at the same time.

Exceptions :

(a) Variable air volume(VAV) systems which, during periods of occupancy, are designed to reduce the air supply to each zone to a minimum before reheating, recooling or mixing takes places. This minimum volume shall be no greater than 30% of the peak supply volume.

(b) At least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.

(c) Zones with a peak supply air quantity of 140 L/s or less.

(d) Zones where specified humidity levels are required to satisfy process needs.

(e) Reheating or recooling of outdoor air which has been previously precooled or preheated by pretreated air handling units(PAUs).

7.4 Off Hours Control

7.4.1 Each AC system should be equipped with automatic controls capable of accomplishing a reduction of energy use through control setback or equipment shutdown during periods of non-use of the spaces served by the system.

Exception : System with cooling or heating capacity not more than 10 kW may be controlled by readily accessible manual off-hour control.

7.4.2 For hotels, each hotel guest room and multiple room suite should be provided with a single master switch at the main entry door to each guest room or suite or each room within a suite to reduce energy use during the period of non-use. The master switch should be able to perform one of the following functions:

a) turn off the conditioned air supply, except outdoor air, to the room(s).

b) reset the thermostatic setting to reduce energy use.

c) reset the thermostatic setting together with reduction of fan speed.

8. INSULATION

8.1 General

All chilled water pipes, refrigerant pipes, ductworks and air handling unit(AHU) casings should be insulated with a minimum insulation thickness in accordance with Equation 8-1, 8-2 or 8-3 as quoted in clause (8.2).

Table(8.1) through Table(8.6) of minimum insulation thickness for chilled water pipes, refrigerant pipes, ductworks and AHU casings respectively are developed based on certain assumed parameters and operating conditions for designers' reference. In case operating conditions or material parameters are different from those assumed in the following tables, Equation 8-1, 8-2 or 8-3 should be used to determine the minimum insulation thickness.

8.2 Minimum Insulation Thickness

The minimum insulation thickness for pipeworks, ductworks and AHU casings should be determined in accordance with Equation 8-1, 8-2 or 8-3 (see Appendix Part A for sample calculations) :-

$\chi = 10^3 \times \lambda/h \times \{(\theta_d - \theta_l)/(\theta_m - \theta_d)\}$ (Equation 8-1)

$\chi = 0.5(d_o + 2L_a) \times \ln [1 + 2L_a/d_o]$ (Equation 8-2) for pipes

$\chi = L_a$ (Equation 8-3) for ductworks and AHU casings where χ = Provisional thickness adopted for calculation purposes, which is related to the actual minimum thickness L_a by Equation 8-2. - mm

L_a = Actual minimum thickness - mm

d_o = Outside diameter of pipe or tube - mm

h = Surface coefficient of external surface of insulation - W/(m^2 ^oC)

λ = Thermal conductivity of insulating material - W/(m ^oC)

θ_d = Dew point temperature - ^oC

θ_l = Temperature of the cold surface(line temperature) - ^oC

θ_m = Temperature of the ambient still air - ^oC

8.3 Piping Insulation

8.3.1 Chilled Water Pipe

All chilled water pipes should be insulated with minimum insulation thickness in accordance with clause 8.2 or Table(8.1) or Table(8.2).

Table(8.1) : Minimum Insulation Thickness for Indoor Chilled Water Pipe

Indoor				
Minimum Thickness of Insulation for Chilled Water Pipe Installations (mm)				
	Thermal Conductivity(2) , λ - W/(m ^oC·)			
	0.024		0.04	
	Indoor Conditions (still air)		Indoor Conditions (still air)	
Nominal size of Pipe(mm)(1)	28^oC, 80% RH	30^oC, 95% RH	28^oC, 80% RH	30^oC, 95% RH
	h(3)=5.7	h(3)=10	h(3)=5.7	h(3)=10
15	15	35	22	51
20	15	36	23	54
25	16	38	24	57
32	17	40	25	60
40	17	41	26	61
50	18	43	27	64
65	18	45	28	68
80	19	47	29	70
100	19	49	30	73
125	19	50	30	76
150	20	52	30	79
200	20	54	32	83
250	20	55	32	85
300	21	56	33	88
350	21	57	33	89
400	21	57	33	90

Notes : (1) The above table assumes pipes to be steel pipe of BS1387 or BS3600. For other metal pipes, same insulation thickness is applied to comparable outer diameters.

(2) The insulation thickness in above table is based on thermal conductivity rated at 20^oC mean for fluid operating temperature of 5^oC.

(3) The surface coefficient h=5.7 is assumed for bright metal surfaces and h=10 for cement or black matt surfaces at indoor still air condition.

Table(8.2) : Minimum Insulation Thickness for Outdoor Chilled Water Pipe

Outdoor				
Minimum Thickness of Insulation for Chilled Water Pipe Installations (mm)				
	Thermal Conductivity[(2)], λ - W/(m ·°C)			
	0.024		0.04	
	Outdoor Conditions (wind speed = 1m/s)		Outdoor Conditions (wind speed = 1m/s)	
Nominal size of Pipe(mm)[(1)]	35°C, 95% RH	35°C, 95% RH	35°C, 95% RH	35°C, 95% RH
	h[(3)]=9	h[(3)]=13.5	h[(3)]=9	h[(3)]=13.5
15	43	32	64	47
20	46	33	67	49
25	48	35	71	52
32	50	37	75	55
40	52	38	77	57
50	54	40	81	59
65	57	41	85	62
80	59	42	88	64
100	62	44	93	67
125	64	46	97	70
150	66	47	100	72
200	69	49	105	75
250	71	50	109	78
300	72	51	112	80
350	73	51	114	81
400	74	52	116	82

Notes :
(1) The above table assumes pipes to be steel pipe of BS1387 or BS3600. For other metal pipes, same insulation thickness is applied to comparable outer diameters.
(2) The insulation thickness in above table is based on thermal conductivity rated at 20°C mean for fluid operating temperature of 5°C.
(3) The surface coefficient h=9 is assumed for bright metal surfaces and h=13.5 for cement or black matt surfaces at outdoor condition with a wind speed of 1m/s.

8.3.2 Refrigerant Pipe

All refrigerant pipes except pipes on high pressure side of refrigeration cycle should be insulated with minimum insulation thickness in accordance with clause (8.2) or Table(8.3), Table(8.4) or Table(8.5):-

Table(8.3) : Minimum Insulation Thickness for Indoor Refrigerant Pipe (Case 1)

Minimum Thickness of Insulation for Refrigerant Pipe Installations (mm)									
Indoor Condition at 28 °C, 80% RH; still air; h[(3)]=10									
	Fluid Operating Temperature								
Outer Diameter of Pipe(mm)[(1)]	0°C			-10°C			-20°C		
	Thermal Conductivity[(2)], λ			Thermal Conductivity[(2)], λ			Thermal Conductivity[(2)], λ		
	0.02	0.03	0.04	0.02	0.03	0.04	0.02	0.03	0.04
6	8	10	13	10	13	16	12	16	20
8	8	11	14	10	14	18	13	17	21
10	8	11	14	11	15	18	13	18	22
12	9	12	15	11	15	19	14	19	23
15	9	12	15	12	16	20	14	20	25
22	10	13	17	13	18	22	16	21	27
28	10	14	18	13	18	23	16	22	28
35	10	15	18	14	19	24	17	23	29
42	11	15	19	14	20	25	18	24	30
54	11	15	20	15	21	26	18	25	32
76	11	16	21	15	22	28	19	27	34

Table(8.4) : Minimum Insulation Thickness for Indoor Refrigerant Pipe (Case 2)

Minimum Thickness of Insulation for Refrigerant Pipe Installations (mm)									
Indoor Condition at 30 °C, 95% RH; still air; h[(3)]=10									
	Fluid Operating Temperature								
Outer Diameter of Pipe(mm)[(1)]	0°C			-10°C			-20°C		
	Thermal Conductivity[(2)], λ			Thermal Conductivity[(2)], λ			Thermal Conductivity[(2)], λ		
	0.02	0.03	0.04	0.02	0.03	0.04	0.02	0.03	0.04
6	26	36	44	33	45	56	39	53	67
8	28	38	47	35	48	60	42	57	71
10	29	40	50	37	50	62	44	60	75
12	31	42	52	38	52	65	45	62	78
15	32	44	54	40	55	68	48	65	81
22	35	48	59	44	60	74	52	71	89
28	37	50	63	46	63	79	55	75	94
35	39	53	66	49	66	83	58	79	99
42	40	55	69	51	69	86	60	82	103
54	42	58	73	53	73	91	64	87	109
76	45	63	78	57	79	99	69	94	118

Note :
(1) The above tables assume pipes to be copper pipe of BS2871 : Part 1. For other metal pipes, same insulation thickness is applied to comparable outer diameters.
(2) The insulation thickness in above tables are based on thermal conductivity rated at 20°C mean.
(3) The surface coefficient h=10 is assumed for cement or black matt surfaces at indoor still air condition.

Table (8.5) : Minimum Insulation Thickness for Outdoor Refrigerant Pipe

Minimum Thickness of Insulation for Refrigerant Pipe Installations (mm)									
Outdoor Condition at 35 °C, 95% RH; wind speed = 1m/s; h[3]=13.5									
	Fluid Operating Temperature								
Outer Diameter of Pipe(mm)[1]	0°C			-10°C			-20°C		
	Thermal Conductivity[2], λ			Thermal Conductivity[2], λ			Thermal Conductivity[2], λ		
	0.02	0.03	0.04	0.02	0.03	0.04	0.02	0.03	0.04
6	23	32	40	29	39	49	33	46	57
8	25	34	42	30	41	52	36	49	61
10	26	36	45	32	44	54	38	51	64
12	27	37	46	33	45	57	39	53	66
15	29	39	49	35	48	59	41	56	70
22	31	43	53	38	52	65	45	61	76
28	33	45	56	40	55	69	48	64	80
35	35	48	59	42	58	72	50	68	85
42	36	49	62	44	60	75	52	71	88
54	38	52	65	46	64	80	55	75	93
76	41	56	70	50	69	86	59	80	101

Note :
(1) The table assumes pipes to be copper pipe of BS2871 : Part 1. For other metal pipes, same insulation thickness is applied to comparable outer diameters.
(2) Insulation thickness is based on thermal conductivity rated at 20°C mean.
(3) The surface coefficient h=13.5 is assumed for cement or black matt surfaces at outdoor condition with a wind speed of 1m/s.

8.4 Ductwork and AHU Casing Insulation

All ductworks & AHU casings carrying warmed or chilled air should be insulated with a minimum thickness in accordance with clause (8.2) or Table (8.6) :

Table(8.6) : Minimum Insulation Thickness for Ductworks and AHU Casings

Minimum Insulation Thickness (mm)				
Maximum temp. difference[1]	Thermal conductivity[2] - λ - W/(m ·°C)			
	0.024	0.04	0.055	0.07
15°C max. for indoor condition at 80%RH; still air; h[3]=5.7	13	21	29	37
15°C max. for indoor condition at 95%RH; still air; h[3]=10	43	72	99	126
20°C max. for outdoor condition at 95%RH; wind speed = 1m/s; h[3]=13.5	38	63	87	110

Notes :
(1) The maximum temperature difference at design conditions is the greatest temperature difference between the space within which the duct is located and the design temperature of the air carried by the duct. Where the duct is used for both heating and cooling purposes, the larger temperature difference should be used.
(2) The insulation thickness in above table is based on thermal conductivity rated at 20°C mean.
(3) The surface coefficient h=5.7 is assumed for bright metal surfaces at indoor still air condition; h=10 for cement or black matt surfaces at indoor still air condition and h=13.5 for cement or black matt surfaces at outdoor condition with a wind speed of 1m/s.

9. MINIMUM AC EQUIPMENT EFFICIENCY

9.1 Factory-designed & Prefabricated, Electrically-driven Equipment

All factory-designed and pre-fabricated electrically-driven equipment shown in Table(9.5) through Table(9.12), with a rating above 10 kW of cooling/heating capacity, shall have a minimum coefficient of performance (COP) at the following specified rating conditions as listed in Table(9.1) through Table(9.4). The reference water-side fouling factor allowance shall be 0.000018m^2 ^{0}C/W for evaporator, and 0.000044m^2 ^{0}C/W for condenser. Equipment not listed in Table(9.5) through Table(9.12) have no minimum COP requirements.

Table (9.1)
Standard Rating Conditions for Air-Cooled Unitary Air Conditioner

Mode	Condenser Ambient	Room Air Entering Equipment
Cooling	35^{o}C d.b.	26.7^{o}C d.b./19.4^{o}C w.b.
Heating	7^{o}C d.b./6^{o}C w.b.	21^{o}C d.b.

Table (9.2)
Standard Rating Conditions for Water-Cooled Unitary Air Conditioner

Mode	Entering Water Temp.	Room Air Entering Equipment
Cooling	29.5^{o}C	26.7^{o}C d.b./19.4^{o}C w.b.

Table (9.3)
Standard Rating Conditions for Air-Cooled Water Chillers

Mode	Condenser Ambient Temp.	Chilled Water Temp.	
		In	Out
Cooling	35^{o}C	12.5^{o}C	7^{o}C

Table (9.4)
Standard Rating Conditions for Water-Cooled Water Chillers

Mode	Condenser Water Temp.		Chilled Water Temp.	
	In	Out	In	Out
Cooling	32°C	37°C	12.5°C	7.0°C

Table (9.5)
Minimum COP for Air-Cooled Unitary Air Conditioner
(including Single Package and Split Type)

Capacity Range (kW)	10 and Below	Above 10 & Below 40	40 to 200	Above 200
Minimum COP (Cooling mode)	Comply with latest requirements on Grade 3 Energy Label or better in The Hong Kong Voluntary Energy Efficiency Labelling Scheme for Room Coolers, EMSD. #	2.4	2.4	2.6
		3 for VRV	2.9 for VRV	
Minimum COP - Heat Pump (Heating Mode)		2.7	2.8	2.9
VRV: Capacity control through variation of refrigerant volume flow. #: Available for download at http://www.emsd.gov.hk/emsd/eng/pee/eels_sch_doc.shtml				

Table (9.6)
Minimum COP for Water-Cooled Unitary Air Conditioner

Capacity Range (kW)	All Ratings
Minimum COP (cooling mode)	3

Table (9.7)
Minimum COP for Air-Cooled Water Chiller with Reciprocating Compressors

Capacity Range (kW)	below 400	400 and above
Minimum COP (Cooling)	2.6	2.8

Table (9.8)
Minimum COP for Air-Cooled Water Chiller with Centrifugal Compressors

Capacity Range (kW)	All Ratings
Minimum COP (Cooling)	2.8

Table (9.9a)
Minimum COP for Air-Cooled Water Chiller with Scroll Compressors

Capacity Range (kW)	All Ratings
Minimum COP (Cooling)	2.7

Table (9.9b)
Minimum COP for Air-Cooled Water Chiller with Screw Compressors

Capacity Range (kW)	All Ratings
Minimum COP (Cooling)	2.9

Table (9.10)
Minimum COP for Water-Cooled Water Chiller with Reciprocating Compressors

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	3.4	3.9	4.1

Table (9.11)
Minimum COP for Water-Cooled Water Chiller with Centrifugal Compressors

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	4	4.5	5.7

Table (9.12a)
Minimum COP for Water-Cooled Water Chiller with Scroll Compressors

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	4	4.5	5.2

Table (9.12b)
Minimum COP for Water-Cooled Water Chiller with Screw Compressors

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	4.6	4.6	5.5

9.2 Field-assembled Equipment & Components

When components from more than one manufacturer are used as parts of AC equipment with a rating above 10 kW of cooling/heating capacity, the overall system efficiency (COP), based on component efficiency provided by the component manufacturers, shall also satisfy the requirements of clause (9.1).

9.3 Part Load Performance

The AC equipment shall also be of energy efficient type at part load conditions.

10. SUBMISSION OF INFORMATION

The following standard forms are relevant to the provision of information for this Code:

FORM AC-G1 : AC Installations Summary
FORM AC-G2(1) : Design Parameters Worksheet
FORM AC-G2(2) : Design Parameters Worksheet
FORM AC-G3(1) : AC Systems and Controls Worksheet
FORM AC-G3(2) : AC Systems and Controls Worksheet
FORM AC-G3(3) : AC Systems and Controls Worksheet
FORM AC-D1 : Air Duct Leakage Test Worksheet
FORM AC-EQ1 : AC Equipment Efficiency Worksheet
FORM AC-F1 : Fan Motor Power Worksheet
FORM AC-F2 : Fan Motor Power Worksheet.

Job Ref. No. ______________________
[for office use only]

AC Installations Summary	Form AC-G1

Project/Building* Name : ____

AC Installation Works Completion Date : ______________________

AC Load	AC Area (m^2) ______________________
Calculated Block Cooling Load (kW)_________	Installed Total Plant Capacity (kW)______________________

Calculation Method : ☐ ASHRAE ☐ CIBSE ☐ Others ______________________(Please specify)
(tick where applicable) Note : Calculation details should be properly filed for ready retrieval.

Submitted AC Forms, Drawings, Catalog etc. (tick where applicable)

	No. of Sheets
☐ Form AC-G2 series (Design Parameters Worksheet)	
☐ Form AC-G3 series (AC Systems and Controls Worksheet)	
☐ Form AC-D1 (Air Duct Leakage Test Worksheet)	
☐ Form AC-F1 (Fan Motor Power Worksheet)	
☐ Form AC-EQ1 (AC Equipment Efficiency Worksheet)	
☐ Drawings (separate list to be provided)	
☐ Other supportive documents such as catalog, calculation etc. (separate list to be provided)	

Design Parameters Worksheet	Form AC-G2(1)

Part (A) : Outdoor Design Conditions (Clause 4.3)

Summer		Winter	
Design d.b. Temp. ^oC	Design R.H. %	Design d.b. Temp. ^oC	Design R.H. %

Part (B) : Indoor Design Conditions (Clause 4.2)

Applications/Zone Ref. (e.g. Offices, shops etc.)	Summer		Winter	
	Design d.b. Temp. ^oC	Design R.H. %	Design d.b. Temp. ^oC	Design R.H.%

Note : Design condition of each typical application/zone should be given. If different design conditions are adopted for the same type of application, these conditions should be given with different zone ref.

Design Parameters Worksheet	Form AC-G2(2)

Part (C) : Friction Loss (Clause 6.2)

System Ref. No.		Piping System Description	Friction Loss (Pa/m)
Primary chilled water			
Secondary chilled water			
Condenser water			

Part (D) : Insulation (Clause 8)

Applications[i] a) Chilled Water b) Refrigerant c) Air	Pipe Size[ii] dia.(mm)	Operating Conditions		Surface Coefficient h W/(m^2 ^{o}C)	Thermal [iv] Conductivity λ W/(m ^{o}C)	Calculated Thickness (mm)	Thickness Applied (mm)
		In/Out[iii] d.b. ^{o}C	RH %				

[i] Fill in a, b or c.
[ii] Only applicable for pipes. Fill in the outer diameters.
[iii] "In" denotes indoor & "Out" denotes outdoor.
[iv] The thermal conductivity should be rated at 20^{o}C mean

AC Systems and Controls Worksheet	Form AC-G3(1)
Part (A) : Air Distribution System (Clause 5.1)	
(Clause 5.1.1 - Separate Distribution System) Any air distribution system supplying air to both zones having special process temperature/humidity requirements and zones having only comfort requirements ?	
☐ Yes Sys. Ref.____________________ Separate distribution system or supplementary control provided? ☐ Yes ☐ No (Ref. clause 5.1.1) Exception : ☐ (a) ☐ (b)	☐ No
(Clause 5.1.2 - Air Leakage Limit On Ducts) Operating static pressure > 750 pa ?	
☐ Yes Sys. Ref. ____________________ (Ref. clause 5.1.2) Leakage Class : ☐ I ☐ II ☐ III	☐ No
Part (B) : Fan System (Clause 5.2)	
Any fan system with a total fan motor power ≥ 5 kW ?	
☐ Yes - including : ☐ CAV ☐ VAV ☐ Others ___________________	☐ No
Any individual VAV supply fan motor power ≥ 5 kW ?	
☐ Yes - Volume control method : ☐ Variable speed drive ☐ Inlet guide vane ☐ Others_______________	☐ No
The fan motor power of the above VAV fan > 55% of design wattage at 50% of design air volume ?	
☐ Yes Sys. Ref. ____________________	☐ No
Note : Form AC-F1 & AC-F2 should be used for calculation of fan motor power of above fan systems.	
Part (C) : Pumping System (Clause 6.1)	
Any variable flow system ?	
☐ Yes - capable of reducing system flow to 50% or less ☐ Yes ☐ No (Ref. Clause 6.1) Exceptions : ☐ (a) ☐ (b) ☐ (c)	☐ No

AC Systems and Controls Worksheet		Form AC-G3(2)
Part (D) : Temperature Control (Clause 7.1)		
(Clause 7.1.1) Each AC system is provided with at least one automatic control device for regulation of temperature ?		
☐ Yes		☐ No
(Clause 7.1.2) Thermostatic controls for comfort cooling are capable of adjusting the set point up to 29^{o}C ?		
☐ Yes		☐ No
(Clause 7.1.3) Thermostatic controls for comfort heating are capable of adjusting the set point down to 16^{o}C ?		
☐ Yes		☐ No
(Clause 7.1.4) Thermostatic controls for both comfort cooling and heating are capable of providing a temperature range or dead band of at least 2 ^{o}C ?		
☐ Yes	☐ No Exceptions : Thermostats requiring manual changeover ? ☐ Yes ☐ No	☐ Not Applicable
Part (E) : Humidity Control (Clause 7.2)		
Any humidifier or dehumidifier installed for maintaining specific humidity level ?		
☐ Yes Zone Ref. ____________________		☐ No
Humidistat provided for the above purpose ?		
☐ Yes	☐ No	
Humidistat capable of preventing the humidifier to increase RH above 30% ?		
☐ Yes	☐ No	
Humidistat capable of preventing the dehumidifier to decrease RH below 60% ?		
☐ Yes	☐ No	

AC Systems and Controls Worksheet — Form AC-G3(3)

Part (F) : Zone Control (Clause 7.3)

(Clause 7.3.1)
Each AC zone controlled by individual thermostatic control ?

☐ Yes	☐ No Zone Ref. ________________ With exceptions (a) and (b) (para 7.3.1) ☐ Yes ☐ No

(Clause 7.3.2)
No zone control permit a) reheating, b) recooling or c) simultaneous heating and cooling to a zone ?

☐ Yes	☐ No Zone Ref. ________________ (Ref. clause 7.3.2) Exceptions : ☐ (a) ☐ (b) ☐ (c) ☐ (d) ☐ (e)

Part (G) : Off Hours Control (Clause 7.4)

(Clause 7.4.1)
Each AC system equipped with automatic controls capable of reducing energy use during non-use period of the zone ?

☐ Yes Control method : ________________ ____________________________ ____________________________	☐ No Sys. Ref. ________________ Exceptions : System with cooling/heating capacity not more than 10kW and with manual off-hour control ? ☐ Yes ☐ No

(Clause 7.4.2)
- ☐ For hotels, a single master switch provided at main entry door to each guest room or suite, or each room with a suite, that perform one of the following functions to reduce energy use during the period of non-use ?

☐ Yes ☐ No ☐ Not applicable.

☐ (a)
☐ (b)
☐ (c)

Air Duct Leakage Test Worksheet

Form AC-D1

Test Section :________________________________ Drawing No. : ________________________________

Total Surface Area of Tested Ducts

Width and depth or diameter (mm)	Periphery (mm)	Length (m)	Area (m^2)
		Total	

Design Data

Total duct surface area (m^2)	
Total surface area under test (m^2) [From above table]	
Duct operating static pressure - *p* (Pa)	
Air leakage class [From Table (5.1)]	
Air leakage limit (L/s per m^2) [From Table (5.1)]	
Maximum permitted leakage (L/s)	

Test Records Summary

Date of test	
Duct static pressure reading (Pa)	
Duration of test (min) [Not less than 10 minutes]	

AC Equipment Efficiency Worksheet

Form AC-EQ1

Equipment. Ref. No.	Unit Type (From Tables (9.5) to (9.12))	Quantity (No.)	Rated Capacity (kW)	Total Rated Capacity (kW)	Equipment Efficiency					Rating Standard of COP & PLV (to state standard (such as ARI), or other standards with details *)	Accredited Body (such as ARI)
					Rated COP at 100% load	Required COP (for office use)	Rated PLV (to be provided for equipment above 10kW)				
							75% load	50% load	25% load		
Total											

* details to include as appropriate: condenser water entering temperature, water flow rate & fouling factor, condenser entering air conditions, evaporator water leaving temperature, flow rate & fouling factor, refrigerant saturated discharge temperature & liquid temperature etc.

Fan Motor Power Worksheet

Form AC-F1

☐ Constant Air Volume System ☐ Variable Air Volume System

System Ref. No.	Supply Air (L/s)	Supply Fan			Return Fan			Pre-treated Air Fan				Exhaust Fan				Total fan motor power (kW)
		FSP_s (kW)	η_m	η_d	FSP_r (kW)	η_m	η_d	FSP_p (kW)	η_m	η_d	$\Re_p$	FSP_e (kW)	η_m	η_d	$\Re_e$	
Total Q															Total P_T	

Notes :

Q - Air flow rate (L/s)
FSP_x - Fan shaft power or fan brake power of respective motor in kW.
η_m - Motor efficiency of respective motor.
η_d - Drive/belt efficiency of respective fan drive.
$\Re_p$ - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.
$\Re_e$ - Ratio of exhausted air quantity extracted from the fan system to the total air quantity handled by the exhaust fan.
P_T = Total fan motor power in kW
= $FSP_s/(\eta_m \times \eta_d) + FSP_r/(\eta_m \times \eta_d) + (FSP_p \times \Re_p)/(\eta_m \times \eta_d) + (FSP_e \times \Re_e)/(\eta_m \times \eta_d)$.
P_f = Total fan motor power for air treatment/filtering in kW.
☐ - Tick where applicable.

Total fan motor power $(P_T - P_f) \geq 5$ kW ? [P_f = ____ kW (From Form AC-F2)]

☐ If no, clause (5.2) is not applicable.
☐ If yes, then

☐ CAV System $(P_T - P_f) \times 1000/Q$ = ______W per L/s ≤ **1.6 W per L/s**

☐ VAV System $(P_T - P_f) \times 1000/Q$ = ______W per L/s ≤ **2.1 W per L/s**

For exempted systems stipulated in (a) & (b) of clause 5.2.1 (page 6) in this Code, fans and corresponding motor efficiencies have to be listed.

N.A. - Not Applicable.

Fan Motor Power Worksheet			Form AC-F2
System Ref. No.:			
Supply Fan Filtering Sys.	Air Flow Rate	V (m^3/s)	
	Clean Air Pressure Drop	P_d (Pa)	
	Fan Efficiency	η_f	
	Motor Efficiency	η_m	
	Drive/Belt Efficiency	η_d	
	Additional Motor Power	P_f (kW)	
Return Fan Filtering Sys.	Air Flow Rate	V (m^3/s)	
	Clean Air Pressure Drop	P_d (Pa)	
	Fan Efficiency	η_f	
	Motor Efficiency	η_m	
	Drive/Belt Efficiency	η_d	
	Additional Motor Power	P_f (kW)	
Pre-treated Air Fan Filtering Sys.	Air Flow Rate	V (m^3/s)	
	Clean Air Pressure Drop	P_d (Pa)	
	Fan Efficiency	η_f	
	Motor Efficiency	η_m	
	Drive/Belt Efficiency	η_d	
	Ratio of pre-treated air quantity supplied to the system to the total air quantity handled by the pre-treated air fan	$\Re_p$	
	Additional Motor Power	P_f (kW)	
Exhaust Fan Filtering Sys.	Air Flow Rate	V (m^3/s)	
	Clean Air Pressure Drop	P_d (Pa)	
	Fan Efficiency	η_f	
	Motor Efficiency	η_m	
	Drive/Belt Efficiency	η_d	
	Ratio of exhausted air quantity from the system to the total air quantity handled by the exhaust fan	$\Re_e$	
	Additional Motor Power	P_f (kW)	
		Total P_f (kW)	

Notes:
P_f = V x (P_d - 250)/(η_f x η_m x η_d). For pre-treated air fan and exhaust fan filtering systems, multiply $\Re_p$ & $\Re_e$ respectively.
Total P_f = Sum of the additional motor power of all filtering systems.

Appendix A : Sample Calculation for Minimum Insulation Thickness

Example 1

A 100 mm dia. (OD= 114.3mm) steel pipe carrying 5^0C Chilled water runs through a plant room at an indoor condition of 30 ^{0}C, 95% R.H. and still air. The pipe is to be insulated with insulation material of thermal conductivity of 0.03 W/m ^{0}C and protected by polished aluminium cladding with a surface coefficient of 5.7 W/m^2 ^{0}C. Calculate the minimum insulation thickness by using Eq. 8-1 and Eq 8-2 from clause (8.2).

The dew point temperature for air at 30 ^{0}C, 95% R.H. is 29.1 ^{0}C. The provisional thickness is :

$\chi = 10^3 \times \lambda/h \times \{(\theta_d - \theta_i)/(\theta_m - \theta_d)\}$ --- Eq. 8-1

$= 10^3 \times 0.03/5.7 \times \{(29.1 – 5)/(30 – 29.1)\}$

$= 140.94$mm

By iteration of Eq. 8-2 :

$\chi = 0.5(d_0 + 2 L_a) \times \ln [1 + 2L_a / d_o]$

for d_0 = 114.3mm, then :

L_a	χ
85	129.53
90	139.17
91	141.12

The minimum insulation thickness is 91 mm.

Example 2

A 1000 x 800 mm air duct carrying 15 ^{0}C cold air runs beneath the outdoor canopy at an outdoor condition of 35 ^{0}C, 95% and wind speed of 1 m/s. The air duct is to be insulated with insulation material of thermal conductivity of 0.045 W/m-K and protected by polished aluminium cladding with a surface coefficient of W/m^2 K. Calculate the minimum insulation thickness by using Eq. 8-1 and Eq. 8-3 from clause (8.4).

The dew point temperature for air at 35 ^{0}C, 95% R.H. is 34.1 ^{0}C. The provisional thickness is :

$\chi = 10^3 \times \lambda/h \times \{(\theta_d - \theta_i)/(\theta_m - \theta_d)\}$ --- Eq. 8-1

$= 10^3 \times 0.045/5.7 \times \{(34.1 – 15)/(35 – 34.1)\}$

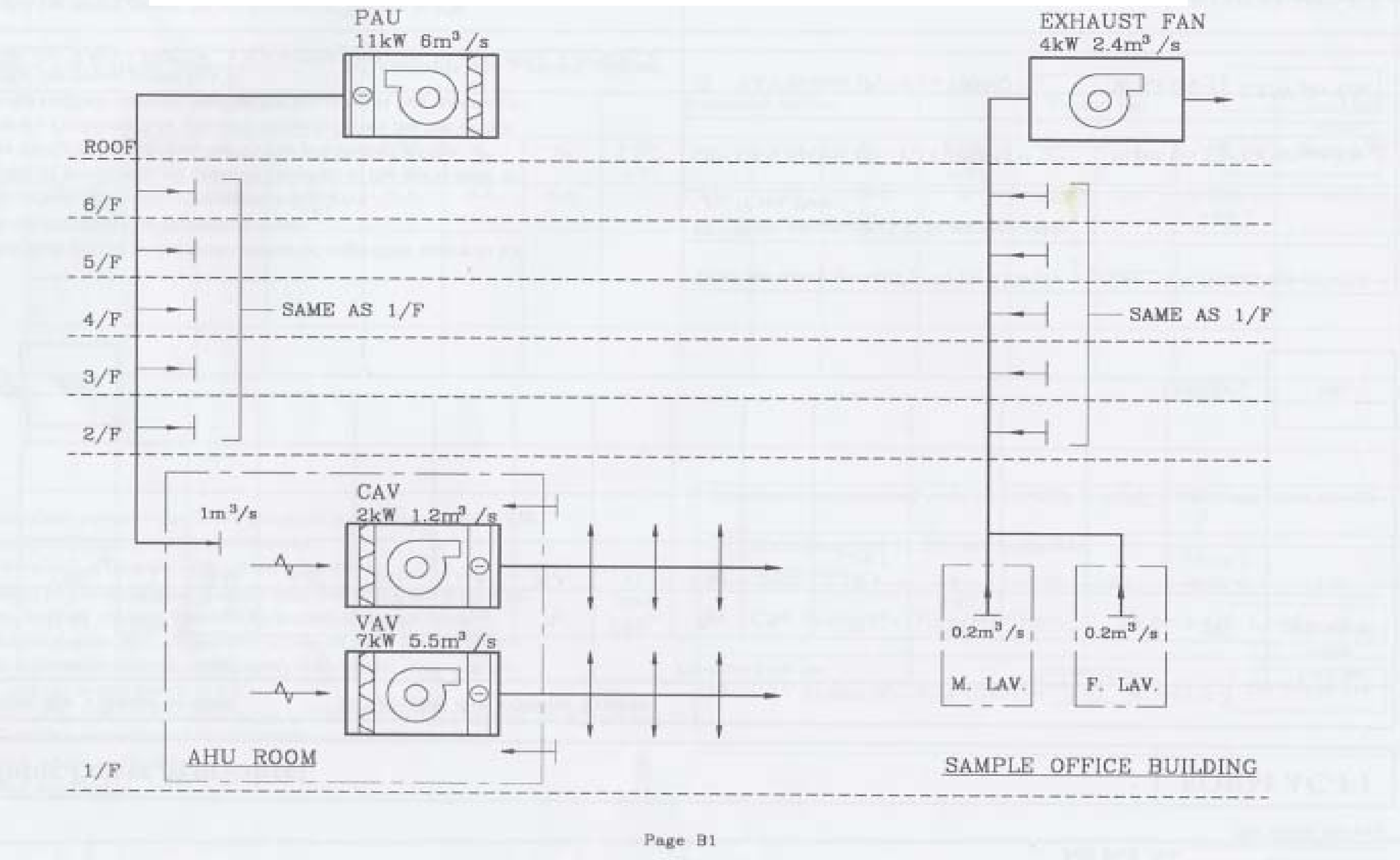
$= 167.54$mm

From Eq. 8-3 : $\chi = L_a$

The minimum insulation thickness is 168 mm.

Appendix B : Sample Calculation for Fan Motor Power

(Refer to following pages 33 & 34 for calculations)



Fan Motor Power Worksheet

Sheet 1 of (2) | **Form AC-F1**

☑ Constant Air Volume System ☐ Variable Air Volume System

System Ref. No.	Supply Air (L/s)	Supply Fan			Return Fan			Pre-treated Air Fan				Exhaust Fan				Total fan motor power (kW)
		FSP_s (kW)	η_m	η_d	FSP_r (kW)	η_m	η_d	FSP_p (kW)	η_m	η_d	$\Re_p$	FSP_e (kW)	η_m	η_d	$\Re_e$	
1F-CA01	1200	2	0.84	0.97	N.A.	N.A.	N.A.	11	0.86	0.97	1/6 x 1.2/6.7	4	0.82	0.97	0.4/2.4 x1.2/6.7	3.00
Total Q	1200														Total P_T	3.00

Notes :

FSP_x - Fan shaft power or fan brake power of respective motor in kW.

η_m - Motor efficiency of respective motor.

η_d - Drive/belt efficiency of respective fan drive.

$\Re_p$ - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.

$\Re_e$ - Ratio of exhausted air quantity extracted from the fan system to the total air quantity handled by the exhaust fan.

P_T = Total fan motor power in kW

= $FSP_s/(\eta_m \times \eta_d) + FSP_r/(\eta_m \times \eta_d) + (FSP_p \times \Re_p)/(\eta_m \times \eta_d) + (FSP_e \times \Re_e)/(\eta_m \times \eta_d)$.

P_f = Total fan motor power for air treatment/filtering in kW.

☐ - Tick where applicable.

Total fan motor power(P_T - P_f) ≥ 5 kW ? [P_f = N.A. kW (From Form AC-F2)]

☑ If no, clause (5.2) is not applicable.

☐ If yes, then

☐ CAV System (P_T - P_f) x 1000/Q = _____W per L/s ≤ **1.6 W per L/s**

☐ VAV System (P_T - P_f) x 1000/Q = _____W per L/s ≤ **2.1 W per L/s**

For exempted systems stipulated in (a) & (b) of clause 5.2.1 (page 6) in this Code, fans and corresponding motor efficiencies have to be listed.

N.A. - Not Applicable.

Fan Motor Power Worksheet

Sheet 2 of (2) **Form AC-F1**

☐ Constant Air Volume System ☑ Variable Air Volume System

System Ref. No.	Supply Air (L/s)	Supply Fan			Return Fan			Pre-treated Air Fan				Exhaust Fan				Total fan motor power (kW)
		FSP_s (kW)	η_m	η_d	FSP_r (kW)	η_m	η_d	FSP_p (kW)	η_m	η_d	$\Re_p$	FSP_e (kW)	η_m	η_d	$\Re_e$	
1F-VA01	5500	7	0.94	0.97 x 0.95	N.A.	N.A.	N.A.	11	0.86	0.97	1/6 x 5.5/6.7	4	0.82	0.97	0.4/2.4 x 5.5/6.7	10.57
Total Q	5500														Total P_T	10.57

<u>Notes</u> :

FSP_x - Fan shaft power or fan brake power of respective motor in kW.

η_m - Motor efficiency of respective motor.

η_d - Drive/belt efficiency of respective fan drive.

$\Re_p$ - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.

$\Re_e$ - Ratio of exhausted air quantity extracted from the fan system to the total air quantity handled by the exhaust fan.

P_T = Total fan motor power in kW

$= FSP_s/(\eta_m \times \eta_d) + FSP_r/(\eta_m \times \eta_d) + (FSP_p \times \Re_p)/(\eta_m \times \eta_d) + (FSP_e \times \Re_e)/(\eta_m \times \eta_d)$.

P_f = Total fan motor power for air treatment/filtering in kW.

☐ - Tick where applicable.

Total fan motor power(P_T - P_f) ≥ 5 kW ? [P_f = <u>N.A.</u> kW (From Form AC-F2]

☐ If no, clause (5.2) is not applicable.

☑ If yes, then

☐ CAV System (P_T - P_f) x 1000/Q = _____W per L/s ≤ **1.6 W per L/s**

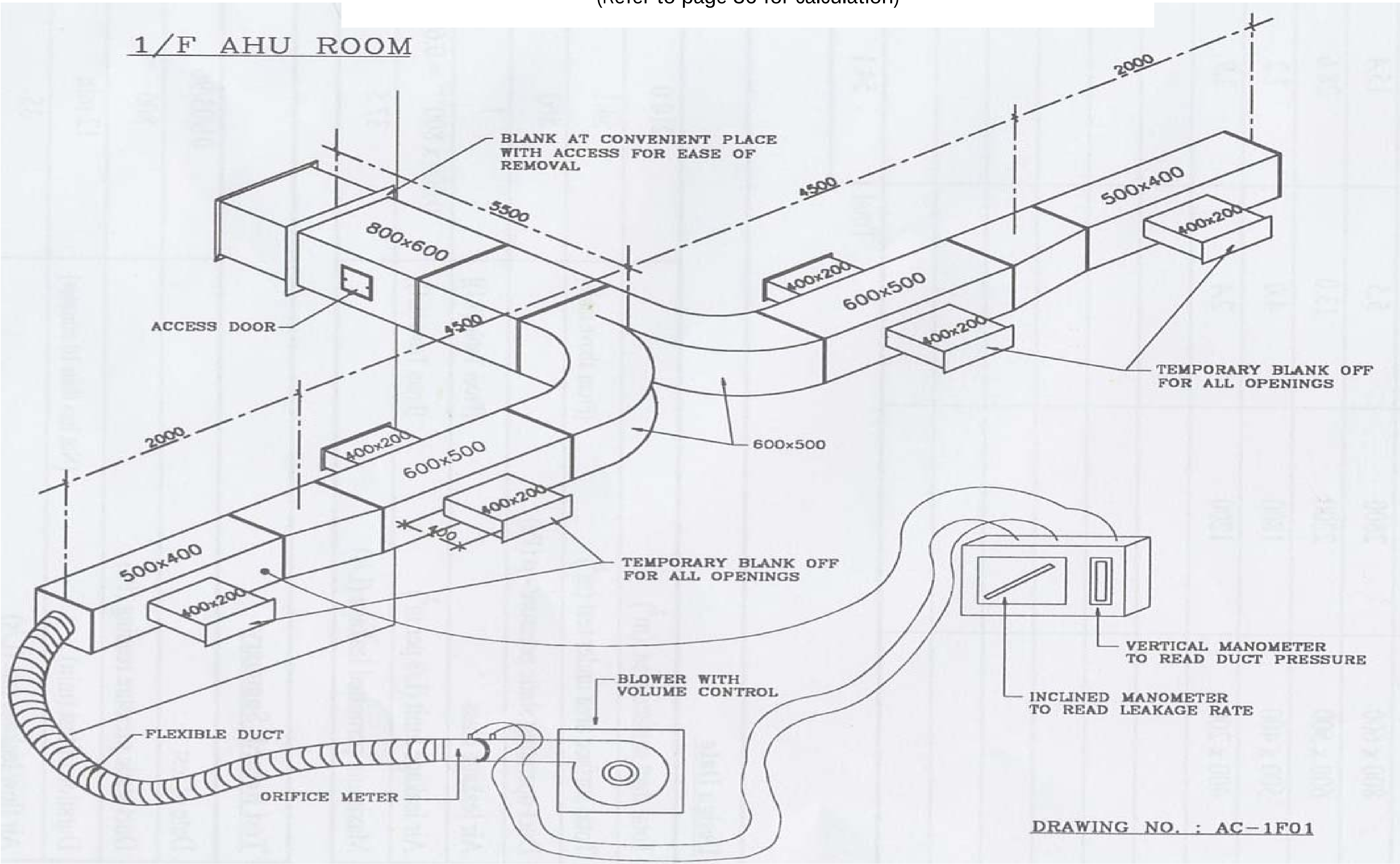
☑ VAV System (P_T - P_f) x 1000/Q = <u>1.92</u> W per L/s ≤ **2.1 W per L/s**

For exempted systems stipulated in (a) & (b) of clause 5.2.1 (page 6) in this Code, fans and corresponding motor efficiencies have to be listed.

N.A. - Not Applicable.

Appendix C : Sample Calculation for Air Duct Leakage Test

(Refer to page 36 for calculation)



Air Duct Leakage Test Worksheet			Form AC-D1
Test Section : 1st floor, west wing supply system		Drawing No. : AC-1F01	
Total Surface Area of Tested Ducts			
Width and depth or diameter (mm)	Periphery (mm)	Length (m)	Area (m^2)
800 x 600	2800	5.5	15.4
600 x 500	2200	13.0	28.6
500 x 400	1800	4.0	7.2
400 x 200	1200	2.4	2.9
		Total	54.1

Design Data

Total duct surface area (m^2)		210.0
Total surface area under test (m^2)	[From above table]	54.1
Duct operating static pressure - p (Pa)		800
Air leakage class	[From Table (5.1)]	I
Air leakage limit (L/s per m^2)	[From Table (5.1)]	$0.009 \times 800^{0.65} = 0.694$
Maximum permitted leakage (L/s)		37.5

Test Records Summary

Date of test		01/03/96
Duct static pressure reading (Pa)		800
Duration of test (min)	[Not less than 10 minutes]	12 min
Air flow leakage rate (L/s)		35

Energy Efficiency EMSD
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