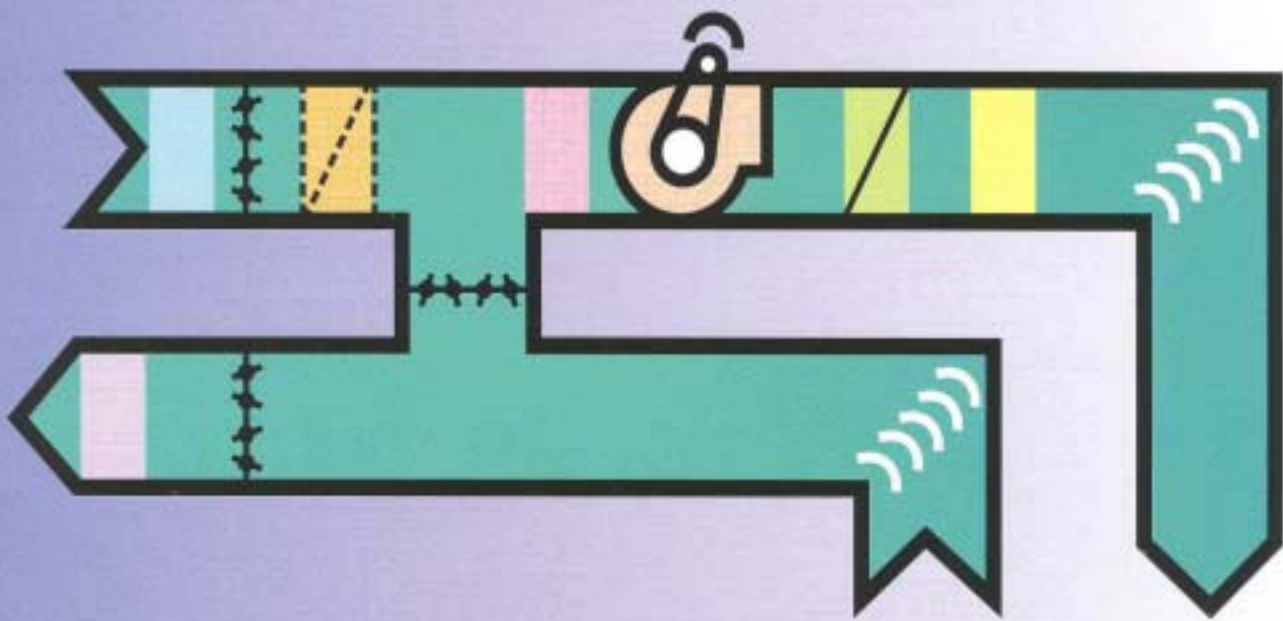


CODE OF PRACTICE FOR

Energy Efficiency of Air Conditioning Installations

2005 EDITION



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 addresses energy efficiency requirements on building services installations. Designers are encouraged to adopt a proactive approach to exceed the minimum requirements.

This code was developed by the *Task Force on Air Conditioning Code* that was established under the *Energy Efficiency & Conservation Sub-committee* of the *Energy Advisory Committee*. The Task Force members include -

Convenor: Mr. Ronald S. Chin (Electrical & Mechanical Services Department)

Members :

Mr. Artur Au-Yeung	(The Hong Kong Institute of Architects)
Mr. M. Chan	(Environmental Protection Department)
Mr. Matthew Cheung	(The Hong Kong Institution of Engineers)
Mr. S.F. Chow	(China Light and Power Company Limited)
Mrs. Terry Chow	(The Hongkong Electric Company Limited)
Mr. Kevin K.K. Chung	(The Hong Kong Institute of Surveyors)
Mr. Carl Lam	(Electrical & Mechanical Services Department)
Mr. W.K. Lam	(The Hong Kong E&M Contractors' Association Ltd.)
Mr. Victor Law	(Air Conditioning & Refrigeration Association of Hong Kong)
Mr. W.K. Pau	(ASHRAE, Hong Kong Chapter)
Dr. Francis Yik	(The Hong Kong Polytechnic University)

Secretary : Mr. H.K. Wong (Electrical & Mechanical Services Department)

This Code was first published in 1998 by the Electrical & Mechanical Services Department.

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.

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

Amendment to 1998 Edition

To suit changes in technological advancement, there are the following amendments, which were agreed in meetings of ad-hoc code review task force with members from representative organizations in the building industry:

- Second paragraph of Sub-Sections 5.2.2 and 5.2.3.1
- Table (9.3):- Standard Rating Conditions for Air-Cooled Water Chillers;
- Table (9.4):- Standard Rating Conditions for Water-Cooled Water Chillers;
- Table (9.5):- Minimum COP for Air-Cooled Unitary Air Conditioner;
- Table (9.6):- Minimum COP for Water-Cooled Unitary Air Conditioner.

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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. It should be calculated from fan shaft power/fan brake power divided by motor efficiency and drive efficiency and 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.
- “ 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 : $W/m^2 \cdot ^\circ C$)”** 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 : $W/m \cdot ^\circ C$)” 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°C
Minimum relative humidity	50%

Other Applications except Office and Classroom

Minimum dry bulb temperature	22°C
Minimum relative humidity	50%

Winter

Hotel

Maximum dry bulb temperature	24°C
Maximum relative humidity	50%

Other Applications except Hotel

Maximum dry bulb temperature	22°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°C
Maximum relative humidity	68%

Winter

Minimum dry bulb temperature	7°C
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 should be served by air distribution systems separate from those serving the zones requiring only comfort conditions; or should 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 100m².

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 should 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 should satisfy paragraph(5.2.2) or paragraph(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.

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 should 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 should 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 should 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 should 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 should 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 should not exceed 400 Pa/m. The designer should also consider lower friction loss for noise or erosion control.

7. CONTROL

7.1 Temperature Control

- 7.1.1 Each AC system should 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 should 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 should 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 should be controlled by individual thermostatic control corresponding to temperature within the zone. As a minimum each floor of a building should 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 should 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 should 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 paragraph(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) :-

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

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

$$\chi = L_a \quad \text{(Equation 8-3) for ductworks and AHU casings}$$

- 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/(m² °C)
- λ = Thermal conductivity of insulating material - W/(m °C)
- θ_d = Dew point temperature - °C
- θ_l = Temperature of the cold surface(line temperature) - °C
- θ_m = Temperature of the ambient still air - °C

8.3 Piping Insulation

8.3.1 Chilled Water Pipe

All chilled water pipes should be insulated with minimum insulation thickness in accordance with paragraph(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)				
Nominal size of Pipe(mm) ⁽¹⁾	Thermal Conductivity ⁽²⁾ , λ - W/(m °C)			
	0.024		0.04	
	Indoor Conditions (still air)		Indoor Conditions (still air)	
	28°C, 80% RH	30°C, 95% RH	28°C, 80% RH	30°C, 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°C mean for fluid operating temperature of 5°C.

(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	
Nominal size of Pipe(mm) ⁽¹⁾	Outdoor Conditions (wind speed = 1m/s)		Outdoor Conditions (wind speed = 1m/s)	
	35°C, 95% RH $h^{(3)}=9$	35°C, 95% RH $h^{(3)}=13.5$	35°C, 95% RH $h^{(3)}=9$	35°C, 95% RH $h^{(3)}=13.5$
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 paragraph(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									
Outer Diameter of Pipe(mm) ⁽¹⁾	Fluid Operating Temperature								
	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

- Note :
- (1) The above 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) The insulation thickness in above table is 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(8.4) : 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; $h^{(3)}=10$									
Outer Diameter of Pipe(mm) ⁽¹⁾	Fluid Operating Temperature								
	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 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) The insulation thickness in above table is 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; $h^{(3)}=13.5$									
Outer Diameter of Pipe(mm) ⁽¹⁾	Fluid Operating Temperature								
	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 above 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) The insulation thickness in above table 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 and AHU casings carrying warmed or chilled air should be insulated with a minimum insulation thickness in accordance with paragraph(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, should have a minimum coefficient of performance(COP) at the following specified rating conditions as listed in Table(9.1) through Table(9.4). 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°C d.b.	26.7°C d.b./19.4°C w.b.
Heating	7°C d.b./6°C w.b.	21°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°C	26.7°C d.b./19.4°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°C	12.5°C	7°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 but excluding Room Cooler)

Capacity Range (kW)	Above 10 and Below 40	40 to 200	Above 200
Minimum COP (Cooling mode)	2.4	2.4	2.6
Minimum COP -Heat Pump (Heating Mode)	2.7	2.8	2.9

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

Capacity Range (kW)	All Ratings
Minimum COP (cooling mode)	2.7

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

Capacity Range (kW)	below 400	400 and above
Minimum COP (Cooling)	2.4	2.7

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

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

Table (9.9)
Minimum COP for Air-Cooled Water Chiller w/Screw or Scroll Compressors

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

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

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	3.2	3.7	4.0

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

Capacity Range (kW)	Below 500	500 to 1000	Above 1000
Minimum COP (Cooling)	3.8	4.2	5.2

Table (9.12)
Minimum COP for Water-Cooled Water Chiller w/ Screw or Scroll Compressors

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

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, should also satisfy the requirements of paragraph(9.1).

10. SUBMISSION OF INFORMATION

The following information and calculations should be submitted on the standard forms set out in the schedule of this Code:

- (a) Installations summary on **Form AC-G1**.
- (b) Design parameters on **Form AC-G2(1) to AC-G2(3)**.
- (c) AC systems and controls on **Form AC-G3(1) to AC-G3(4)**.
- (d) Air duct leakage test results on **Form AC-D1**.
- (e) AC equipment efficiency on **Form AC-EQ1**.
- (f) Fan motor power calculations on **Form AC-F1 and AC-F2**.

Schedule of Forms

FORM AC-G1	-	AC Installations Summary.....	F1
FORM AC-G2(1)	-	Design Parameters Worksheet.....	F2
FORM AC-G2(2)	-	Design Parameters Worksheet.....	F3
FORM AC-G2(3)	-	Design Parameters Worksheet.....	F4
FORM AC-G3(1)	-	AC Systems and Controls Worksheet.....	F5
FORM AC-G3(2)	-	AC Systems and Controls Worksheet.....	F6
FORM AC-G3(3)	-	AC Systems and Controls Worksheet.....	F7
FORM AC-G3(4)	-	AC Systems and Controls Worksheet.....	F8
FORM AC-D1	-	Air Duct Leakage Test Worksheet.....	F9
FORM AC-EQ1	-	AC Equipment Efficiency Worksheet.....	F10
FORM AC-F1	-	Fan Motor Power Worksheet.....	F11
FORM AC-F2	-	Fan Motor Power Worksheet.....	F12

AC Installations Summary	Form AC-G1
---------------------------------	-------------------

Part (A) : General Information of AC Installation

Project/Building* Name : _____	
Project/Building* Address : _____	
Type of Building : Office/Hotel/Others* _____	
AC Installation Works : Expected Start Date : _____ Expected 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)	
Note : Calculation details should be submitted.	

Part (B) : Submitted AC Forms

AC Forms	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)	

Note : All paragraphs quoted in the above forms are referred to the corresponding paragraphs of the AC Code of Practice.

- * - delete as appropriate
- tick where applicable

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

E. Humidity Control (Paragraph 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	

F. Zone Control (Paragraph 7.3)

(Paragraph 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
(Paragraph 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. paragraph 7.3.2) Exceptions : (a) (b) (c) (d) (e)

AC Systems and Controls Worksheet	Form AC-G3(4)
--	----------------------

G. Off Hours Control (Paragraph 7.4)

(Paragraph 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 ? <div style="text-align: right;"> Yes No </div>	
(Paragraph 7.4.2) <input type="checkbox"/> 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 (a) (b) (c)	No	Not applicable.

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			

<u>Design Data</u>	
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)	

<u>Test Records Summary</u>	
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)	Unit Efficiency(COP)		Rating Standard	Accredited Body
					Rated	Required COP (for office use)		
Total								

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	℞ _p	FSP _e (kW)	η _m	η _d	℞ _e		
Total Q		Total P _T															

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.
- ℞_p - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.
- ℞_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 / (η_m × η_d) + FSP_r / (η_m × η_d) + (FSP_p × ℞_p) / (η_m × η_d) + (FSP_e × ℞_e) / (η_m × η_d).
- P_f = Total fan motor power for air treatment/filtering in kW.
 - Tick where applicable.
- N.A. - Not Applicable.

Total fan motor power (P_T - P_f) ≥ 5 kW [P_f = _____ kW (From Form AC-F2)]

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

CAV System (P_T - P_f) × 1000/Q = _____ W per L/s ≤ **1.6 W per L/s**

VAV System (P_T - P_f) × 1000/Q = _____ W per L/s ≤ **2.1 W per L/s**

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	\mathfrak{R}_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	\mathfrak{R}_e	
	Additional Motor Power	P_f (kW)	
Total P_f (kW)			

Notes:

$P_f = V \times (P_d - 250) / (\eta_f \times \eta_m \times \eta_d)$. For pre-treated air fan and exhaust fan filtering systems, multiply \mathfrak{R}_p & \mathfrak{R}_e respectively.

Total P_f = Sum of the additional motor power of all filtering systems.

Appendix

PART A

Sample Calculation of Insulation Thickness

PART A : Example Of Calculation of Insulation Thickness

Example 1

A 100 mm dia. (OD= 114.3mm) steel pipe carrying 5°C Chilled water runs through a plant room at an indoor condition of 30 °C, 95% R.H. and still air. The pipe is to be insulated with insulation material of thermal conductivity of 0.03 W/m °C and protected by polished aluminium cladding with a surface coefficient of 5.7 W/m² °C. Calculate the minimum insulation thickness by using Eq. 8-1 and Eq 8-2 from paragraph (8.2).

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

$$\begin{aligned}\chi &= 10^3 \times \lambda/h \times \{(\theta_d - \theta_i)/(\theta_m - \theta_d)\} && \text{--- Eq. 8-1} \\ &= 10^3 \times 0.03/5.7 \times \{(29.1 - 5)/(30 - 29.1)\} \\ &= 140.94\text{mm}\end{aligned}$$

By iteration of Eq. 8-2 :

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

for $d_0 = 114.3\text{mm}$, 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 °C cold air runs beneath the outdoor canopy at an outdoor condition of 35 °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/m² K. Calculate the minimum insulation thickness by using Eq. 8-1 and Eq. 8-3 from paragraph (8.4).

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

$$\begin{aligned}\chi &= 10^3 \times \lambda/h \times \{(\theta_d - \theta_i)/(\theta_m - \theta_d)\} && \text{--- Eq. 8-1} \\ &= 10^3 \times 0.045/5.7 \times \{(34.1 - 15)/(35 - 34.1)\} \\ &= 167.54\text{mm}\end{aligned}$$

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

The minimum insulation thickness is 168 mm.

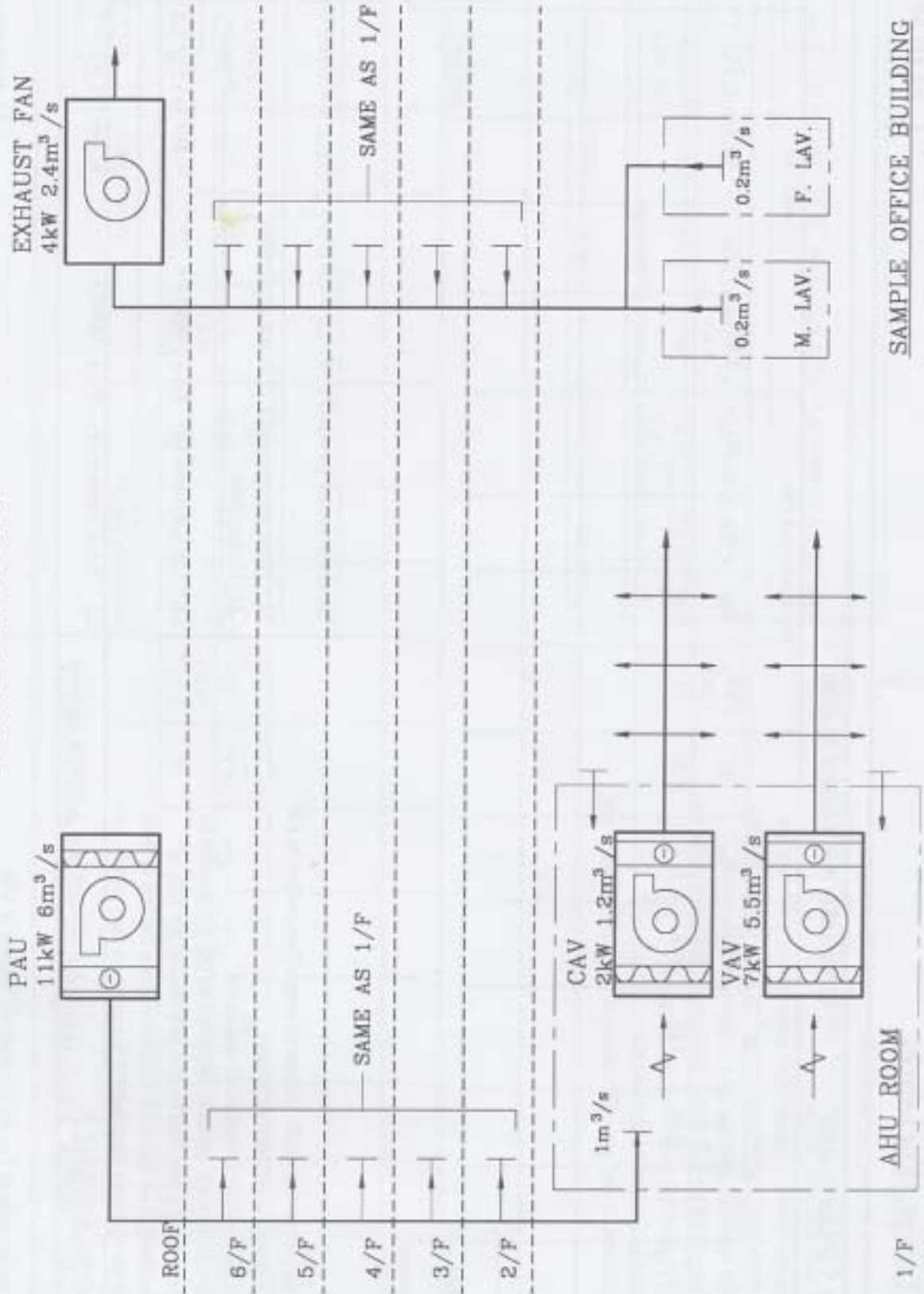
Appendix

PART B

Sample Calculation of Fan Motor Power

PART B SAMPLE CALCULATION FOR FAN POWER

(Refer to Page B2 & B3.)



SAMPLE OFFICE BUILDING

Fan Motor Power Worksheet	FORM AC-F1
----------------------------------	-------------------

<input checked="" type="checkbox"/> 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	℞ _p	FSP _e (kW)	η _m	η _d	℞ _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 x 1.2/6.7	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.
- ℞_p - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.
- ℞_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 / (η_m × η_d) + FSP_r / (η_m × η_d) + (FSP_p × ℞_p) / (η_m × η_d) + (FSP_e × ℞_e) / (η_m × η_d).
- P_f = Total fan motor power for air treatment/filtering in kW.
- Tick where applicable.
- N.A. - Not Applicable.

Total fan motor power (P _T - P _f) ≥ 5 kW [P _f = <u>N.A.</u> kW (From Form AC-F2)]
<input checked="" type="checkbox"/> If no, paragraph (5.2) is not applicable. If yes, then
CAV System (P _T - P _f) × 1000/Q = _____ W per L/s ≤ 1.6 W per L/s
VAV System (P _T - P _f) × 1000/Q = _____ W per L/s ≤ 2.1 W per L/s

Fan Motor Power Worksheet	FORM AC-F1
----------------------------------	-------------------

Constant Air Volume System		<input checked="" type="checkbox"/> 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	℞ _p	FSP _e (kW)	η _m	η _d	℞ _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

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.
- ℞_p - Ratio of pre-treated air quantity supplied to the fan system to the total air quantity handled by the pre-treated air fan.
- ℞_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 / (η_m × η_d) + FSP_r / (η_m × η_d) + (FSP_p × ℞_p) / (η_m × η_d) + (FSP_e × ℞_e) / (η_m × η_d).
- P_f = Total fan motor power for air treatment/filtering in kW.
- Tick where applicable.
- N.A. - Not Applicable.

Total fan motor power (P _T - P _f) ≥ 5 [P _f = <u>N.A.</u> kW (From Form AC-F2)] kW
If no, paragraph (5.2) is not applicable. <input checked="" type="checkbox"/> If yes, then
CAV System (P _T - P _f) × 1000/Q = _____ W per L/s ≤ 1.6 W per L/s
<input checked="" type="checkbox"/> VAV System (P _T - P _f) × 1000/Q = <u>1.92</u> W per L/s ≤ 2.1 W per L/s

Appendix

PART C

Sample Calculation for Air Duct Leakage Test

