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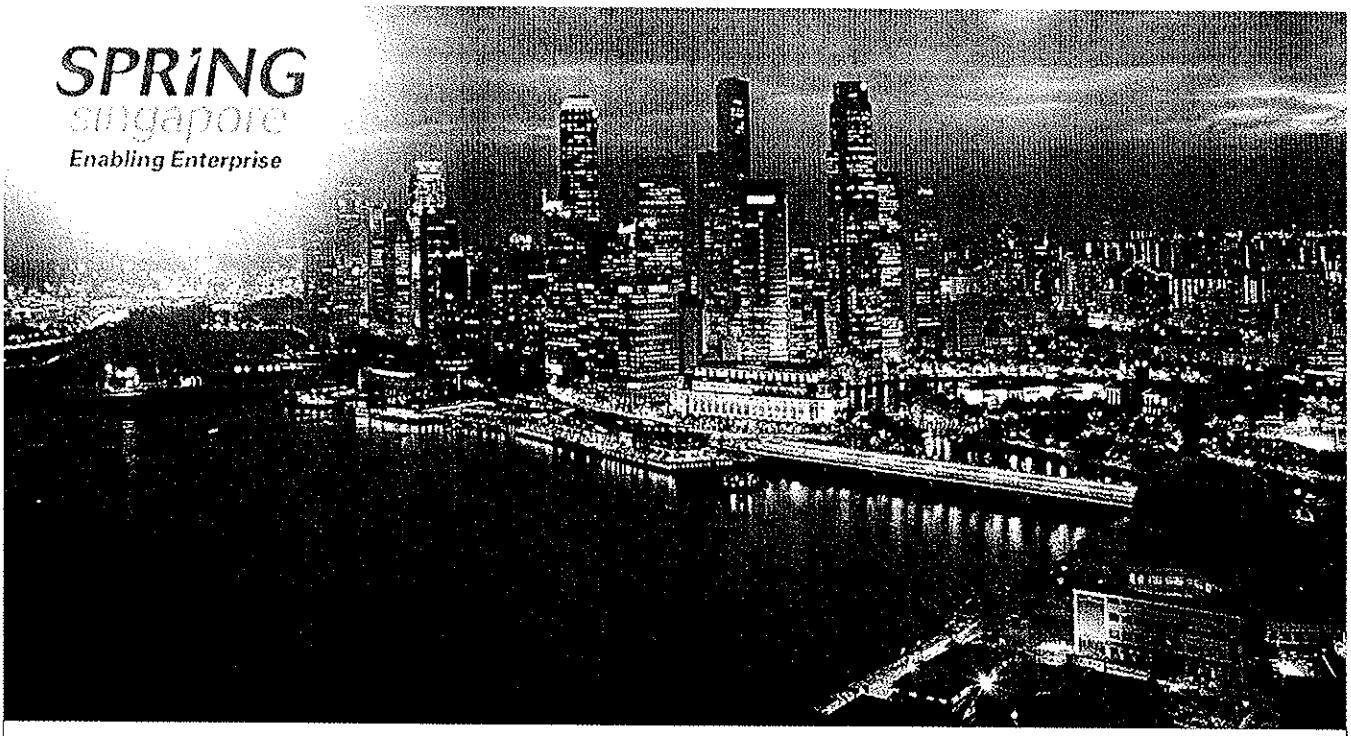

Highlights of the National Building & Construction Standards Committee

Er. Lee Chuan Seng
Deputy Chairman, Building and Construction Standards Committee

Objective

The Building and Construction Standards Committee (BCSC) champions the development, promotion and implementation of relevant building and construction standards to improve the quality, safety and productivity of the construction industry in Singapore.

Scope

- Develops, maintains, promotes and facilitates the use of Singapore Standards, including those referred to by the National Productivity and Quality Specifications (NPQS) or impacted by Eurocodes;
- Supports the government agencies to improve the safety and productivity at construction work sites
- Supports national efforts in the promotion of environmental sustainability
- Supports legislation of buildable design, the durability and maintainability of buildings through standardisation; and
- Managing stakeholders' expectations of Building & Construction standards

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Some of our industry partners

Industry

- Association of Consulting Engineers, Singapore (ACES)
- Institution of Engineers, Singapore (IES)
- Singapore Manufacturers' Federation (SMa)
- Real Estate Developers' Association of Singapore (REDAS)
- Singapore Contractors Association Ltd (SCAL)
- Singapore Institute of Architects (SIA)
- The Singapore Institute of Surveyors and Valuers (SISV)
- The Association of Property and Facility Managers (APFM)
- Singapore Institute of Building Ltd (SIBL)

Academia

- Nanyang Technological University (NTU)
- National University of Singapore (NUS)
- Singapore Polytechnic (SP)

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Some of our industry partners

Government

- Building and Construction Authority (BCA)
- Energy Market Authority (EMA)
- Singapore Civil Defence Force (SCDF)
- Housing and Development Board (HDB)
- Jurong Town Corporation (JTC)
- Land Transport Authority (LTA)
- Ministry of Manpower (MOM)
- National Environment Agency (NEA)
- Public Utilities Board (PUB)
- Urban Redevelopment Authority (URA)

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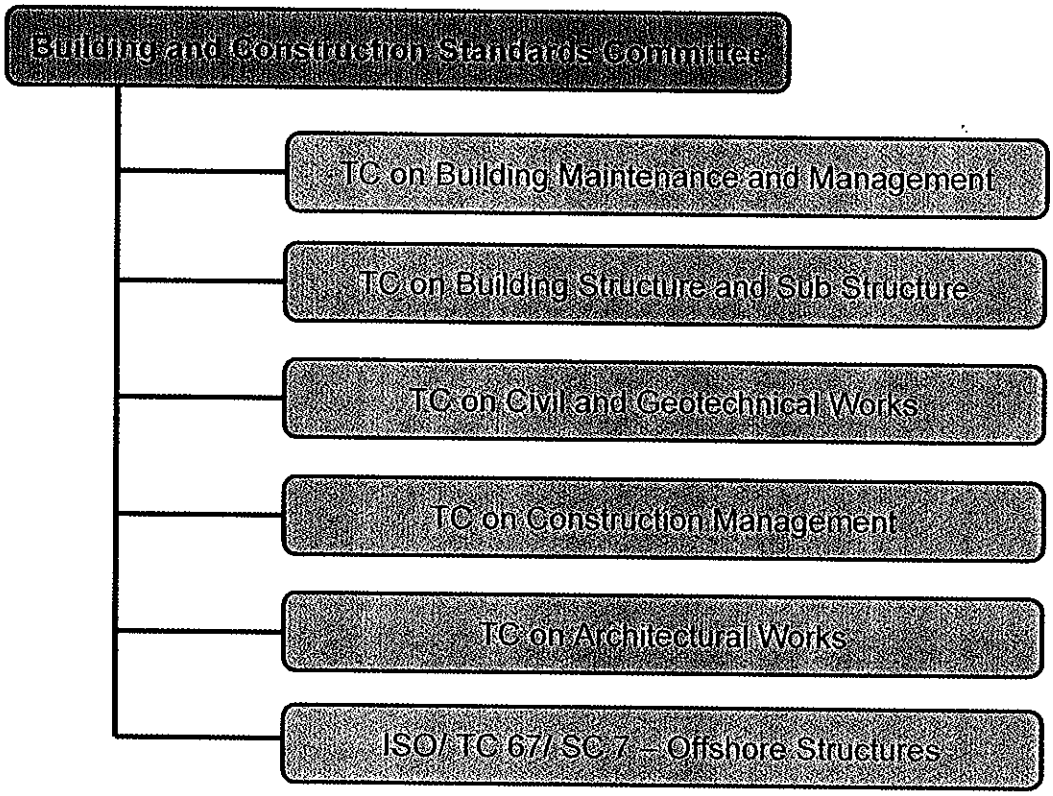
Committee Structure



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Recent standards published under the BCSC

Total number of existing standards under the BCSC: 199

Base code and National Annexes (NA) to the following parts of Eurocodes:

•NA to SS EN 1990 : 2008 Singapore National Annex to Eurocodes - Basis of structural design

•NA to SS EN 1991 - 1-1 : 2008 Singapore National Annex to Eurocode 1 : Actions on structures - Part 1-1: General actions - Densities, self-weight,imposed loads for buildings

•NA to SS EN 1991 - 1-2 : 2008 Singapore National Annex to Eurocode 1 : Actions on structures - Part 1-2 : General actions - Actions on structures exposed to fire

•NA to SS EN 1991 - 1-4 : 2009 Singapore National Annex to Eurocode 1 – Actions on structures. Part 1-4 : General actions – Wind actions

•NA to SS EN 1991 - 1-6 : 2009 Singapore National Annex to Eurocode 1 – Actions on structures. Part 1-6 : General actions – Actions during execution

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Recent standards published under the BCSC

Base code and National Annexes (NA) to the following parts of Eurocodes:

•NA to SS EN 1992 - 1-1 : 2008 Singapore National Annex to Eurocode 2 : Design of concrete structures - Part 1-1 General rules and rules for buildings

•NA to SS EN 1992 - 1-2 : 2008 Singapore National Annex to Eurocode 2 : Design of concrete structures - Part 1-2 General rules - Structural fire design

Material specifications:

•SS EN 197 - 1 : 2008 Cement - Composition, specifications and conformity criteria for common cements

•SS EN 197 - 2 : 2008 Cement - Conformity evaluation

•SS EN 197 - 4 : 2008 Cement - Composition, specifications and conformity criteria for low early strength blast furnace cements

•SS EN 206 - 1 : 2009 Concrete - Specification, performance, production and conformity

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Recent standards published under the BCSC

Material specifications:

•SS 544 - 1 : 2009 Concrete - Complementary Singapore Standard to SS EN 206-1 - Method of specifying and guidance for the specifier

•SS 544 - 2 : 2009 Concrete - Complementary Singapore Standard to SS EN 206-1 - Specification for constituent materials and concrete

•SS EN 934 : 2008 Admixtures for concrete, mortar and grout (Part 1,2,4 & 6)

•SS EN 12620 : 2008 Specification for aggregates for concrete

•SS EN 15167 - 1 : 2008 Ground granulated blast furnace slag for use in concrete, mortar and grout - Definitions, specifications and conformity criteria

•SS EN 15167 - 2 : 2008 Ground granulated blast furnace slag for use in concrete, mortar and grout - Conformity evaluation

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Recent standards published under the BCSC

Other building and construction related standards:

SS 553 : 2009 Code of practice for Air-conditioning and mechanical ventilation in buildings

•SS 554 : 2009 Code of practice for Indoor air quality for air- conditioned buildings

•SS 280 - 2 : 2009 Specification for metal scaffoldings - Modular scaffoldings

•SS 547 : 2009 Code of practice for temporary housing quarters on construction sites

•SS 212 : 2007 Specification for aluminium alloy windows

•SS 332 : 2007 Specification for fire doors

•SS 533 : 2007 Singapore Standard for cleaning performance for public housing estates

•SS 530 : 2006 Code of practice for energy efficiency standard for building services and equipment.

and many more.....

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Need more information? Contact Us!

- More information on the Standardisation Programme at www.standards.org.sg
- Enquiries: stn@spring.gov.sg
- Purchase Standards: www.singaporestandardseshop.sg
- BCSC Secretariat – james_choo@spring.gov.sg

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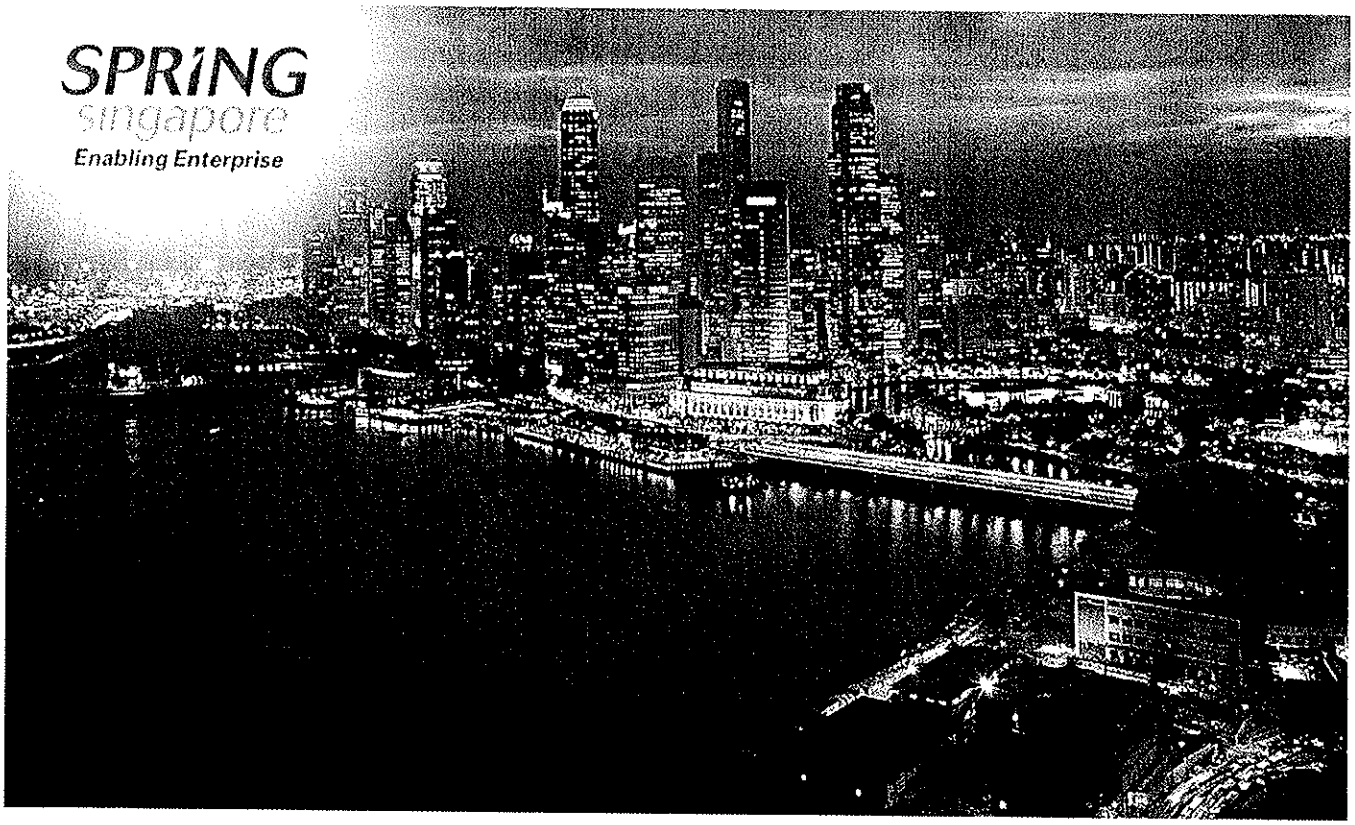

Overview of SS553 : 2009 – Air-conditioning and Mechanical Ventilation in Buildings

A/P Wong Yew Wah, Working Group Convenor

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WG members

- Er Wong Yew Wah - NTU
- Dr Ng Eng Hong – ASHRAE Singapore
- Dr Bong Tet Yin – Individual Capacity
- Mr Thomas Goh – BCA
- A/Prof Chandra Sekhar – NUS
- Mr Vincent Low – SEAS
- Er Chong Bak Peng - IES
- Mr Vijayaratnam Karuppaiah - SCDF
- Dr Jimmy Chen – Individual Capacity

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SS553 Editorial changes from CP13

- Removal of fire-related clauses
- Revision of clauses on;
  - Ventilation & IAQ – Dr Bong
  - Energy efficiency – Er Wong
  - Commissioning
  - O&M – Dr Ng
- Rearrange into parts on A/C, M/V and a part common to both

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Overview of A/C related standards and guides in Singapore

- SS 530:2006 – CP for energy efficiency standards for building services
- BCA Approved Document – Acceptable Solutions
- BCA Green Building Design Guide- A/C Buildings
- SCDF Code of Practice for Fire Precautions in Buildings
- NEA Code of Practice for Environmental Health

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ASHRAE Reference Standards

- Std 90.1 : 2007 – Energy Standard for Buildings except Low Rise residential Buildings
  - Building Envelope
  - HVAC
  - Power & Lighting
  - Energy Cost Budget

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ASHRAE Reference Standards

- Std 62 : 2007 – Ventilation for acceptable indoor air quality
  - Outdoor Air Quality
  - Systems and Equipment
  - Procedures
  - Construction and Start-up
  - O&M

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ASHRAE Reference Standards

- Std 55 : 2004 – Thermal Environmental Conditions for Human Occupancy
  - Conditions for Human Comfort
  - Compliance
  - Evaluation of the thermal environment
- ASHRAE Green Guide – The Design, Construction and Operation of Sustainable Buildings

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Recent ASHRAE Developments

- ASHRAE Advanced Energy Design Guides (AEDG) – 30% improvements over Std 90.1: 1999 as baseline.
  - Small office buildings
  - Small retail
  - K12 schools
  - Small warehouse and self storage buildings
  - Small healthcare facilities
  - Highway lodging

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Recent ASHRAE Developments

- Std 189.1P Standard for the design of high performance green buildings except low-rise residential (Draft)
  - 30% improvements over Std 90.1-2007
  - Carbon equivalency
- Std 180 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems

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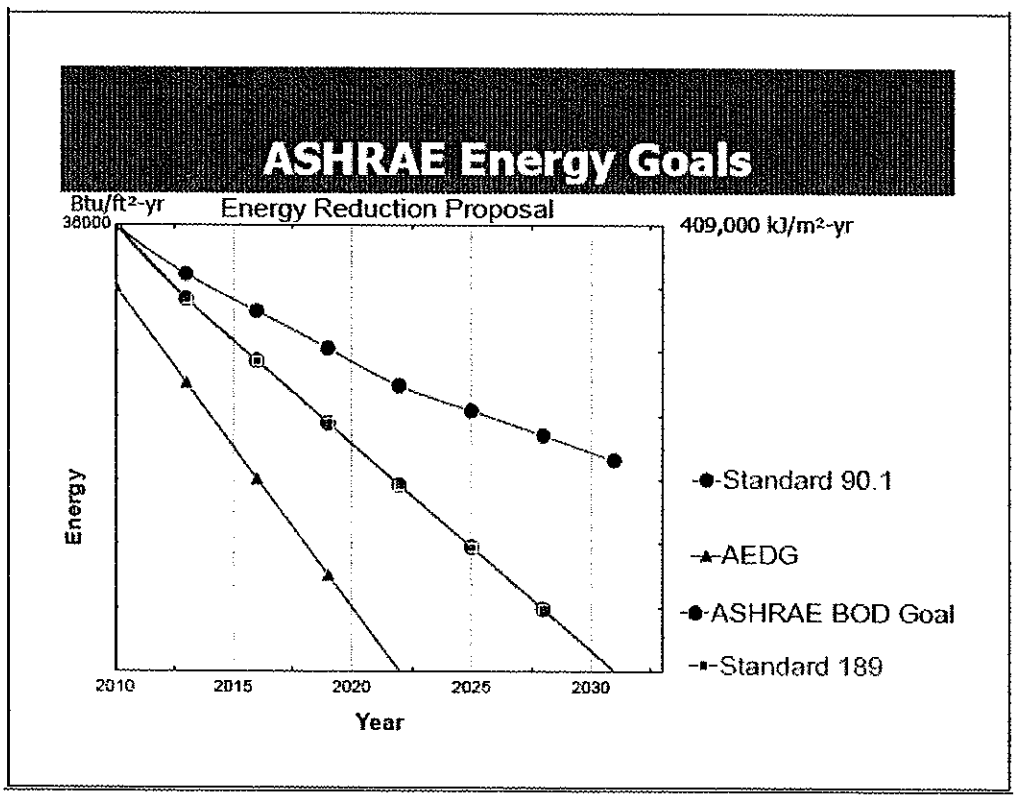
Energy Reduction: Std 90.1 vs Std 189



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EE Related Revisions in SS553:2009

- Cl 8. Controls
  - Automatic shut-down of A/C system either by scheduled timer /occupancy sensor/security system
  - Optimum start control
  - Isolation areas for zones that are occupied non-simultaneously
  - Outdoor air/ exhaust air dampers to A/C space shut when unoccupied
  - Hotels having > 50 guestrooms to have rooms lighting switched off and room thermostat set-up by > 3°C when unoccupied

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EE Related Revisions in SS553:2009

- Cl 9. & 14 Fan power limitations
  - Fan power > 4 kW, Allowable nameplate motor power

	CAV	VAV
SS 553	1.7 kW/m³/s	2.4 kW/m³/s
CP13	1.7 kW/m³/s (0.47kW/m³/h)	2.7 kW/m³/s (0.7kW/m³/h)

  - Motors > 11 kW,

    Part-load power < 30% design power at 50% design volume when static pressure at 33% static pressure

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EE Related Revisions in SS553:2009

- Cl 10. Pumping systems
  - Total pump power > 7.5 kW

	Chilled Water	Condensing Water
SS 553 (Nominal WTF)	349 kW/m³/s (75.5)	301 kW/m³/s (77)
CP13 (WTF)	30	40

  - Motors > 15 kW to have variable speed control
    Part-load power < 30% design power at 50% design volume
  - Pump isolation in multi-chiller set-up
  - Chilled water reset control for systems > 88 kW capacity (fixed flow system)

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EE Related Revisions in SS553:2009

- Cl 12. Energy recovery
  - Exhaust air > 2.5 m³/s from conditioned space in a single location to have energy recovery > 60% energy recovery effectiveness

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EE Related Revisions in SS553:2009

- Cl. 15. Duct
  - Flexible connections limited to 2m length
  - Duct sealing

Location	Supply	Exhaust	Return
Outdoor	A	C	A
Unconditioned	A	B	A
Conditioned	A	B	A

A – Traverse joins, longitudinal seams, penetrations

B – Traverse joints, longitudinal seams

C – Traverse joints

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EE Related Revisions in SS553:2009

- Cl. 15. Duct
  - Leakage test for ducts static > 750 Pa
  - Max leakage L_{max} l/s/m² duct surface area

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

C_L = 8 – rectangular sheetmetal/fibrous duct, round flexible duct

C_L = 4 – round/flat oval sheetmetal, fibrous glass duct

P – design duct pressure rating, Pa

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EE Related Revisions in SS553:2009

- Cl 17. Thermal insulation
  - Duct insulation

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

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EE Related Revisions in SS553:2009

- Cl 17. Thermal insulation
  - Pipe insulation

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

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EE Related Revisions in SS553:2009

- Cl 21. Energy Audit & End use metering
  - Supply energy source metering threshold

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

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EE Related Revisions in SS553:2009

- Cl 21. Energy Audit & End use metering
  - Sub-metering threshold

Subsystem	Sub-metering threshold
Chillers/heat pumps	> 70 kW cooling
Packaged AC systems	> 70 kW cooling
Fan systems	> 15 kW
Pumps	> 15 kW
Cooling towers	> 15 kW
Boilers and other heating systems	> 300 kW input
General lighting circuits	> 100 kVA
Miscellaneous electric loads	> 100 kVA

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Revised Ventilation Rates in SS 553 : 2009

Dr. Bong Tet Yin

Member of Working Group

Introduction

- The CP13:1999 has been revised and is now known as SS553:2009.
- SS553:2009 Code of Practice for air-conditioning and mechanical ventilation

Introduction

- The ventilation rates for comfort air-conditioning given in CP13:1999 have been revised.
- The revised ventilation rates are given in Table 1 - Outdoor air supply requirement for comfort air-conditioning.

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Introduction

- To be in-line with international standard, the revision follows the changes in ASHRAE Standard 62.1-2007,

  Ventilation for Acceptable Indoor Air Quality
- Local requirements are also taken into consideration.

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Theory

- Outdoor air is needed to meet the metabolic requirement of people and to dilute the emission from the space.
- $V_{bz} = R_p P_z + R_a A_z$ [L/s]
  where R_p [L/s.person], R_a [L/s.m^2],
  P_z = number of people, A_z = floor area

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Theory

- When the outdoor air requirement is expressed per unit floor area,
  $V_{bz} / A_z = R_p P_z / A_z + R_a$
  in [L/s per m^2 floor area]

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Theory

- The Fire Code in Singapore specifies the floor area that should be provided for a person in a space for different applications: L_o [m^2/person]
- $L_o = A_z / P_z$ [m^2/person]

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Theory

- The minimum outdoor air requirement is determined using the value of

  L_o [m^2/person] given in the local Fire Code and the values of R_p [L/s.person] and R_a [L/s.m^2] from the ASHRAE Standard 62.1-2007

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Theory

- Since

$$V_{bz} / A_z = R_p P_z / A_z + R_a \quad [L/s \text{ per } m^2]$$

and $L_o = A_z / P_z \quad [m^2/person]$

therefore

$$V_{min} = R_p / L_o + R_a \quad [L/s \text{ per } m^2]$$

- The outdoor air requirement in Table 1 are given in both [L/s per m^2 floor area] as well as [m^3/h per m^2 floor area] .

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Theory

- This value of V_{min} is given in Table 1, SS553: 2009. The table also includes the minimum outdoor air requirement in [L/s per person], which has taken into account the emission from the space ($V_{min} \times L_o = R_p + R_a L_o$).

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Theory

- It is assumed that the said amount of outdoor air would be available in the breathing zone.

Outdoor air requirement for Restaurant

- Restaurant
  R_p = 3.8 [L/s.person] , R_a = 0.9 [L/s.m^2]
  for restaurant dining room
  (ASHRAE Standard 62.1-2007)
- L_o = 1.5 [m^2/person] (Fire Code)
- Minimum outdoor air supply:
  V_{min} = 3.4 [L/s per m^2 floor area]
  or 12.2 [m^3/h per m^2 floor area]
- V_{min} L_o = 5.1 [L/s.person]

Outdoor air requirement for restaurant

- In the CP13: 1999, the minimum outdoor air requirement was 2.8 [L/s per m^2] or 10 [m^3/h per m^2 floor area]
- The revised value is 22% higher than the value required in the CP13. This is because the Standard 62.1-2007 has increased the values of R_p and R_a for restaurant dining room.

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Outdoor air requirement for Offices

- Offices

  R_p = 2.5 [L/s.person] , R_a = 0.3 [L/s.m^2] for office space
- L_o = 10 [m^2/person]
- V_{min} = 0.6 [L/s per m^2 floor area] or 2.0 [m^3/h per m^2 floor area]

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Outdoor air requirement for offices

- In the CP13: 1999, the corresponding value was 0.65 [L/s per m^2]

  or 2.3 [m^3/h per m^2]
- The revised value is 13% lower than the value required in CP13.

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Outdoor air requirement for Lobbies and Corridors

- Lobbies and Corridors

  The occupants in these spaces are transient.
- The Fire code does not specify the floor area required per person.

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Outdoor air requirement for lobbies and corridors

- V_{min} = 0.3 [L/s.m^2] has been adopted, which is the R_a value in Standard 62.1.
- In the CP13: 1999, the corresponding value was 0.25 [L/s per m^2]
- The revised value is higher than the value required in CP13.

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Outdoor air requirement for Concourses

- Concourses are often used for a variety of purposes.
- The Fire Code specifies L_o = 3 [m^2/person]
- The ASHRAE Standard 62.1 does not specify the values of R_p and R_a for concourses.
- The values of R_p and R_a values for lobbies have been used for concourses.

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Outdoor air requirement for concourses

- R_p = 2.5 [L/s.person] , R_a = 0.3 [L/s.m2] as for lobbies
- V_{min} = 1.1 [L/s per m^2] or 4.0 [m^3/h per m^2]
- In the CP13, the corresponding value for V_{min} was 0.25 [L/s per m^2] or 0.9 [m^3/h per m^2].
- The revised value is significantly higher.
- V_{min} L_o = 3.3 [L/s.person]

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Outdoor air requirement for Classes

- Classrooms are now subdivided into classrooms for primary school children and above and classrooms in childcare centers.

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Outdoor air requirement for classes in primary school and above

- R_p = 3.8 [L/s.person] , R_a = 0.3 [L/s.m^2] for lecture classrooms
- L_o = 1.5 [m^2/person]
- V_{min} = 2.8 [L/s per m^2] or 10 [m^3/h per m^2]
- The corresponding value in CP13 for classes in general was 2.6 [L/s per m^2] or 9.2 [m^3/h per m^2]

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Outdoor air requirement for classes in childcare centers

- For child care centers, the Ministry of Community Development, Youth and Sports has a guide, requiring 3 m^2 of floor space per child.
- V_{min} = 2.8 [L/s per m^2] or 10 [m^3/h per m^2] Same value has been taken as for primary school classes.
- V_{min} L_o = 8.4 [L/s.person]

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Factories and Workshops

- The ventilation requirement for factories and workshop should conform to the Guidelines on Design, Operation and Maintenance of Local Exhaust Ventilation Systems, Ministry of Manpower.
- The SS553:2009 does not cover industrial ventilation.

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Maintenance of Air-conditioning and Mechanical Ventilation Systems

Dr. Ng Eng Hong

Member of Working Group

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General requirements

- **Competent Staff** - trained in ACMV
- **Documentation** - Shop drawings, operation manual, schematic diagrams are available for the maintenance team
- **Provisions for Maintenance Operation** –
  - Adequate access for inspection, maintenance and repair
  - Facilities for emptying the piping services,
  - Reasonable operating space,
  - 600mm minimum clearance around AHU

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General requirements

- **Operating Log Sheets** - reference for operation and planned maintenance
  - Hourly and daily records of operating conditions
  - records of all faults, breakdown and repairs

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Air-conditioning Installations

- **General**
- **Monthly Maintenance**
- **Half-yearly maintenance**
- **Annual maintenance**
- **Overhaul**

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Mechanical Ventilation Installations

- Monthly Maintenance
- Half-yearly maintenance
- Annual maintenance

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Air-conditioning Installations - General

- Inspect all the equipments and systems to ensure satisfactory operation of the equipments and systems within designed conditions.

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Monthly Maintenance

- Refrigerant Compressors
  - Check refrigerant & oil levels, filters, safety devices, leaks and operating pressures
  - Check & adjust belt tension
  - Lubricate bearings

- Condenser
  - Check for proper operation
  - Check water operating temperatures, pressures and flow rate
  - Perform water treatment

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Monthly Maintenance

- AHUs/FCUs
  - Check for proper operation
  - Check & clean condensate drain pan & pipe, strainers
  - Check thermostats & safety cut outs
  - Check & clean evaporator coils
  - Check & adjust belt tension
  - Check & rectify abnormal running noise & vibration
  - Clean/replace air filters
  - Check duct insulation condition (for AHUs)
  - Check blower fan & its bearing + housing
  - Lubricate bearings

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Monthly Maintenance

- Pumps
  - Check operating pressure & flow rate
  - Check & rectify abnormal running noise & vibration
  - Check seals & glands
  - Check motor & pump alignment

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Monthly Maintenance

- Cooling Towers
  - Check for proper operation & ensure tower cleanliness
  - Check & clean in-fills, drift eliminators, basin, etc
  - Check for corrosion in pipes
  - Check make-up water system & float valve operation
  - Check & clean fan assembly
  - Check on chemical treatment system
  - Check & clean tower structure & supports
  - Water treatment according to *Code of Practice for the Control of Legionella Bacteria in Air-conditioning Cooling Towers in Singapore by NEA*
  - Check water balancing

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Monthly Maintenance

- Motors
  - Check running to ensure proper operating conditions
  - Check motor casing
  - Lubricate bearings
  - Check circuit protective devices
  - Check electrical circuit
  - Check & adjust belt tension
  - Check & rectify abnormal running noise & vibration

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Monthly Maintenance

- Chilled Water Expansion Tank
  - Check float valve position
  - Clean water expansion tank

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Half-Yearly Maintenance

- AHUs
  - Check & balance outside air quantities
  - Clean electrical contacts
  - Clean and touch up corroded parts
- FCUs
  - Clean electrical contacts
  - Clean and touch up corroded parts
  - Check pipe insulation
- Pumps
  - Inspect & clean strainers

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Annual Maintenance

- Refrigerant Compressors
  - Open up compressor assembly inspection cover to inspect for abnormalities and excessive wear on gear package
  - Replace refrigeration filter
  - Service oil pump, replace oil filter
  - Check & analyse oil & refrigerant. Replace if necessary
  - Perform leak test
  - Test & recalibrate safety controls

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Annual Maintenance

- Chiller Condenser
  - Clean condenser tubes
  - Check & clean strainers
  - Check & balance water flow rates
  - Automatic tube cleaning system to keep the condenser tubes from scaling and fouling may be used.

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Annual Maintenance

- AHUs/FCUs
  - Replace filters as required
  - Test and record electrical insulation of all motors and wiring with megger
  - Clean cooling coils

- Supply & Return Air Ducts
  - Inspect for cleanliness

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Annual Maintenance

- Pumps
  - Check associated controls
  - Check casing & components for wear & corrosion
  - Check pumps and motor couplings
  - Check grease, oil and gland packing
  - Realign pump and motor

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Annual Maintenance

- Motors
  - Check winding insulation by megger test
  - Check cable terminals and cables
  - Check associated circuit protection devices, electrical starter and equipment
  - Check for loose motor bolts and nuts

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Overhaul

- When necessary
- According to manufacturer's procedures & instructions

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Mechanical Ventilation Installations – Monthly Maintenance

- Check motor running ampere for normal motor operating conditions
- Inspect fan blades for wear and tear
- Check & lubricate fan and motor bearings
- Check electrical circuits
- Check motor drive. Adjust belt tension and pulleys
- Check flexible connections and anti-vibration mountings

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Monthly Maintenance

- Check for proper operation of the fan, its associated controls and control circuit
- Clean supply and return air grilles
- Clean air filters

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Half-Yearly Maintenance

- Check all electrical wiring and connections, circuit protection devices and electrical starter
- Clean the exhaust hood

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Annual Maintenance

- Check winding insulation, cable terminals and cables
- Check the associated circuit protection devices, electrical starter and equipment
- Check for loose motor bolts and nuts
- Check alignment of fan shaft with motor
- Check fan and metal components for corrosion
- Clean air passages

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Overview of SS 554:2009 Indoor Air Quality for Air-conditioned Buildings

Dr Chandra Sekhar

Co-Convenor of SS 554 Working Group

Associate Professor, Department of Building
National University of Singapore

24 November 2009

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Outline

1. Background
2. Scope and Purpose
3. Overview of the SS 554
4. Summary

Background

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Need for SS Indoor Air Quality (IAQ)

- One of the main occupational and environmental health issues identified
- Complements the Workplace Safety and Health Act, which will be expanded to cover all workplaces
- Replaces NEA Guidelines for IAQ in Office Premises (1996)
- Serves as National Standard on IAQ
- Provides assessment criteria for BCA's Green Mark for Buildings

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Target Users

- Government agencies (BCA, MOM, NEA)
- Real estate developers
- Building owners & occupants
- Building designers & architects
- Building management service providers
- Facility managers
- Occupational health & safety personnel

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Committees

Building and Construction Standards Committee (BCSC)



Technical Committee (TC) on Building Maintenance and Management



Working Group (WG) on IAQ

Working Group

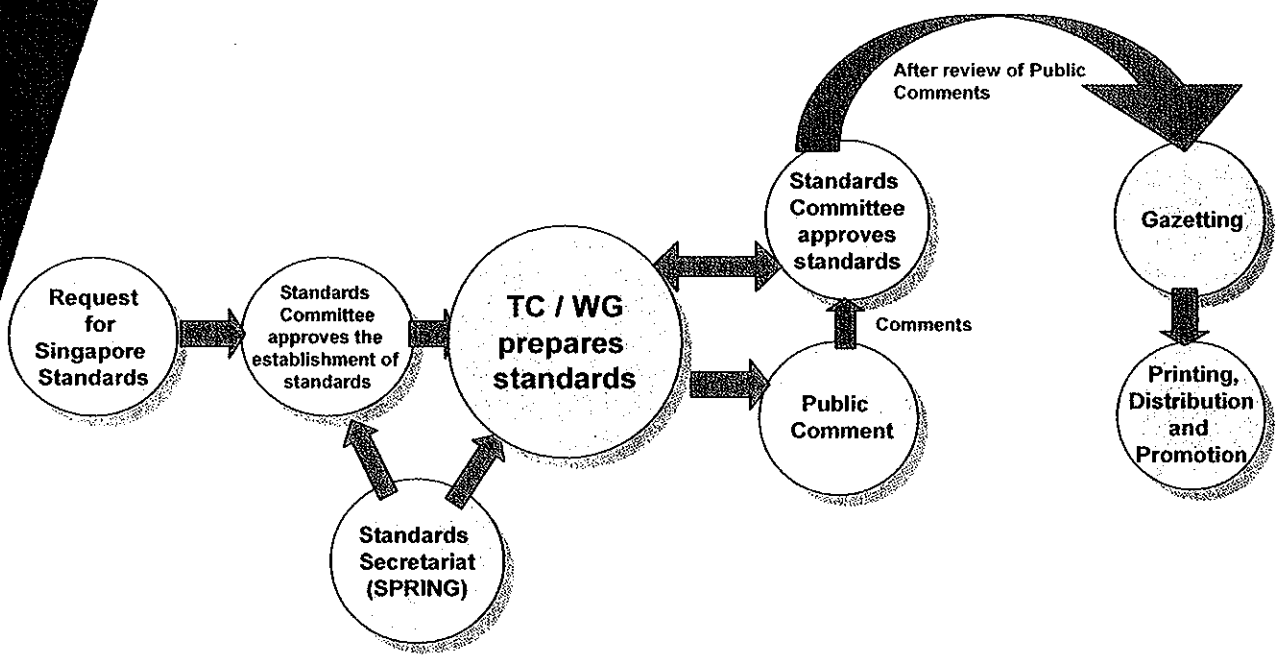
Co-Convenors:

A/Prof Chandra Sekhar (NUS) and Mr Tan Kia Tang (MOM)

Members (Technical Experts):

- ✓ *Dr Bong Tet Yin (ASHRAE Singapore Chapter)*
- ✓ *Mr Thomas Chan (Individual Capacity)*
- ✓ *Mr Simon Chong (Individual Capacity)*
- ✓ *Dr Foo Swee Cheng (NUS)*
- ✓ *Ms Lee Sui Fang (BCA)*
- ✓ *Mr Darion Lim (Individual Capacity)*
- ✓ *Dr Ooi Peng Lim (MOH)*
- ✓ *Mr Sumarni Bin Sarmin (IES)*
- ✓ *Assoc Prof Tham Kwok Wai (NUS)*
- ✓ *Ms Jennifer Yap (NEA)*

Standardisation Process – Establishment of Singapore Standards



Scope and Purpose

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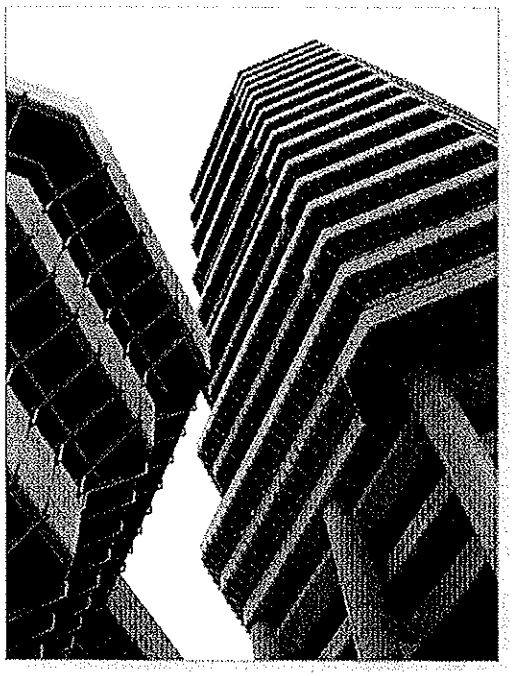
Scope

SS 554 is applicable to

Office premises	√
Commercial buildings	√
Institutional buildings	√
Industrial buildings	X
Residential buildings	X



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Scope

The Code applies to all air-conditioned premises where air-conditioning is used intermittently or continuously, with the exception of residential premises, factory production areas, hospitals, polyclinics and laboratories.

It applies to all types of air-conditioning and air-distribution systems.

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Scope (cont'd)

The Code considers environmental factors, which include thermal, physical, chemical and biological factors.

The purpose of the standard is to specify indoor air quality that will be acceptable to building occupants and to minimise the potential of adverse health effects.

For the recommended minimum ventilation rates, the Code should be used in conjunction with the SS 553, which provides guidance for the design, construction, installation, testing, commissioning, operation and maintenance of air-conditioning and mechanical ventilation (ACMV) system.

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Purpose

- specify IAQ that will be acceptable to building occupants
- minimise potential adverse health effects

What is acceptable indoor air quality?

ISO / ASHRAE definition:

- where substantial *majority* (80%) of building occupants express no dissatisfaction; and
- in which there are not likely to be known contaminants at concentrations leading to exposures that could pose a significant health risk

Overview of SS 554

Key Contents of SS 554

4. Guidelines for achieving acceptable IAQ

4.1 General

4.2 Impact of IAQ on productivity and health (Annex A)

4.3 Design

4.3.1 Location of the building - Environment, Outdoor Air Quality

4.3.2 Sources and control of indoor air contaminants (Annex B)

4.3.3 Ventilation characteristics (Annex C)
Recommended ventilation rates – (SS553)

4.3.4 Nature and use of the building
Flexibility, type of building materials (Annex D), building hygiene activities, air tightness and pressure differentials, air cleaning (Annex E), use or occupancy type, number of people, ACMV O&M considerations

Key Contents of SS 554 (cont'd)

4.3.5 Smoking and no-smoking areas

- Separation, Sign, Pressurisation
- Smoking areas – more ventilation and/or cleaning than no-smoking areas
- Specific ventilation rates for smoking zones cannot be determined

4.4 Construction

4.5 Renovation work

4.6 Commissioning, operation and maintenance (Annex F)

4.7 IAQ management programme (Annex G)

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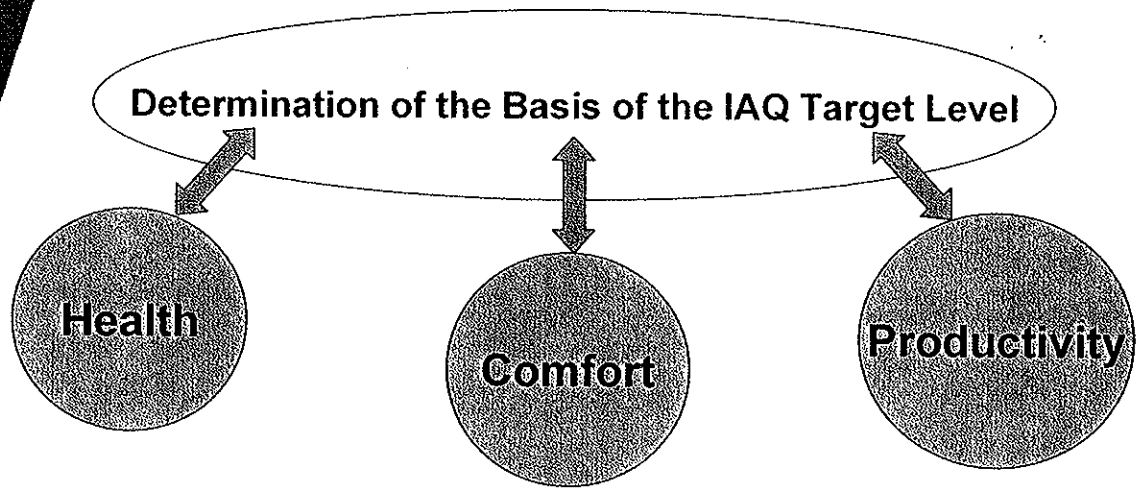
Guidelines for Achieving Acceptable IAQ (Clause 4)



- **Control & prevention of IAQ & health-related problems**
- **Best practices that can help to improve IAQ during design, construction, commissioning, operation, renovation & maintenance of a building**

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Key Contents of SS 554

5 Indoor air quality parameters and measurements

5.1 IAQ parameters (Tables 1 & 2)

5.2 Indoor air quality audit (Figure 1)

5.3 Measurement of indoor air quality

6 Competence of IAQ personnel

Informative Annexes

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IAQ Parameters & Measurement (Clause 5)

- Targeted contaminants approach for sampling and tests
  - Recommended IAQ parameters (Table 1)
  - Target contaminants triggered by specific sources (Table 2)
- Sampling strategies
- Measurement methods

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Recommended IAQ Parameters

1. Micro-climatic Parameters
• Operative temperature • Relative humidity • Air movement
2. Chemical Parameters
• Carbon dioxide • Carbon monoxide • Formaldehyde • Total volatile organic compounds that are photoionisable (at 10.6 eV)

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Recommended IAQ Parameters

3. Respirable suspended particles (aerodynamic diameter less than 10 μm sampled with a size selective device having a median cut off of 4 μm)

4. Biological parameters
• Total viable bacterial count • Total viable mould count

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Target contaminants triggered by specific sources

PM 2.5
Ultra-fine particles
Nitrogen dioxide
Ozone
Radon
Asbestos
Nicotine
Pathogenic bacteria
Pathogenic mould
Semi volatile and volatile organic compounds (VOC)

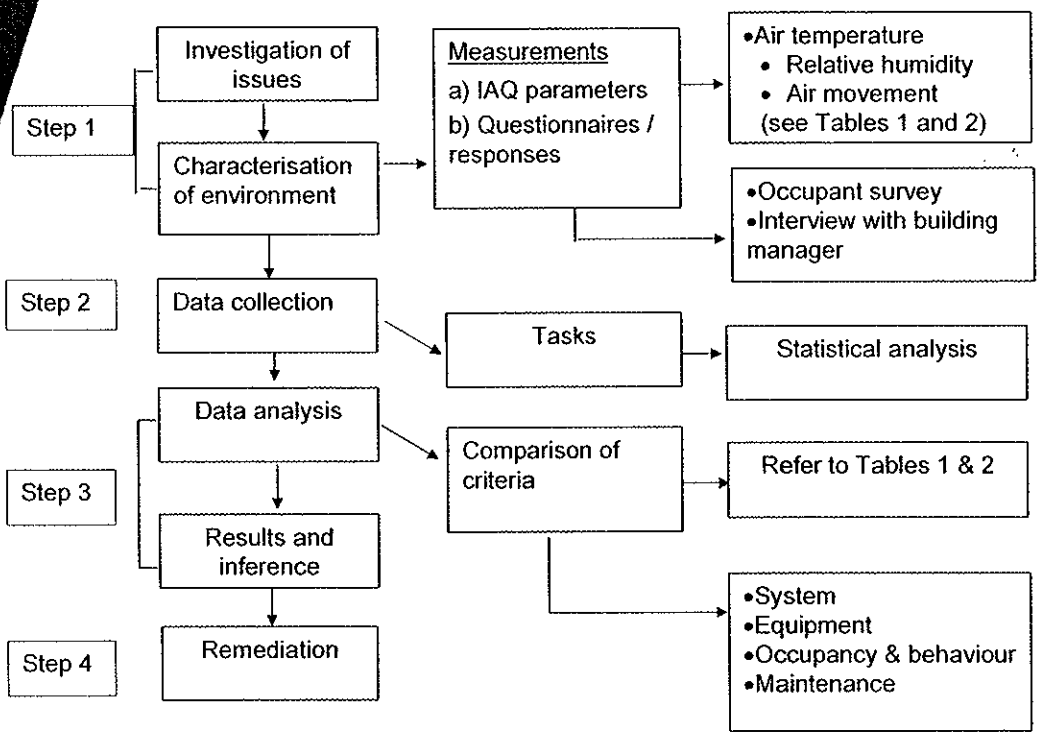

Figure 1 – Indoor air quality audit methodology

Competency of IAQ Personnel (Clause 6)

- Indoor air quality auditing and air sampling should be conducted by a competent person who has attended and met the requirements of an indoor air quality course conducted by a training provider recognised by cognizant authorities.

- Laboratories performing analysis of IAQ parameters to be accredited under the Singapore Laboratory Accreditation Scheme (SINGLAS) administered by Singapore Accreditation Council (SAC)

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Annexes

Information to help users:

- Apply the standard e.g. identifying IAQ problems, signs & symptoms of sick building syndrome & building-related illness, sample inspection checklist / survey questionnaire, air cleaning devices
- Appreciate the benefits of implementing good IAQ e.g. highlighting relevant local & overseas studies to show link between IAQ & health / productivity
- Be aware of current IAQ development & to prepare for future changes in the revision of SS IAQ (including resource information links to useful IAQ websites)

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Key References

- **NEA Guidelines for Good IAQ in Offices Premises (1996)**
- **SS 553:2009 Code of Practice for Air-conditioning and Mechanical ventilation in buildings**
- **ISO 16000 series, 16017, 16813, ISO 16814**
- **WHO Air Quality Guidelines**
- **ASHRAE 55 (2004) Thermal Environmental Conditions for Human Occupancy**
- **ASHRAE 62.1 (2007) Ventilation for Acceptable IAQ**
- **EU Directive: European Energy Performance in Building**
- **USA OSHA IAQ**
- **Hong Kong: Guidance Notes for the management of IAQ**
- **Malaysia DOSH: CP on IAQ**

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Summary

- Better air quality minimises incidence of sick building syndrome & building related illness
- Better IAQ leads to increased work productivity
- Better IAQ leads to improved quality of living
- Quality of built environment is a competitive advantage to draw investors & tourists

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Thank You

Occupational & Environmental Health Concerns

Tan Kia Tang
Co-Convenor of SS 554 Working Group
Deputy Director, Health Risk Control Branch,
Ministry of Manpower

Coverage

- IAQ Problems
- Causes & Sources
- Symptoms & Effects
- IAQ Parameters & Standards
- Control Strategy

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IAQ in a Nutshell

- IAQ is not new
- It started in the 1970s
- It is about comfort, health & well-being
- It is still evolving
- There are many studies / publications
- There are no global IAQ standards

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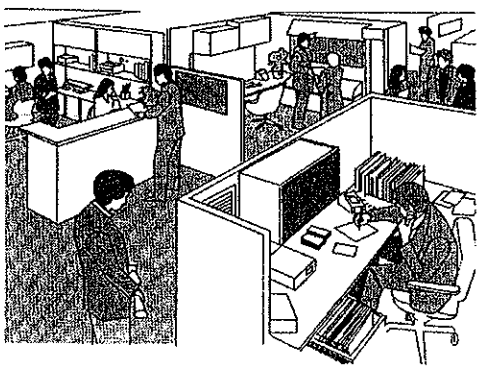
What is IAQ?

Quality of the indoor air

4 aspects:

1. Thermal
2. Chemical
3. Micro-biological
4. Ventilation



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IAQ vs IEQ

Indoor Environmental Quality

1. Thermal
2. Chemicals
3. Bio-organisms
4. Ventilation
5. Visual
6. Acoustics
7. Ergonomics



Today's office environment contains many IAQ concerns.

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Causes of IAQ Problems

1. Construction of airtight buildings
2. Inadequate intake of outside air
3. Re-circulation of stale air
4. Poor air distribution or mixing
5. Poor maintenance of ventilation system
6. Increase in no. of occupants
7. Increase in time spent indoors
8. Use of construction materials
9. Indoor sources of contamination
10. Outdoor sources of pollution

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IAQ problems

(US NIOSH Investigations 1988)

Problem Type	No. of Buildings	% Attributed
Inadequate ventilation	280	53
Inside contamination	80	15
Outside contamination	53	10
Microbiological contamination	27	5
Building materials contamination	21	4
Unknown	68	13
Total	**529**	**100**

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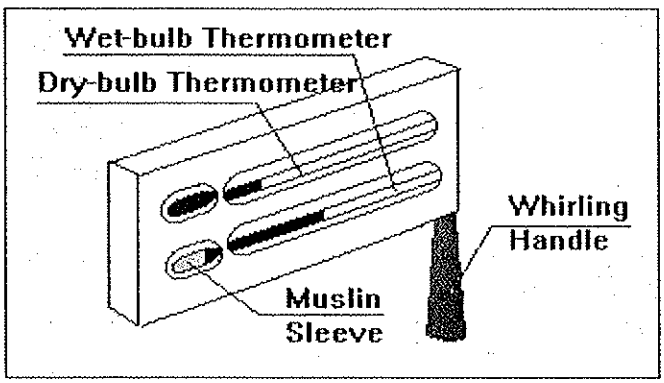
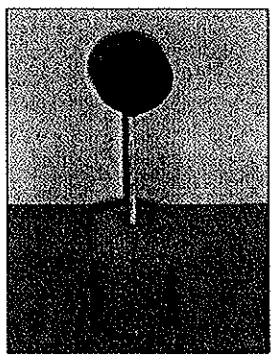
Thermal Environment

1. Air temperature (dry bulb temp.)
2. Humidity (dry bulb & wet bulb temp.)
3. Radiant heat (globe temp.)





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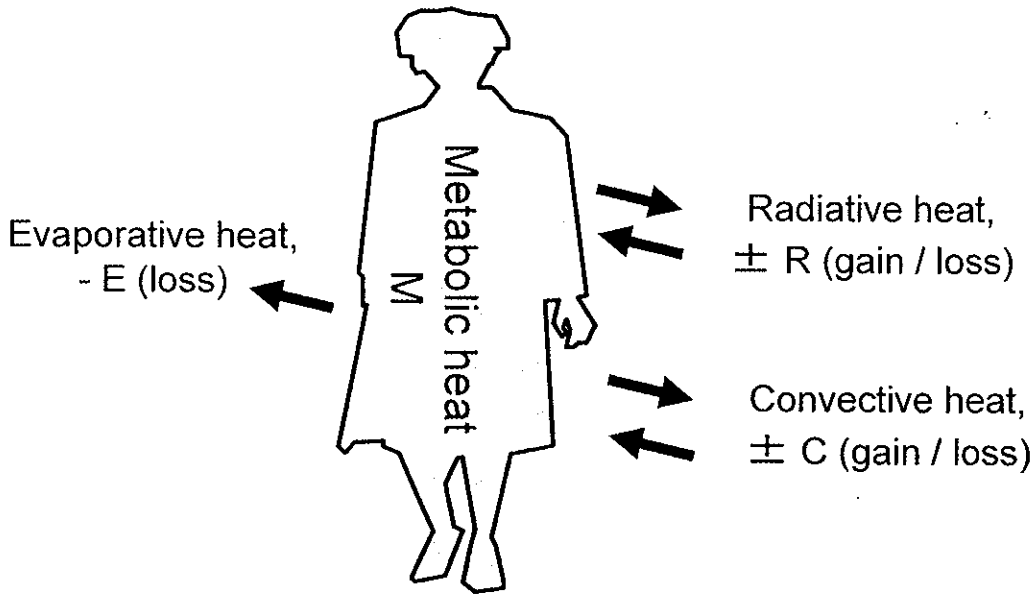
Heat Exchange



S = M ± R ± C – E

Ideally, S = 0 thermal comfort
M = (± R ± C + E)

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Warm vs Cold

Warm Environment

S > 0 ; M > (± R ± C + E)

- Air temperature high
- Body heat generated > heat loss
- Body heat storage positive
- Warmth sensation

Cold Environment

S < 0 ; M < (± R ± C + E)

- Air temperature low
- Body heat loss > heat generated
- Body heat storage negative
- Cold sensation

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Recommended Air Temperature

- *Old NEA IAQ Guidelines*
  Dry Bulb : 22.5° C to 25.5° C

- *SS 554 IAQ recommendation*
  Operative Temperature: 24° C to 26° C

$$T_o = \frac{T_a + T_r}{2}$$

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Dry Air vs Humid Air

Humid Air

- Relative humidity too high
- Too much water vapour in air
- Moisture condensation
- Mould or Fungal growth

Dry Air

- Relative humidity too low
- Too little water vapour in air
- Dry & chapping / fissure skin
- Eye irritation
- Static electricity generation
- Wood shrinkage

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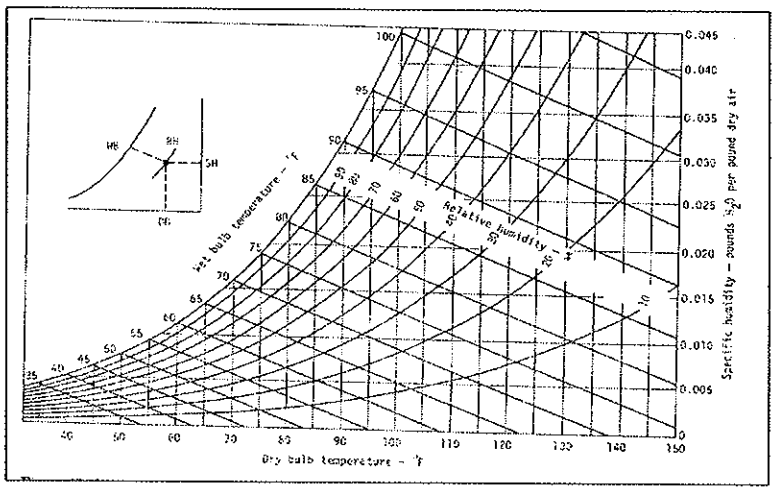
Recommended Humidity

- *Old NEA IAQ Guidelines*
  ≤ 70 % RH
- *SS 554 IAQ recommendation*

  ≤ 70% for existing buildings
  ≤ 65% RH for new buildings



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Ventilation - Purposes

1. Provide oxygen
2. Remove CO_2
3. Remove body odour
4. Improve thermal comfort
5. Others
   e.g. dilute hazardous gases / vapours

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Outdoor Air / Person

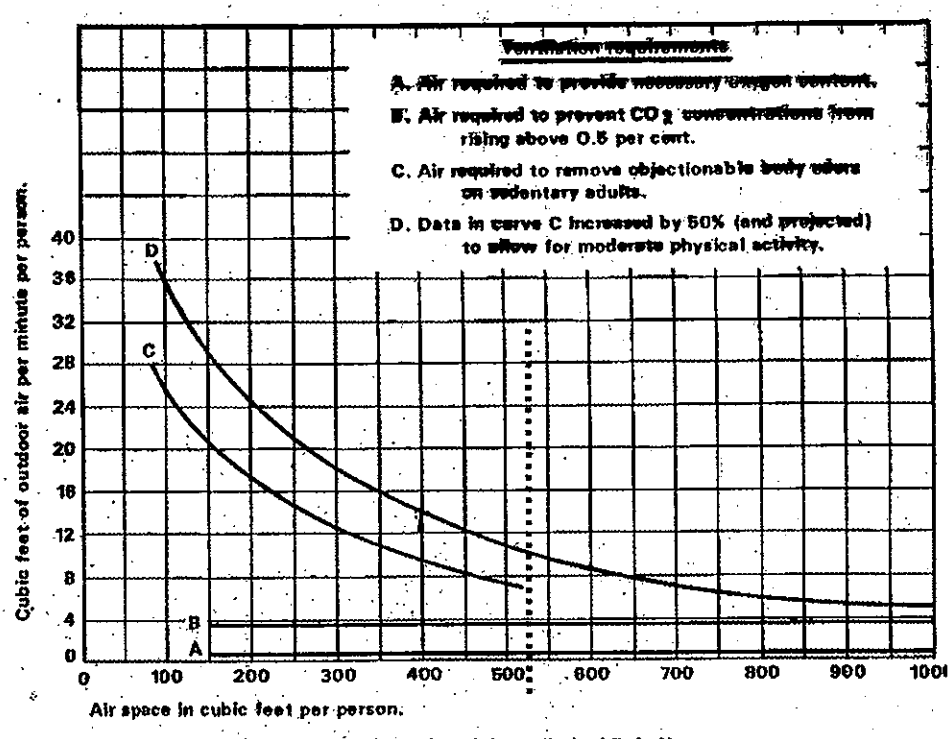

Fig. 1 ('Industrial ventilation'-Ref. 4)

SS 553 recommendation: 5.5 litres/person or 11 cfm for offices

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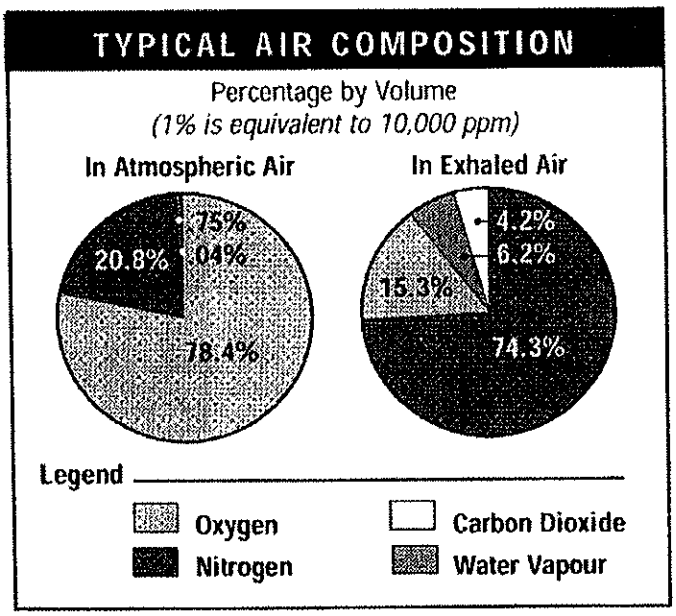
Carbon Dioxide CO_2 in Air



Rate of CO_2 generation

G = 0.011 cfm / person or 5.3×10^{-6} cms / person

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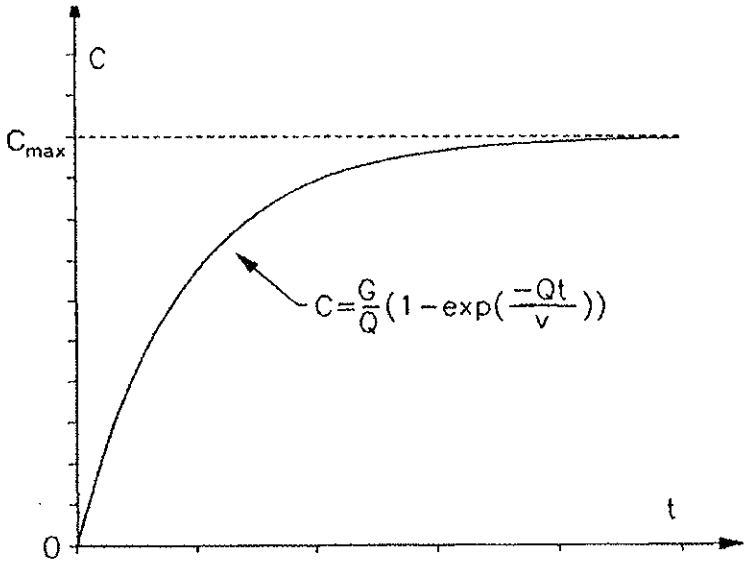
CO_2 – Steady State or Max. Concentration



SS 554 IAQ recommendation:
Not more than 700 ppm above the outdoor CO_2

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Concentration / Airflow Calculation

$$C = \frac{G}{Q}$$

C : steady state CO_2 concentration, ppm x 10^{-6}

G : rate of CO_2 generation, cfm or cms

Q : outdoor air supply, cfm or cms

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Example

- Office with 20 occupants
- Steady state CO_2 concentration = 1,000 ppm
- Outdoor CO_2 concentration = 350 ppm

$$Q = \frac{G}{C}$$

$$= \frac{5.3 \times 10^{-6}\ m^3/s/person \times 20\ persons}{(1{,}000\ ppm - 350\ ppm) \times 10^{-6}}$$

$$= 0.16\ m^3/s$$

or 338 cfm

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Stale Air vs Stuffy Air

Stale Air

- ❄ Inadequate fresh air (oxygen) supply
- ❄ High carbon dioxide CO_2 level
- ❄ O_2 level reduced
- ❄ Lethargy (dull or sluggish)

Stuffy Air

- ❄ Low air movement
  - airflow not balanced
  - low air flowrate
  - poor air distribution & mixing
- ❄ Body heat not readily removed
- ❄ Stuffy

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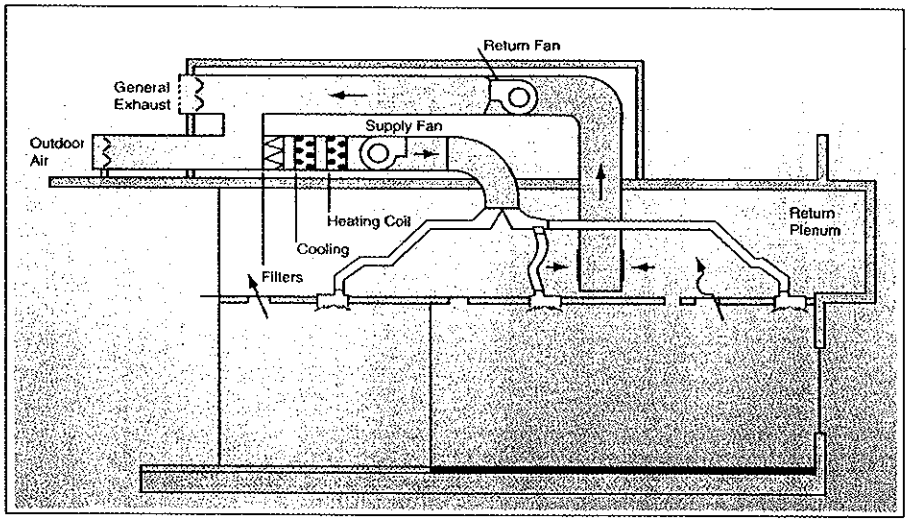
Recommended Ventilation Rates



1. *Outdoor air supply: see SS 553 Table 1*
2. *Air movement : SS 554 IAQ recommendation: 0.10 to 0.30 m/s*

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Chemical Contaminants

1 Inside Contamination
- building occupants
- building materials / contents
- new furniture
- office machines
- cleaning agents
- human activities

2 Outside Contamination
- vehicle exhaust
- construction / renovation work
- ambient air pollutants (PSI index)

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Indoor Air Contaminants
SS 554 IAQ recommendations

Parameter	*Acceptable limit (8 hr)*
CO	*9 ppm*
CO_2	*700 ppm above outdoor*
HCHO	*0.1 ppm*
NO_2	*100 ug/m^3*
O_3	*0.1 ppm*
Radon	*150 Bq/m^3*
VOC	*3 ppm*
Asbestos	*0.01 f/cc*
Respirable dust	*50 ug/m^3*
PM 2.5	*35 ug/m^3*
Nicotine	*NT*
Ultra-fine particles	*NA*

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Unpleasant Odour

- Body odour
- Cooked food
- Cleaning agents
- Sanitary or sewage system
- Tobacco smoke

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Micro-biological Contaminants

1 Fungi
- wet carpet / furnishing / wall / ceiling / plumbing

2 Bacteria
- stagnant water in ventilation system
- cooling tower
- fountain, spa pool
- sprinkler

3 Others
- dust mite
- animal dander
- pest allergens

SS 554 IAQ recommendations:	
Bacterial count :	*500 cfu/m^3*
Mould count :	*500 cfu/m^3*

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Illnesses Related to IAQ

1 Sick (Tight) Building Syndrome (SBS)
- non-specific agents
- may affect up to 20% population

2 Building-Related Illness (BRI)
- due to specific micro-organisms or allergens

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Sick Building Syndrome (SBS)

Signs & symptoms

- eye irritation – dry / watery eyes
- noise irritation – runny / blocked noise
- throat irritation – dry / sore throat
- skin irritation – dryness / redness
- headache
- lethargy
- irritability
- lack of concentrating

- **Experience after 1 or 2 hrs at work**
- **Relieve when leaving the building**

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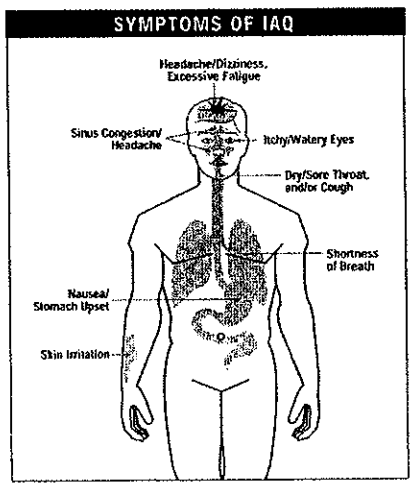
Causes of SBS

Multi-factorial; non-specific

- temperature
- humidity
- ventilation & air distribution
- airborne chemicals e.g. VOC
- particulates
- microorganisms



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Building-related Illness (BRI)

Clinical sickness or disease

- Legionnaires disease
  - Legionella pneumophila
  - acute lung infection
  - cough, chills, headache
  - general aches & pains
  - high fever & mental changes
  - pneumonia
  - respiratory failure
- Humidifier fever
  due to amoebae, thermophilic acetnomycetes,...
- Others –
  e.g. asthma, rhinitis, hypersensitivity pneumonitis, dermatitis, conjunctivitis

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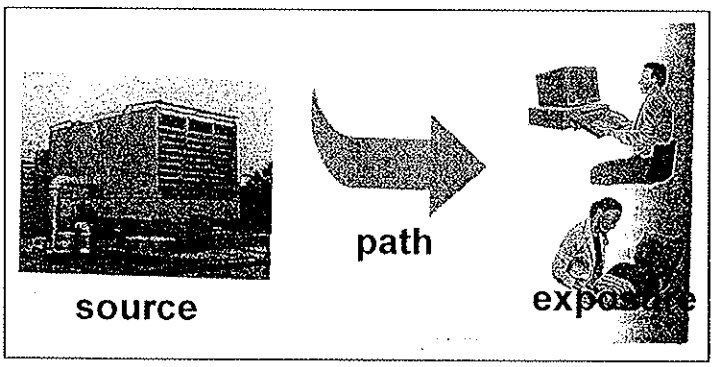
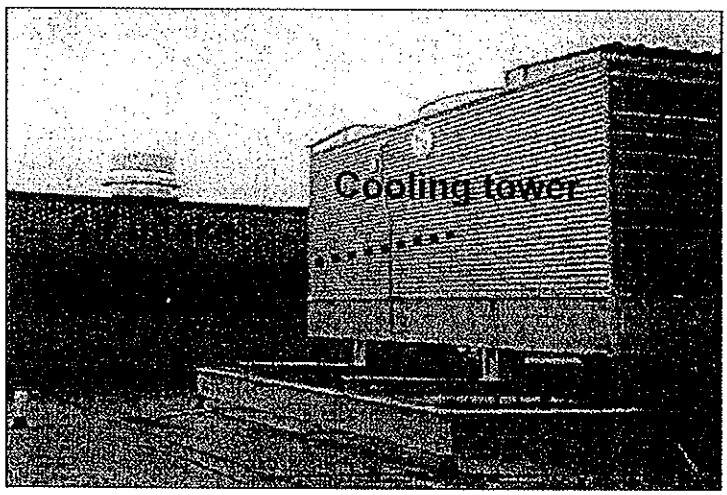
Elements for Exposure to Legionella Bacteria





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Legionnaires Disease

1976 outbreak in US
- Philadelphia, Pennsylvania
- American Legion's Pennsylvania Dept. Convention
- Participants experienced cough & fever
- Developed pneumonia after the Convention
- 29 died
- Legionella pneumophila
- Source : shower heads
- Path: air-conditioning system

10,000 cases per yr in the USA

CP for the Control of Legionella Bacteria in Air-conditioning Cooling Towers in Singapore

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Concerns about IAQ

1. Comfort
2. Health complaints
3. SBS & BRI
4. Sickness absenteeism
5. Staff turnover
6. Health care cost
7. Productivity
8. Degradation of furnishing
9. Liability

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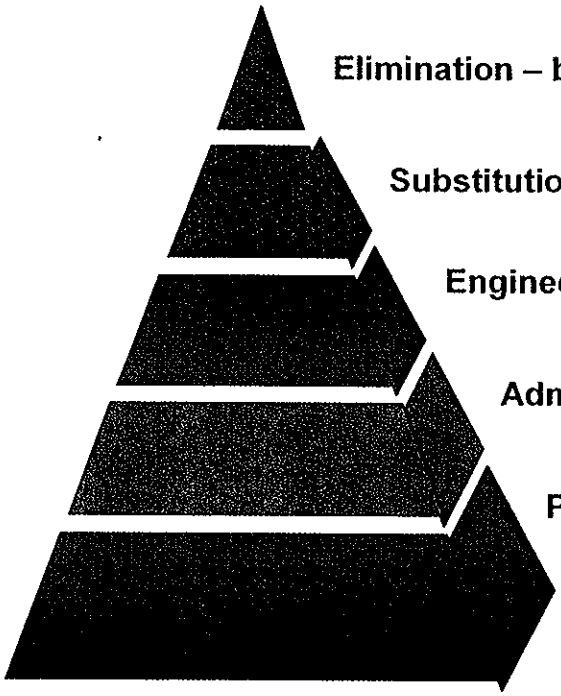
Control Strategy / Hierarchy



Elimination – ban smoking / cooking, building design

Substitution – mild detergent, water-based paint

Engineering – dilution, LEV, air-cleaner

Administrative – maintenance, testing, HK

Personal Protection – N95 mask, gloves

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Reference

- Indoor Air Quality Handbook, 2001 McGraw-Hill, Spengler, Samet, & McCarthy
- Risk Assessment and Indoor Air Quality, 1998 Lewis Publishers, Anderson & Albert Roy
- Indoor Air Quality and HVAC Systems, 1993 : Lewis Publishers, Bearg

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Evaluation Criteria Of Indoor Air Quality

Presented by:

Ms Jennifer Yap
Senior Research Officer
Environmental Health Institute
National Environment Agency

Background

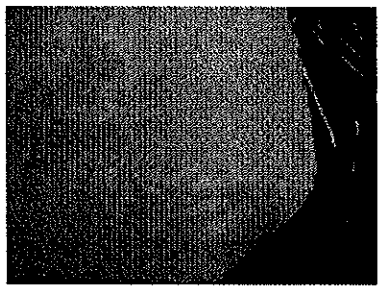
- **I**ndoor **A**ir **Q**uality (IAQ) - a multi-factorial issue
- Health implications:
  - Immediate effect : Sick Building Syndrome (SBS), specific Building Related Illnesses (BRI), allergies
    - 20 - 30 complaints a year, with 200-300 people affected by poor IAQ (offices, shopping centres, homes)
    - Awareness level high among expatriates
  - Long term effect: asthma
    - About 5% of adults and 20% of children have asthma
    - significant increase in asthma cases from 1976 to 1995 for 5-14 year age group (MOH data)
    - However, no comprehensive study to link it to IAQ.

Address the gaps in current guidelines

	NEA Guidelines 1996	New SS CP on IAQ 2009
1) Frequency of IAQ audit	At least once every 2 years • 6 months after commissioning of ACMV	• At least once every 3 years* • 6 months after commissioning of ACMV • Renovation before occupancy

*** WSH (Risk Management) Regulations 2006**

Skin irritation from an office worker working in office with pungent smell of the newly installed vinyl flooring



Address the gaps in current guidelines

	NEA Guidelines 1996	New SS CP on IAQ 2009
2) Sampling duration	8-hours basis	• 8-hour basis • ½-hour (4-time slots) • Detection tubes - ½-hour (4-time slots) • Determined by competent person (target specific)

Address the gaps in current guidelines

	NEA Guidelines 1996	New SS CP on IAQ 2009
3) No of sampling points	Indoor Based on the floor area	• Based on the number of occupied floor • Sample size with 90% confidence that at least from the 10% floors with the highest IAQ levels is included in the sample.

Address the gaps in current guidelines

	NEA Guidelines 1996	New SS CP on IAQ 2009
4) Acceptable IAQ parameters	11 parameters	• Recommended: 10 • Targeted contaminant : 10

Common parameters

	NEA Guidelines 1996	New SS CP on IAQ 2009
1) Operative temperature	22.5-25.5 °C	24-26 °C
2) RH	< 70%	• <65% (new building) • <70% (existing building during peak & common part-load conditions)
3) Air velocity	0.25 m/s	0.10-0.30 m/s

Common parameters- *cont'd*

	NEA Guidelines 1996	New SS CP on IAQ 2009
4) CO_2	1000 ppm	700 above ambient
5) RSP	150 $\mu g/m^3$	50 $\mu g/m^3$

Common parameters- *cont'd*

	NEA Guidelines 1996	New SS CP on IAQ 2009
6) TBC	500 CFU/m^3	500 CFU/m^3 Speciate when dominating by single species
7) TFC	500 CFU/m^3	500 CFU/m^3 • When mainly leafy flora • Speciate when dominating by single species

- TBC/TFC - an indicator of sanitary condition
  - Only a fraction is culturable

Common parameters- *cont'd*

	NEA Guidelines 1996	New SS CP on IAQ 2009
8) TVOC	3000 ppb	-same-
9) CO	9 ppm	-same-
10) HCHO	0.1 ppm/ 120 $\mu g/m^3$	-same-

Contaminants not commonly found

	NEA Guidelines 1996	New SS CP on IAQ 2009
1) PM 2.5	Nil	35 $\mu g/m^3$
2) UFP	Nil	• No limit, based on relativity • Trace the emission source
3) NO_2	Nil	100 $\mu g/m^3$
4) O_3	0.05 ppm	0.1 ppm
5) Radon	Nil	150 Bq/ m^3
6) Asbestos	Nil	0.01 fibre/cc Coupled with TEM/SEM

Contaminants not commonly found

	NEA Guidelines 1996	New SS CP on IAQ 2009
7) Nicotine	Nil	35 $\mu g/m^3$
8) Pathogenic Bacteria	Nil	• No limit, based on relativity • Trace the emission source
9) Pathogenic mould	Nil	100 $\mu g/m^3$
10) Semi-VOC & VOC	0.05 ppm	0.1 ppm

Stepwise IAQ investigation/Action plan

- Walk-through inspection
  - Trace the pollutant pathway
- Collate feedback from occupants
  - Trace the symptoms suffered, duration of occurrence
- Environmental sampling
  - Any obvious deviation from recommended parameters
- Building remedial measures
  - Deemed to be the best for the benefit of occupants/building

Informative Insert

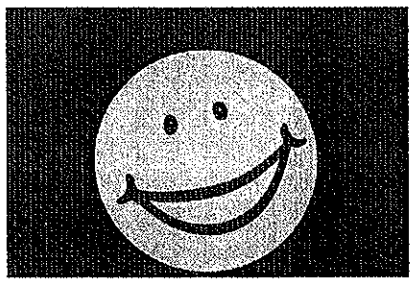
- Annex H
  - Common source of indoor air contaminants
  - Mould remediation
- Annex I
  - Sample checklist for building inspection

Upkeep good IAQ

- Everyone's responsibility
  - From architects to occupants
- IAQ investigation/remediation
  - Can be challenging
  - Look beyond the SS
  - Find the best fit

- If you don't look for it, you wont find it
- If you don't find it, you don't think you have a problem
- If you don't think you have a problem, you don't don't anything about it

Bad control strategy



How to manage Indoor Air Quality through Air Filtration

Introduction

- The airborne environment is dynamic
  1. Biological contaminants
  2. Chemical pollutants
  3. Particles

- Controlling Indoor Air Quality
  1. Physical manipulation of the source of pollution
  2. Dilution of airborne pollutants through ventilation
  3. Air filtration

** HVAC systems may also be a source of pollution*

Why Clean Air?

The air that we breathe:

- 25 kg (or 22 cubic meter per hour) per day
- 10x & 20x more than beverage & food consumption (respectively)
- 1 quarter of our time in office
- Indoor air is mainly recycled and served by a common air conditioner for entire offices.

Understanding the Airborne Environment

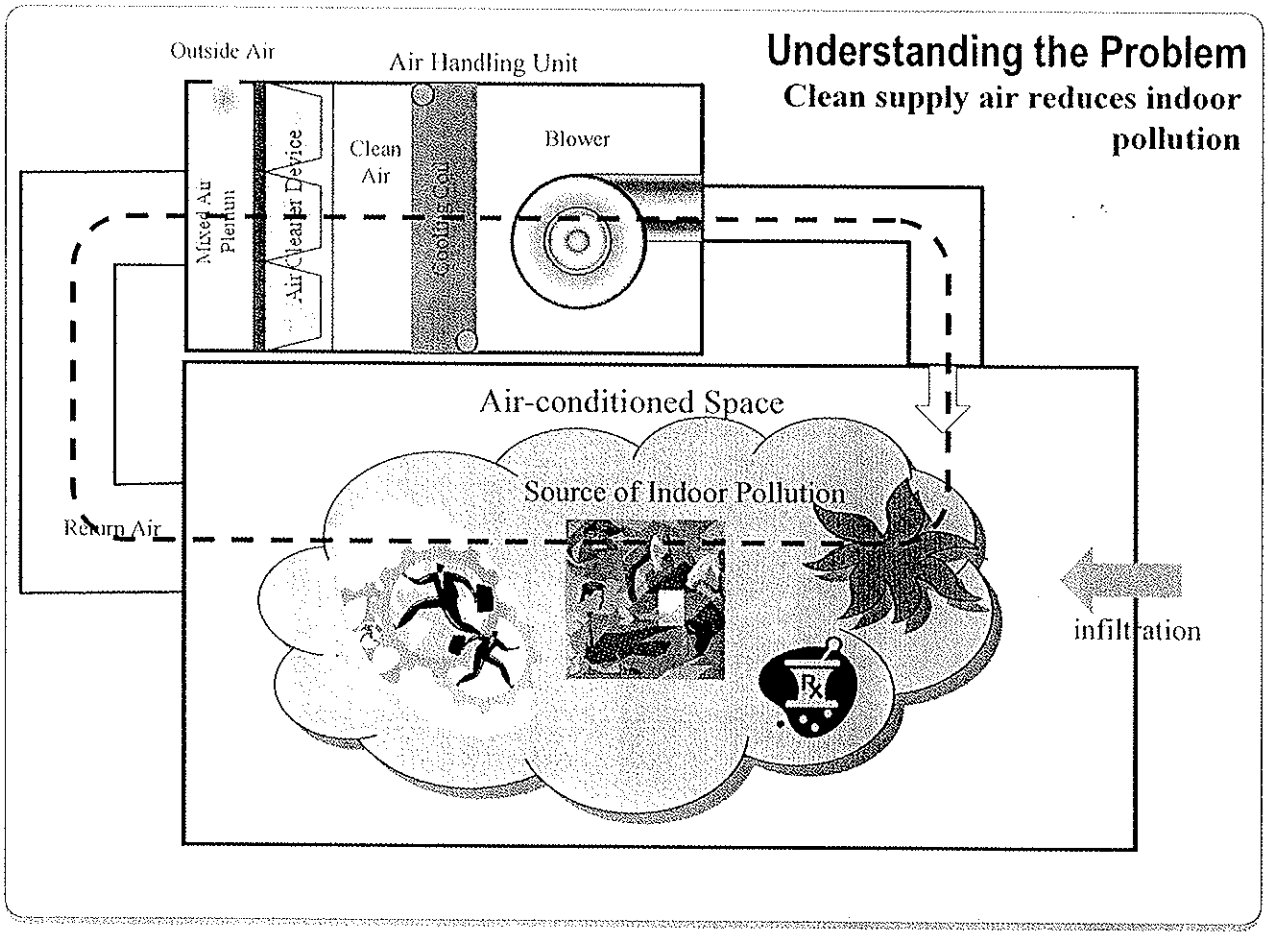
Sources of air pollution

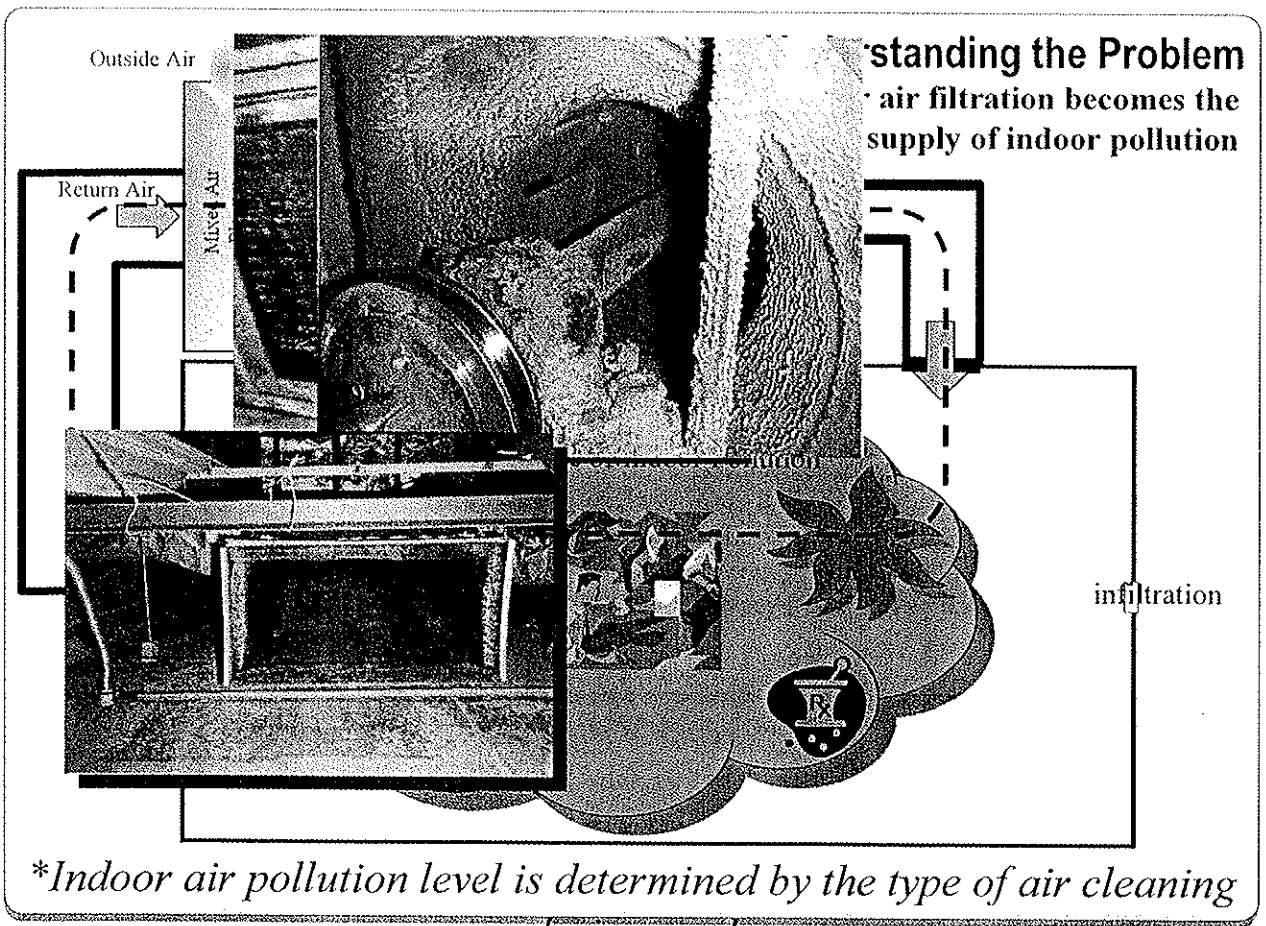
- Human activities
- Emission from materials
- Infiltration from adjacent rooms

Supply of air

- The room must be constantly replenished with clean air in order to avoid building up indoor pollution.
- 100% of indoor air passes through air filters before delivery

** Using the right cleaning device is important*

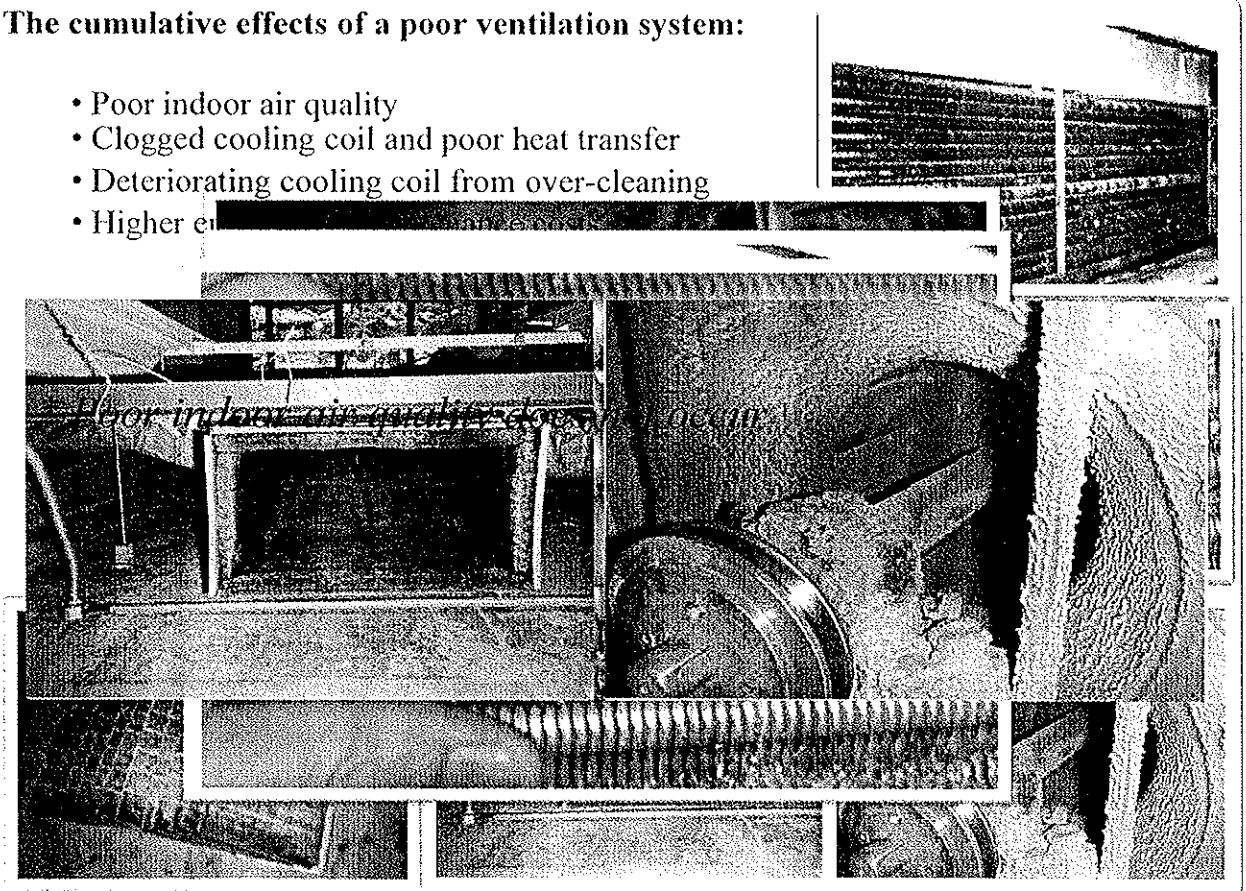




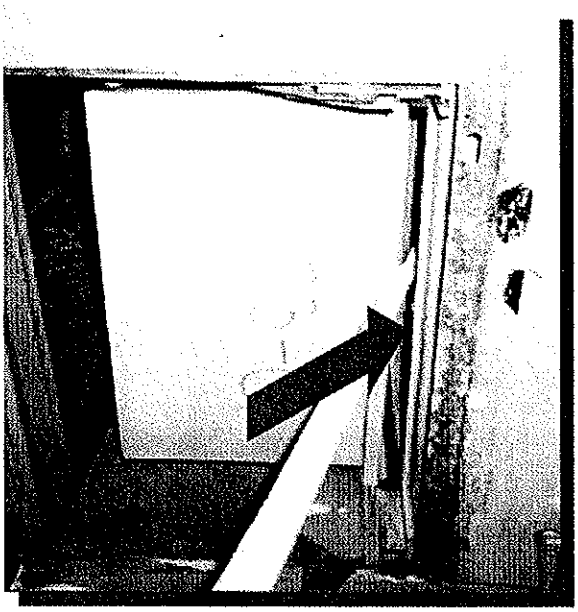
Indoor air pollution level is determined by the type of air cleaning device used

The cumulative effects of a poor ventilation system:

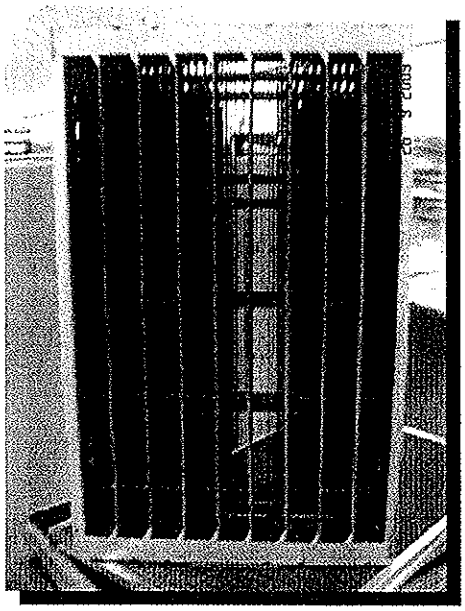
- Poor indoor air quality
- Clogged cooling coil and poor heat transfer
- Deteriorating cooling coil from over-cleaning
- Higher e[redacted]



Avoiding Leaks



Installation Leak

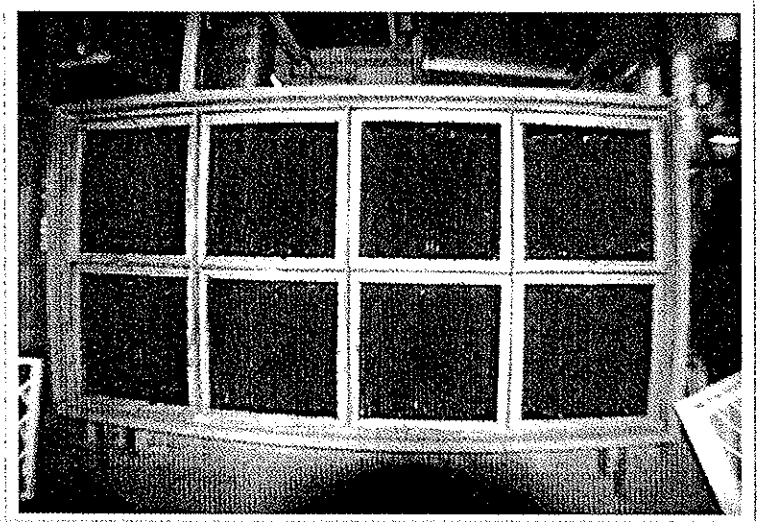


Filtration By-Pass

Understanding the Problem

1. Filter Specifications Restrict Practical application

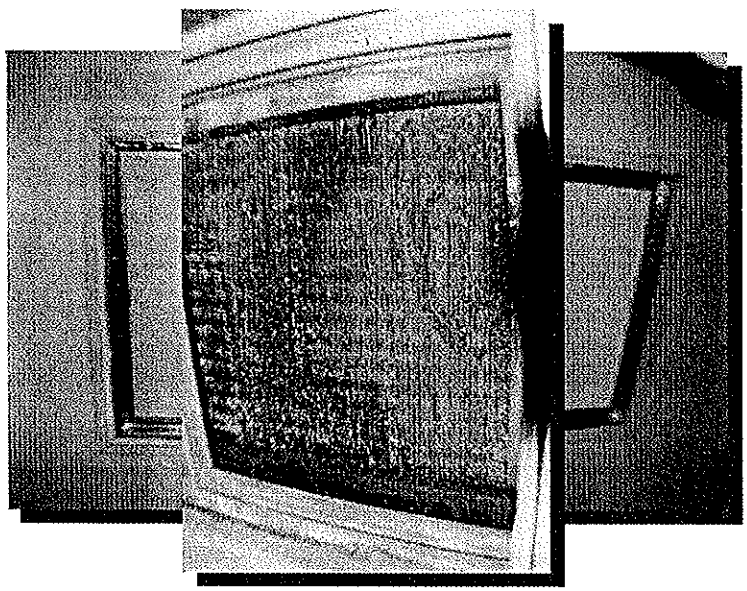
"2.4.3 The filters shall consist of water resistant media made from high density ultra-fine glass fibers. The media shall be pleated and have crimped aluminum separators to maintain uniform spacing between pleats. The pleats media pack shall be..."



**** Filter descriptions are not the best way to determine filter selection.***
**** Key factor for specification: Filter efficiency and pressure drop***

Understanding the Problem

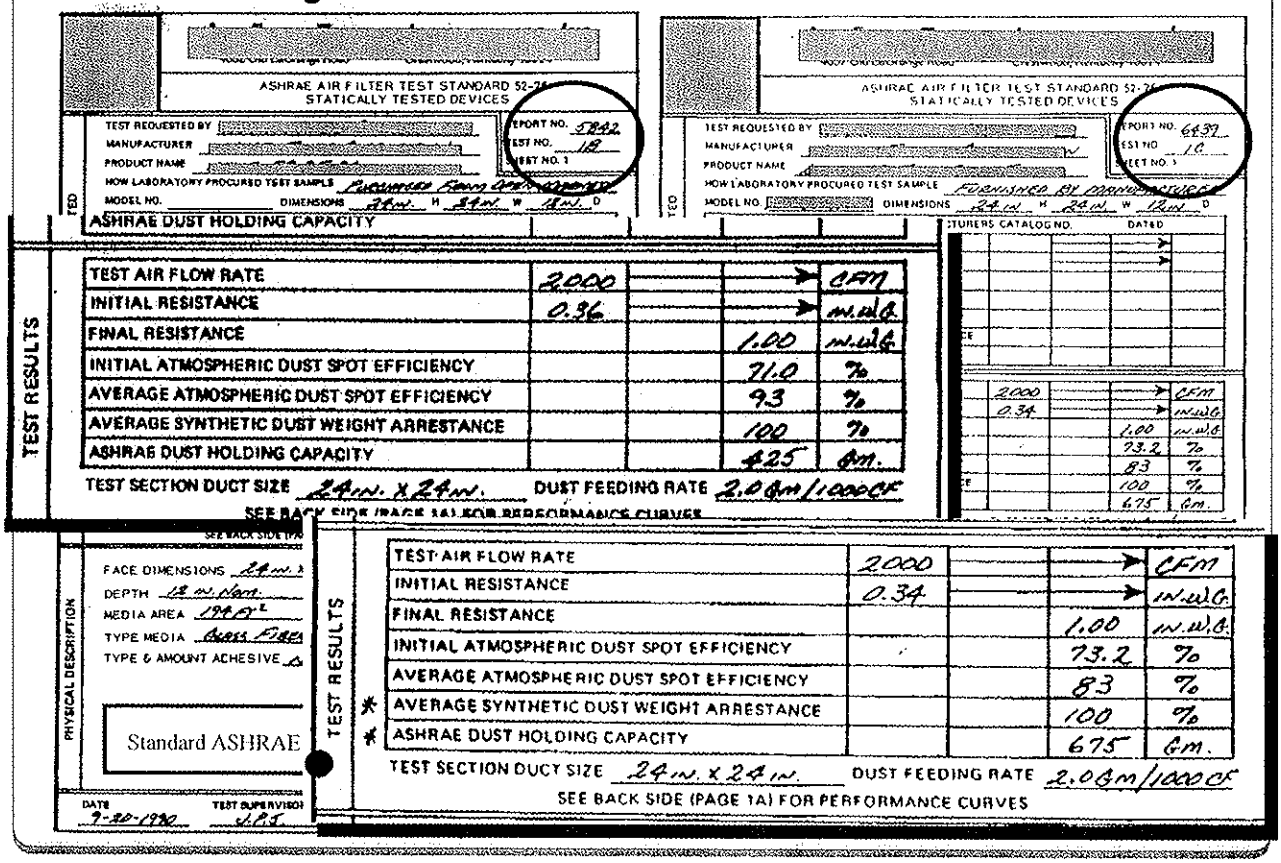
2. Technician's awareness to problem areas



Clean Air Objectives

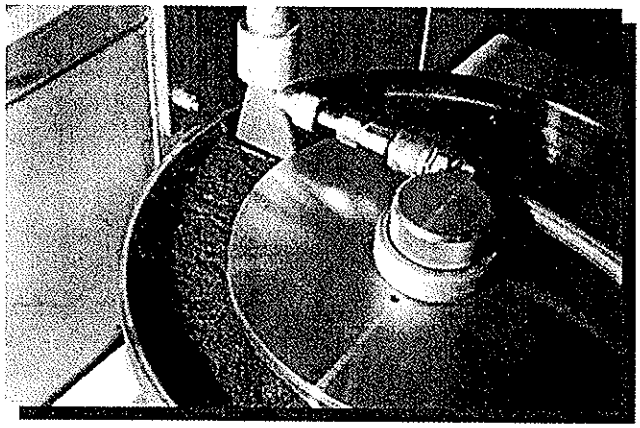
Contaminants	Particulate Filter MERV 13 / F7	Gas Phase Filter	Sources
CO_2	Not effective	Not effective	Indoor, human beings
VOC's	Not effective	Very effective	Outdoor, Indoor
NO_x	Not effective	Little effective	Outdoor, Traffic
Particles	Very effective	Not effective	Outdoor, Indoor
Tobacco Smoke	Effective	Not effective	Indoor
Bacteria	Very effective	Not effective	Outdoor, Indoor
Viruses, spores	Effective	Not effective	Outdoor, A/C Plant
SOx	Not effective	Little Effective	Outdoor, Heating
Ozone	Not effective	Very effective	Outdoor, EAC
Radon	Not effective	Not effective	Indoor, building material

Understanding Filter Characteristics



Understanding Filter Characteristics

Synthetic Test Dust for simulating pressure drop



Standard ASHRAE Test Dust composition

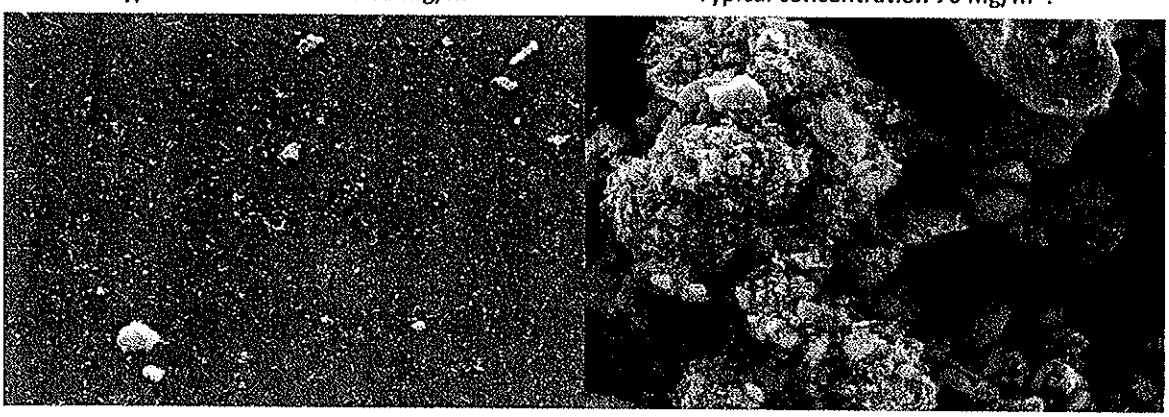
1. 72% standardized air cleaner test dust (fine dust) is classified from gather in a desert area in Arizona. It is predominantly silica and has a mass-mean diameter of approximately 7.7 micrometers, a geometric standard deviation of approximtely 3.6, and a specific gravity of approximately 2.7
2. The linters are No. 7 cotton linters ground in a wiley mill to pass a 4 mm screen in the mill.
3. The powdered carbon is carbon black in powder form

Understanding Filter Characteristics

Dust trapped on filter media

Natural dust
Typical concentration 0.05 mg/m³

ASHRAE 52.1 or EN 779 dust
Typical concentration 70 mg/m³ !



Dynamic natural environment

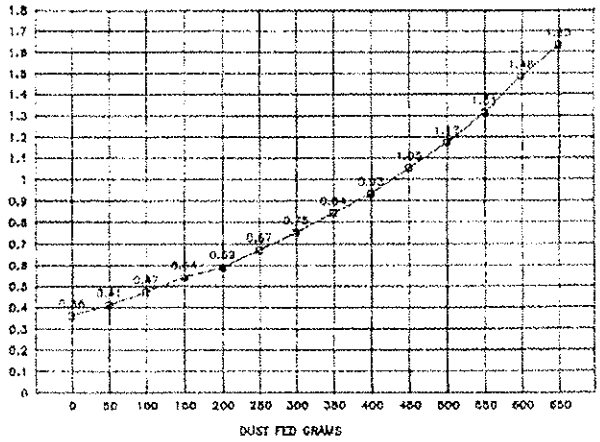
Controlled lab environment

Understanding Filter Characteristics

Pressure drop differs due to the test dust used

Dust fed vs. Resistance

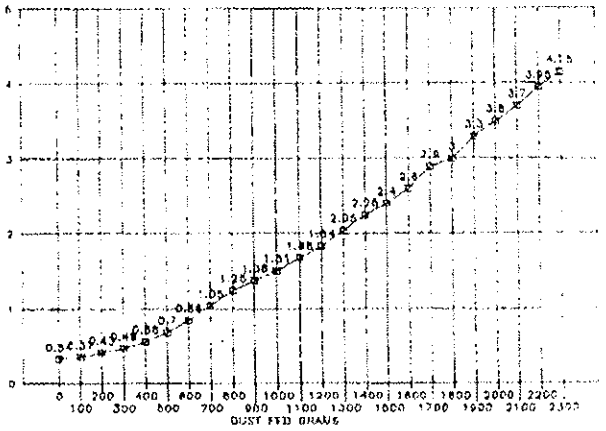
Dust increment – 50mg ASHRAE Standard Test Dust



1 inch / 250 Pa = 450mg

Dust fed vs. Resistance

Dust increment – 100mg AC Fine



1 inch / 250 Pa = 700mg

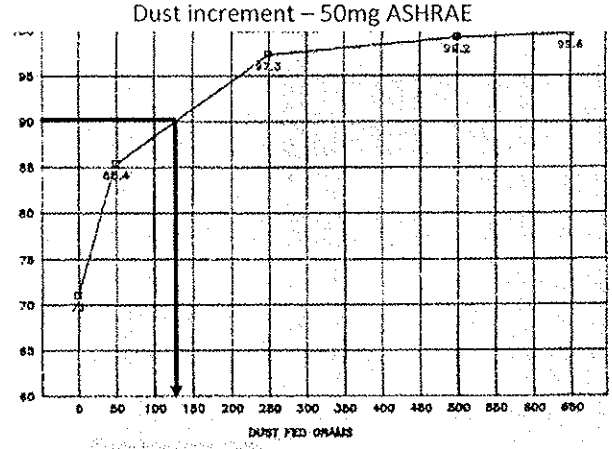
**Coarse dust increases filter pressure drop at a faster pace than fine dust.*

Understanding Filter Characteristics

Efficiency improves with higher dust loading

Dust fed vs. Efficiency

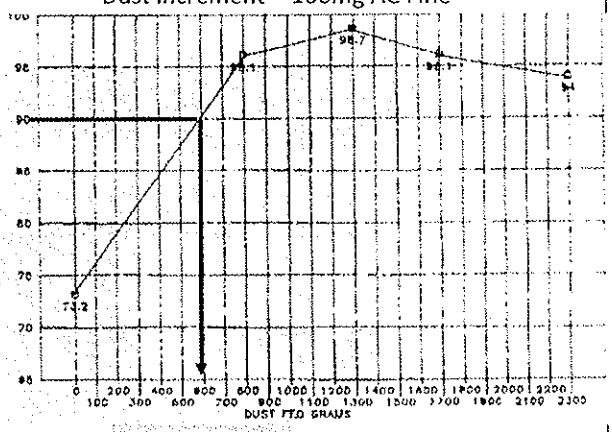
Dust increment – 50mg ASHRAE



<130 gms

Dust fed vs. Efficiency

Dust increment – 100mg AC Fine



600 gms

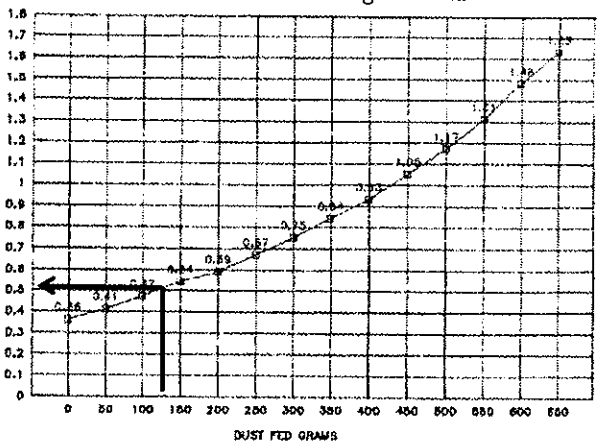
- *Filter efficiency improves throughout its service life.*
- *Efficiency declines when overused.*

Understanding Filter Characteristics

Pressure drop differs due to the test dust used

Dust fed vs. Resistance

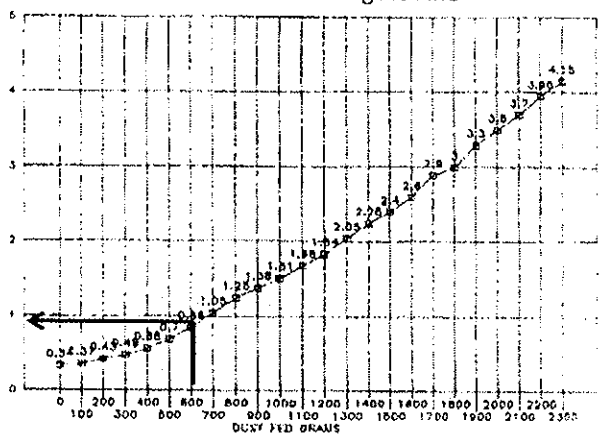
Dust increment – 50mg ASHRAE



130 mg (Dust fed)
90% Efficiency at 0.5 inch / 125 Pa

Dust fed vs. Resistance

Dust increment – 100mg AC Fine



600 mg (Dust fed)
90% Efficiency at 0.8 inch / 200 Pa

Understanding Filter Characteristics

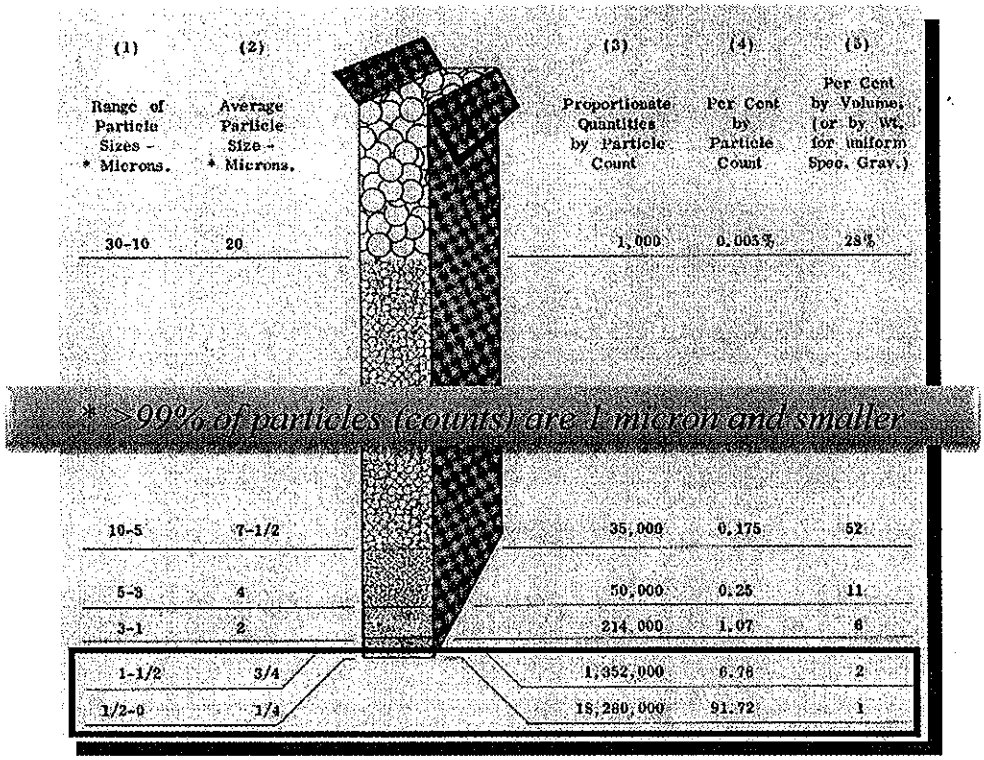
** Dirty filters enhance filter efficiency*

✓ **Optimize filter service life**

✓ **Improve air quality**

Understanding the Airborne Dust

Size Distribution of Typical Atmospheric Dust Sample



(1) Range of Particle Sizes – * Microns.	(2) Average Particle Size – * Microns.	(3) Proportionate Quantities by Particle Count	(4) Per Cent by Particle Count	(5) Per Cent by Volume, (or by Wt. for uniform Spec. Grav.)
30–10	20	1,000	0.003%	28%
10–5	7–1/2	35,000	0.175	52
5–3	4	50,000	0.25	11
3–1	2	214,000	1.07	6
1–1/2	3/4	1,352,000	6.76	2
1/2–0	1/4	18,280,000	91.72	1

** >99% of particles (counts) are 1 micron and smaller*

Understanding the Airborne Dust

Description	Size (in micron)
Human hair	35 – 200
Cement dust	3.5 – 95
Bacteria	3.5 – 35
Dust harmful to lungs	0.5 – 5
Cigarette smoke	0.01 – 0.9
Viruses	0.003 – 0.005

USA - ASHRAE 52.2				ASHRAE 52.1	Category	European - EN 779 / EN 1822		
Class	Separation Performance - %					Class	Separation Performance %	
	Particle Size Range Efficiency			Arrestance				
MERV	0.3 – 1 µm	1 – 3 µm	3 – 10 µm	ASHRAE Test Dust		Measuring Principle	Arrestance Gravimetric	Ave. Efficiency Discoloration / 0.4 µm
1	Not Applicable	Not Applicable	< 20	< 65	Coarse dust	G1	< 65	Not Applicable
2			< 20	65 - 70				
3			< 20	70 - 75		G2	65 ≤ – < 80	
4			< 20	≥ 75				
5			20 – 35	Not Applicable	Low Efficiency	G3	80 ≤ – < 90	
6			35 – 50					
7			50 – 70			G4	> 90	
8			> 70					
9		< 50	≥ 85		Medium Efficiency	F5		40 ≤ – < 60
10		50 - 65	≥ 85					
11		65 - 80	≥ 85			F6		60 ≤ - <80
12		> 80	≥ 90					
13	< 75	≥ 90	≥ 90		High Efficiency	F7		80 ≤ – 90
14	75 – 85	≥ 90	≥ 90			F8		90 ≤ – <95
15	85 – 95	≥ 90	≥ 90			F9		≥ 95
16	≥ 95	≥ 95	> 95			H10		*100%

Filter Selection

Objective: To obtain the cleanest air at the lowest cost

1. Identify your objective or concern.
2. Know your filter efficiency. Is it applicable?
3. Select filters based on decontamination factor.

For Example:

F7 (efficiency 0.4micron) = <85%
Inefficiency = 15%
Decontamination Factor is 100 / 15
= 6.7 times cleaner downstream

F8 (efficiency 0.4micron) = < 92%
Inefficiency = 8%
Decontamination Factor is 100 / 8
= 12.5 times cleaner downstream

Large Media Area = Low Pressure Drop = long service life & low life cycle cost

Therefore: F8 provides 1.9 times cleaner air than F7 *(12.5 / 6.7 = 1.9)*

Benefit from good filtration

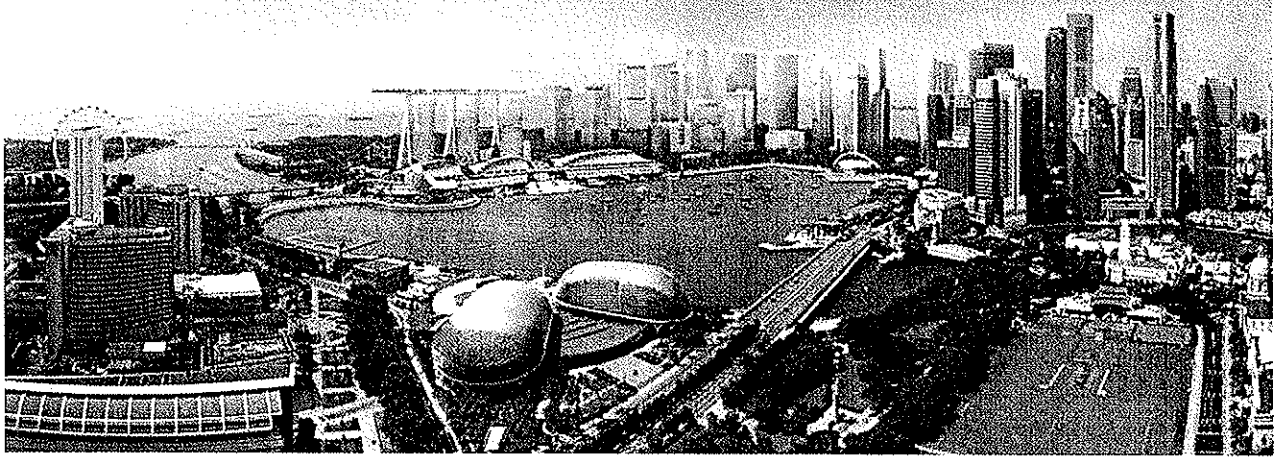
- Clean HVAC system facilitates efficiency and improves performance
- Efficient heat exchangers improves energy consumption.
- Less cleaning work in HVAC plant and of duct system
- Lowers long-term operation cost of HVAC plant
- No cleaning of ductwork required in life time of building - Delays deterioration of equipment
- Lower risk of hidden microbial contamination

Better IAQ

- Higher removal rate of undesirable contaminants.
- Reducing the risk of Sick Building Syndrome (SBS) due to IAQ problems.
- Helps to promote a healthy environment and improves attendance and work performance of staff.

Application of SS553 and SS554 in BCA Green Mark criteria

Dr Gao Chun Ping
Building and Construction Authority



Building and Construction Authority

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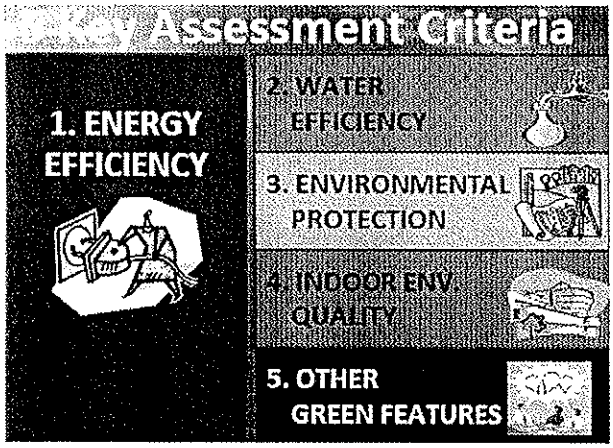
3 Impact of New SS 553/554

4 Summary

BCA Green Mark Scheme

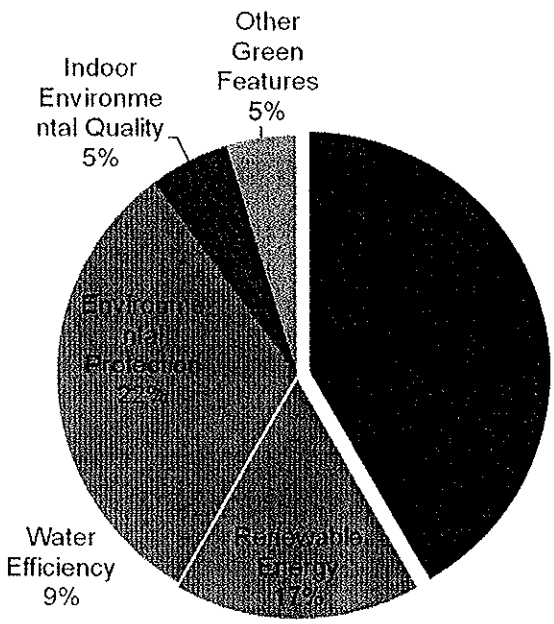
BCA GREEN MARK

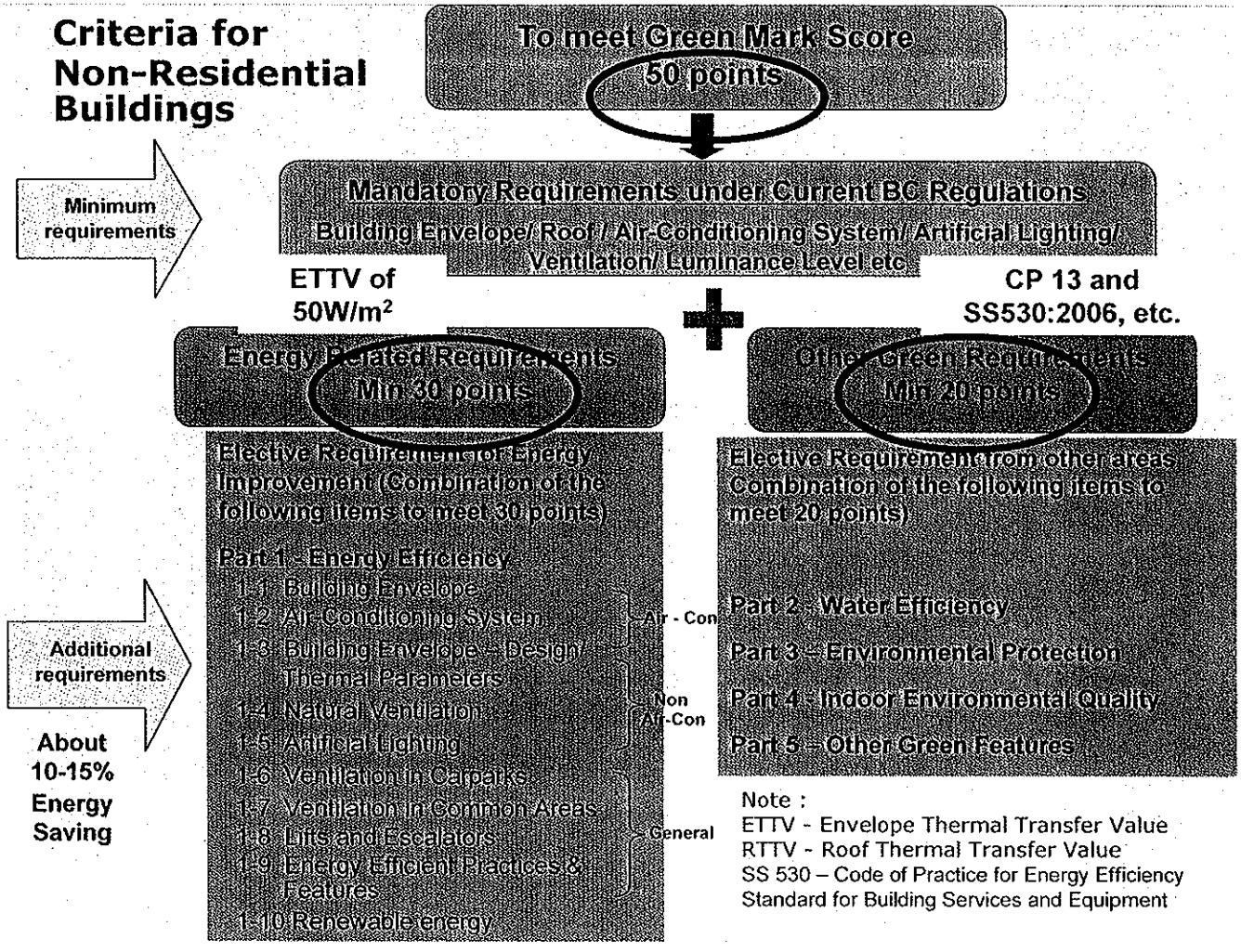


Green Mark	Try Again	Certified	Gold	GoldPlus	Platinum
Score	0 – 49	50 – 74	75 – 84	85 – 89	90 – 100
Estimated Energy Savings		10% to 15%	15% to 25%	> 25%	> 30%

BCA Green Mark Scheme

Non Residential Version 3.0 Weighted Score Percentage





Green Mark Referenced Standards

- **CP 13, SS 530 etc. as references**
- **Green Mark points calculation based on referenced standards**
- **Direct link to energy simulation: baseline or reference model setting**

Referenced Standards

(a)(i) Air-Conditioned Plant

1.45 points for every percentage improvement in the efficiency of chiller, chilled-water pump and condenser water pump.

Points awarded = 1.45 x (% improvement)

0.05 point for every percentage improvement in the performance required for cooling tower.

Points awarded = 0.05 x (% improvement)

(Up to 20 points)

(a)(ii) Air Distribution System

0.5 points for every percentage improvement in the air distribution system efficiency.

Points awarded = 0.5 x (% improvement)

(Up to 5 points)

(Excerpt from Green Mark version 3)

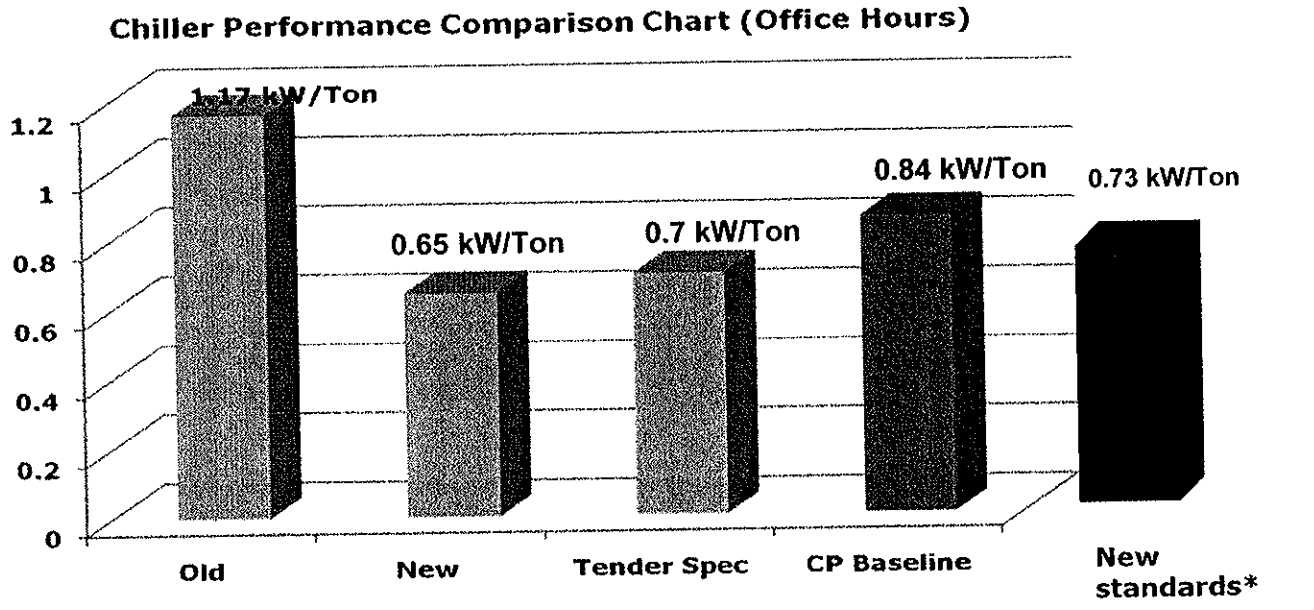
Energy Modeling References

S/N	Component	Baseline standard	Minimum Requirement
3	Pump Efficiency (Chilled water, Condenser water,	CP13:1999 (cl 7.11.6 – Pump system design criteria)	Chilled Water Pump energy consumption shall not exceed 0.033 kW/kW Condenser Water Pump energy consumption shall not exceed 0.025 kW/kW 7.11.6 Pumping system design criteria
5	Mechanical Fans	CP13:1999 (cl 7.11.5 – Fan system design criteria)	Fan power shall not exceed 0.47 W per m^3/h and 0.74 W per m^3/h for CAV and VAV system respectively. 7.11.5 Fan system design criteria (a) For fan systems which provide a constant air volume whenever the fans are running, the power required by the motor for the combined fan system at design conditions shall not exceed 0.47 W per m^3/h of supply air.

Impact of New Standards - SS553/554

- **Enhanced requirements on testing and commissioning, energy audit, etc.**
  - Measurement and verification requirement
  - Energy modeling verification
- **Better connection between energy efficiency and indoor environment quality**
- **Others, e.g. detailed energy requirements on energy recovery and piping and ducting insulation, etc.**

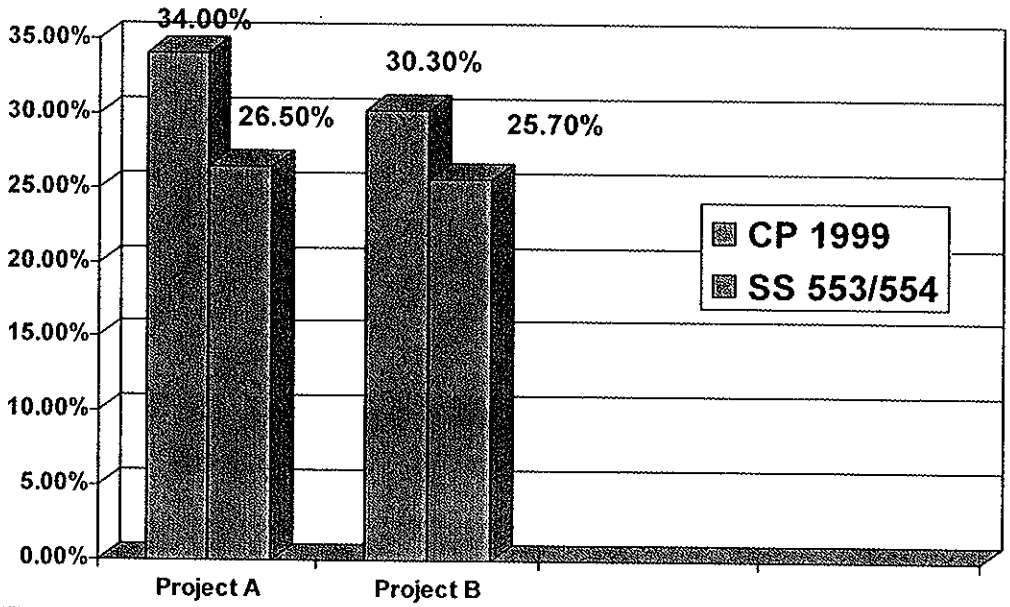
More Emphasis on Energy Efficiency



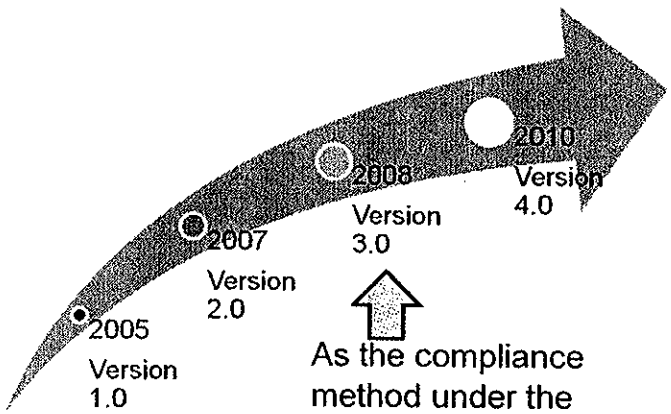
(*Under typical assumptions)

Energy Modeling Case Study

- **Energy baseline raised by 5~7%**



Versioning of GM for New Building



As the compliance method under the Building Control (Environmental Sustainability) Regulation 2008

GM Version 4.0 (in progress)

Incorporation of SS553/554

- Enhanced Commissioning, M&V
- Greater Emphasis on Energy related Compliance check
- Advocate Passive Design
- Promote Sustainable Construction
- Enhanced pre-requisites for higher GM rating

Getting industry feedbacks and fine-tuning criteria

About 120 developers, buildings architects, M&E consultants

Summary

- New standards place more emphasis on energy efficiency
- New standards are being evaluated and will be incorporated in the Green Mark criteria development
- Going forward, Green Mark will enhance energy efficiency compliance check and Green Building performance verification based on new standards

