# Evolution of ventilation strategies in air-conditioned buildings in Singapore – IAQ and Energy perspectives

Chandra Sekhar

*National University of Singapore*
*Department of Building,*
*School of Design and Environment*
*4, Architecture Drive, Singapore 117566*

## SUMMARY

Situated 1º North of the equator, Singapore has a year-round hot and humid climate with temperatures in the range of 25 and 32º C and relative humidity around 70%. In view of these environmental conditions, there is really no need for "Heating (or simply "H") in the traditional Heating, Ventilating and Air-Conditioning (HVAC) terminology. Consequently, the term Air-Conditioning and Mechanical Ventilation (ACMV) is used in the local industry. Air-conditioning has over the years become a necessity across the entire building sector, and in particular, in commercial, office, institutional, hotel and hospital buildings. With rising affluence levels, air-conditioning has also become more prevalent in the residential building sector. This presentation tracks the evolution of ventilation strategies in ACMV systems as well as the associated ventilation and IAQ guidelines and standards in Singapore since the 70s. Whilst the early years in Singapore's built environment evolution and development (70s through 90s) were primarily driven by energy considerations, ventilation and IAQ requirements were not ignored. In fact, ventilation provisions were always integral to the building regulations even from those early years. Since the nineties, IAQ awareness rose considerably that also led to the launch of IAQ guidelines in 1996, followed by two related standards in 2009, one on ventilation and the other on IAQ, both of which are part of the design specifications for the built environment. Singapore's own building rating system, called the Green Mark scheme launched in 2005, started with a primary focus on energy and has, since 2015, incorporated an enhanced IEQ and well-being criteria. The fundamental philosophy of ensuring a good balance between energy and IEQ is key to the whole notion of designing and operating energy-efficient healthy buildings.

## KEYWORDS

Air-Conditioning and Mechanical Ventilation; Hot and Humid Climate; Ventilation Strategies; High Recirculation Rates; IAQ; Energy

## 1 INTRODUCTION

The high energy penalty associated with air-conditioning in hot and humid climates has always been a challenge and, hence, a driver for the design of such systems for different types of buildings. Inherent in these designs for energy conservation and energy efficiency are also the considerations for good Indoor Air Quality (IAQ) in the built environment. As "heating" is not needed for comfort air-conditioning in hot and humid climates, the industry term is Air-Conditioning and Mechanical Ventilation (ACMV) rather than the more commonly used Heating, Ventilating and Air-Conditioning (HVAC). This presentation traces the origin of the typical air-conditioning system design concept in Singapore buildings with a particular focus on the ventilation strategies of the various systems adopted and its evolution over the past four decades to the present-day notion of creating and sustaining energy efficient healthy buildings. Singapore introduced its building rating system, called the Green Mark scheme in 2005, which started with a primary focus on energy and has, since 2015, incorporated an enhanced Indoor Environmental Quality (IEQ) and well-being criteria.

## 2 ACMV CONCEPT AND EVOLUTION IN SINGAPORE

Since the 70s, the most commonly employed ACMV systems in Singapore include the following:

1. Constant Air Volume (CAV)
2. Variable Air Volume (VAV)
3. Primary Air Fan Coil Units (PA-FCU)

VAV systems and PA-FCUs are still popular in current designs. In view of the high energy penalty associated with air-conditioning in hot and humid climates, a high amount of recirculation up to 90% is generally used. This leads to the design and operation of air-conditioned buildings having minimum ventilation provisions, and by design, would not have the possibility of free-cooling or economiser cycle operation.

PA-FCUs are commonly used in designs of hotel buildings as it provides ventilation to all guest rooms at all times and gives considerable flexibility in the operation of the secondary FCUs for additional cooling on demand. A related concept, called the Pre-cooled AHU has also been used in some high-rise building designs with the view of a centralised means of conditioning all the outdoor air needed in a building and distributing through a vertical shaft to the various secondary AHUs at each level. It is, however, to be noted that the Pre-cooled AHU located on the roof-top of a building only caters to partial cooling and dehumidification of the outdoor air and the secondary AHUs need to be designed for additional cooling and dehumidifying capacities.

The 90s also saw the entry of refrigerant modulation systems in buildings in Singapore, which continues to be popular to this day. Although the energy benefits of such systems are fairly well established, it is important to acknowledge the potential IAQ challenges involved if a separate ventilation system or strategy is not considered. The designer needs to ensure that adequate ventilation is provided in these buildings.

The above systems could be considered as typical ACMV systems for Singapore and cover almost the entire sector of commercial, office, institutional, hotel and hospital buildings.

The energy issues and indoor humidity concerns in air-conditioned buildings have also been addressed by employing technologies to better handle the cooling and dehumidification processes. Heat pipes have begun to be used in some buildings since the 90s as they provide significant energy savings and simultaneously achieve good humidity control, especially in applications needing 100% Outdoor Air.

Within the past decade or so, the concept of DOAS integrated with chilled beams or other means of providing secondary localised cooling is drawing considerable attention. Some examples of such recent applications will be presented.

Since the 70s, there has been a gradual evolution of the ACMV concept in buildings in Singapore. Energy, ventilation and IAQ criteria have been the primary drivers for this evolution and the current thinking encompasses the following key considerations:

- High Temperature cooling and dehumidification
- Move only as much air as is needed for ventilation

- It is much more energy efficient to move water/fluid to occupied zones for heat transfer/cooling
- Elevated space temperature and elevated air speed for Thermal Comfort

## 3 EVOLUTION OF VENTILATION AND IAQ STANDARDS

Ventilation requirements have been an integral part of the Singapore Building Regulations since the early 80s. As mentioned earlier, energy considerations were the prime mover and minimum ventilation provisions were specified (CP13, 1980), which underwent one revision in 1999. It was only in 1996 that IAQ guidelines were first introduced in Singapore. In 2009, CP13 was further revised and redesignated as SS553 and a new standard on IAQ was also simultaneously launched (SS553, 2009; SS554, 2009). These two standards are now to be used in tandem for specifying indoor environmental requirements in buildings.

## 4 REFERENCES

CP 13, 1980. *Code of Practice for Mechanical Ventilation and Air-conditioning in Buildings* Singapore

SS 553, 2009. Singapore Standard. *Code of Practice for air-conditioning and mechanical ventilation in buildings,* Singapore.

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