VENTILATION SYSTEMS

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Summary

Heating, Ventilating and Air-Conditioning (HVAC) has attained a major industry status and is continuously growing despite the serious challenges being faced. The role of HVAC systems has grown from temperature and humidity control and the supply of outdoor air, to more elaborate control of outdoor and indoor contaminants and odors, providing proper indoor environmental quality (thermal and acoustical comfort and air quality) at the lowest possible energy cost.

Along these lines, the evolution of ventilation systems has also been dramatic during the twentieth century. Natural ventilation was surpassed by mechanical ventilation combined with comfort air conditioning in order to resolve practical problems for the year-round control of the indoor environmental conditions.

The possibilities of HVAC buildings seemed to be trouble-free, until concerns arose about indoor air quality associated with sick building syndrome and the energy crisis with subsequent continuous concerns for energy conservation. These problems have generated the need to pay a lot more attention to design options and equipment

maintenance, the development of strict standards, and design guidelines that take into consideration all aspects of indoor environmental quality and energy efficiency. This section presents some fundamental information on ventilation and related parameters that can affect its performance related to indoor environmental quality (IEQ) which involves thermal comfort, acoustical comfort, and indoor air quality (IAQ).

An outline of energy conservation measures appropriate for ventilation systems are included at the end.

1. Introduction

Control of the indoor environment has developed over the centuries from simply providing heating for living and working spaces to the use of mechanical cooling systems for more comfortable year round indoor environments by the mid-nineteenth century. However, growing concern about the quality of indoor air and the development of more elaborate central air conditioning systems have given more emphasis to ventilation systems and the control of indoor air quality in relation to airborne contaminants, odors, and irritants. Heating, Ventilating and Air-Conditioning (HVAC) has attained a major industry status and is continuously growing despite the serious challenges being faced.

The energy crisis in the mid-1970s shifted concern to increased equipment efficiency and to improved standards of insulation for the control of heat losses and gains. However, efforts for reducing heating and cooling costs resulted in reduced air infiltration into buildings and reduced use of outdoor fresh air, and gave rise to various indoor air quality problems. At the same time, poor outdoor air quality in urban environments and an increase of indoor contaminant sources have justifiably increased the importance of ventilation systems. The role of HVAC systems has grown from temperature and humidity control and the supply of outdoor air, to more elaborate control of outdoor and indoor contaminants and odors, providing proper indoor environmental quality (thermal and acoustical comfort and air quality) at the lowest possible energy cost. To reach this goal engineers, architects, contractors, technicians, and occupants have developed elaborate ties to maintain the delicate balance and quality of building and indoor environments.

Figure 1. One of the first historic naturally ventilated buildings in Palermo, Italy. Main building facade (left) and the building's model (right).

The evolution of ventilation systems has been dramatic during the twentieth century. The concern with supplying fresh (outdoor) air to indoor environments became more elaborate as buildings grew in size and as occupants became more demanding for indoor thermal comfort conditions.

The use of outdoor air for natural ventilation, combined with natural cooling techniques and the use of daylight, have been essential elements of architecture since ancient times. Classical architecture with H, L, T or U-shaped floor plans, the use of open courts and limited space depth, and maximized windows to facilitate the interaction of the indoor environment with the outdoors for daylight and natural ventilation.

This was common practice even for large commercial buildings up until the end of the nineteenth century.

Naturally ventilated buildings have been common in several parts of the world from the ancient Hellenic architecture to the Arabian wind towers. A prime example of a naturally ventilated building is the Arabian palace in Palermo, Italy (Figure 1).

Comfort air conditioning with the advancement of mechanical cooling gave rise to new attitudes to luxury with better control of indoor environments despite the outdoor weather conditions. HVAC systems were promoted for providing exceptional indoor comfort conditions and healthier air quality.

Technology advancements led to market growth and cost decreases, to the point that HVAC has become common practice. Building architecture broke loose from its dependence on the outdoor environment, since HVAC could practically provide any kind of indoor conditions despite the outdoor weather.

However, since other critical parameters like energy conservation and sick building syndrome have also come into play, the use of HVAC systems and the function of the building envelope has somewhat followed a circular motion.

The first attempts to use HVAC systems and all-air ventilation systems in large commercial buildings in the United States recognized the potential of exploiting the combined effects of natural ventilation with mechanical systems in order to resolve practical problems and limitations.

Since lower floors suffer from noise and odors coming from the street level, natural ventilation can be problematic. Accordingly, for one of the first applications in a 21-storey office building in New York City the mechanical warm air supply and extract ventilation system only served the lower seven floors. Similar practices continued into the late 1930s.

Even from the beginning of the twentieth century, sealed buildings with mechanical ventilation made their appearance. However, HVAC systems were first installed in movie theaters, followed by other recreational environments, auditoriums, hotels, and then residences around the mid-twentieth century, predominantly in the United States. One of the first fully air-conditioned applications was the New York Stock Exchange (the cooling and ventilation system, designed by Alfred Wolff and installed in 1904, used ammonia absorption machines to control indoor temperature and humidity and to distribute clean, conditioned air to the trading room). The first skyscrapers and the great majority of large office buildings still relied on natural ventilation.

Technology continued to advance and the terms "air conditioning" and "mechanical ventilation" started coming into common use. Understandably, modern large commercial buildings had to follow the general trend and become fully equipped with HVAC systems for year-round comfort, with the additional prospects of increased property value.

Building architecture could finally break away from the need to have specific building forms and interior space layout to allow for natural ventilation and daylight, since HVAC and electric lighting could allow deep-plan buildings, even to an extreme of not having windows. Interior space layout and exterior building appearance changed dramatically. All-glazed sealed buildings became very popular, especially for large commercial buildings.

However, modern architecture became fully dependent on HVAC systems in order to operate. The possibilities of HVAC buildings seemed to be trouble-free until concerns arose about indoor air quality associated with sick building syndrome and the energy crisis with subsequent continuous concerns for energy conservation.

These problems have generated a need to pay a lot more attention to design options and equipment maintenance, the development of strict standards, and design guidelines that take into consideration all aspects of indoor environmental quality.

A re-evaluation of previously common practices have returned back to mixed modes of HVAC systems and naturally ventilated buildings, combined with new technology features of controls and automation that enhance the positive and minimize the negative aspects, to the benefit of occupant's comfort and optimum energy use.

Certain practices rediscovered the positive features that promoted good indoor environmental conditions in the past, but were unfortunately "forgotten" when HVAC systems became popular. Now, these practices try to combine the "old know-how" with the conventional HVAC systems, in an effort to get them working together.

For example, natural cross ventilation and the use of wind towers (Figure 2) to enhance system effectiveness, coupled with a building automation system to operate windows and the HVAC system, are a few examples of how traditional systems can be combined in a modern office building design.

Figure 2. Modern office building with a blend of HVAC systems and classical features of natural ventilation. The BRE office building in Garston, UK uses among other features five wind towers to enhance natural ventilation.

The Commerzbank office building (Frankfurt, Germany), the tallest building in Europe (63 floors with a height of 259 m) constructed in 1997 (Figure 3), is another prime example of how HVAC systems can be put to work together with natural ventilation, even in modern high-rise office buildings.

The building utilizes natural ventilation of office spaces through openable windows up to the 50th floor, interior courtyards with naturally ventilated gardens by openable window sections that minimize overheating, and building management systems for optimum control of indoor conditions and operation of the various systems.

The goal is to design, build, and operate healthier buildings that satisfy environmental and energy concerns. These can be achieved by using new technologies like efficient air filtration, floor-level and other improved air distribution techniques, off-peak energy storage, improved efficiency equipment supported by new control and management systems, and proper maintenance, along with traditional methods like natural ventilation, effective external and internal load reduction.

This introductory section presents some fundamental information on ventilation and related parameters that can affect its performance related to indoor environmental quality (IEQ) which involves thermal comfort, acoustical comfort, and indoor air quality (IAQ). The underlying operation of ventilation systems for IAQ includes filtration, humidity control, and contaminant control for both outdoor and indoor sources, at appropriate ventilation rates. An outline of energy conservation measures appropriate for ventilation systems are included at the end. Following sections provide greater detail, technical data, and other relevant information on calculations, experimental work, and standardization in the areas of IAQ, natural ventilation, mechanical ventilation, filtration, and energy conservation.

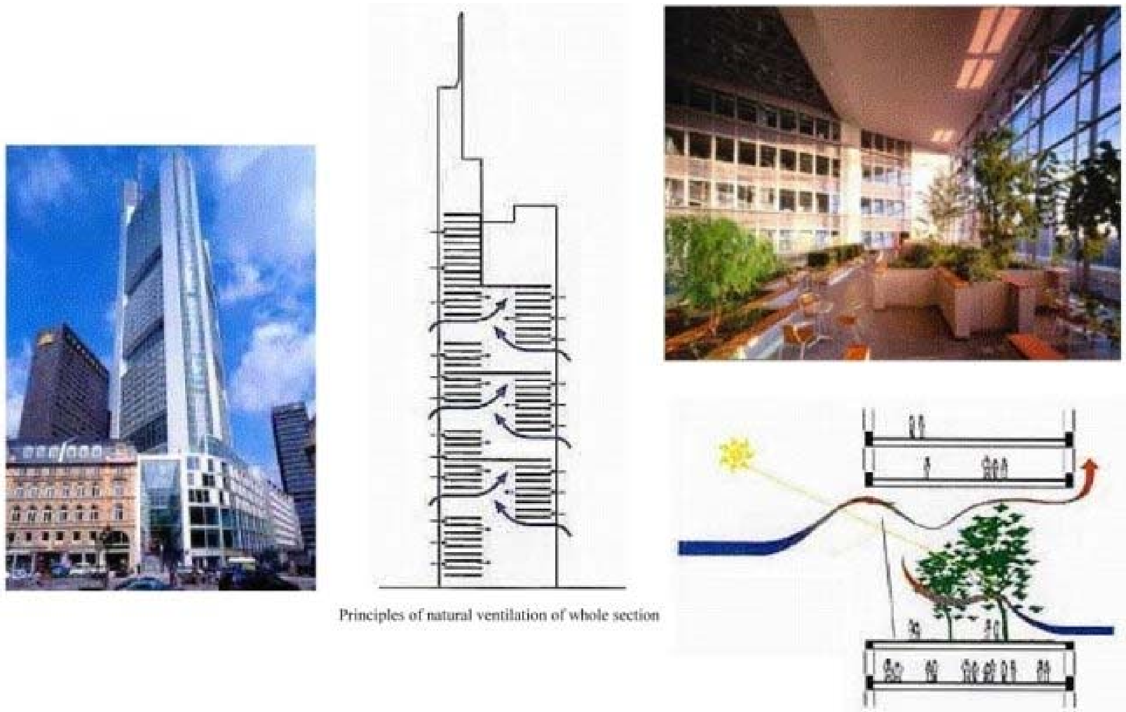

Figure 3. The tallest building in Europe using natural ventilation. General view of the building (left), building cross section and outline of natural ventilation and stack effects (center), detail of the court yards viewed from inside (top right picture), and cross section and outline of natural ventilation (bottom right picture) [Source: Commerzbank, 2000.]

2. Ventilation Systems

The indoor environment quality has a direct impact on the well-being and health of building occupants. This comes as a direct result of the fact that:

- “Most people spend 60–90% of their time indoors” (American Lung Association);
- “50% of ALL illness is either caused or aggravated by polluted indoor air” (American College of Allergists);
- “Indoor air is found to be up to 70 times more polluted than outdoor air” (Environmental Protection Agency).

Air ventilation plays a dominant role in achieving and maintaining comfort conditions and acceptable indoor environmental quality in any environment. Ventilation supplies the necessary amounts of fresh air, either by:

- Natural ventilation: the outdoor air enters into the space and the indoor air exits from the space as a result of physical processes (wind and temperature differences). The ventilation rates depend on the prevailing outdoor (e.g. variability of wind velocity and direction) and indoor conditions, and thus there is limited control. However, when it is properly designed it can improve indoor thermal comfort conditions and air quality at no energy cost. Natural ventilation is effective in terms of its positive impact for improving the indoor thermal comfort conditions in summer and for the control of indoor air quality when it occurs through large openings (i.e. windows or doors). The size, space, and opening geometry, play a determinant role on the resulting air flow rates. Infiltration, that is air coming through very small openings (cracks) is another way that outdoor air can enter into a space. However, this air flow is associated with heat losses during winter (cold outdoor air coming into the space) and heat gains during summer (warm outdoor air coming into the space), thus increasing the heating and cooling loads. Infiltration has a small contribution in the fresh air supply of a space but it does not play a role in terms of improving the indoor thermal comfort conditions. The air flow is too low to have any meaningful impact on summer thermal comfort, while in winter infiltration can result in disturbing cold drafts.
- Mechanical ventilation: the outdoor air is supplied and the indoor air is exhausted by mechanical means using fans and ductwork. The air flow can be controlled in terms of quantity, velocity, quality, and thermal conditions, at the expense of higher energy consumption. Several systems and techniques are available for the proper handling of indoor air quality problems (using various types of filters) and for energy conservation.
- Hybrid ventilation: the outdoor air supply is primarily based on natural ventilation assisted with simple fans to enhance the effectiveness and control the air flow rates, at a minimal energy cost.

The quantity of outdoor air that needs to be brought into the space is determined by national standards, depending on the function of the space. The air movement into the space must be handled with care, since there is a direct influence of air velocity on occupant comfort.

Outdoor air quality will influence indoor conditions, thus one needs to exercise caution when using untreated outdoor air. This is of great importance especially in large metropolitan cities, where outdoor air may be heavily polluted with particulate and gaseous contaminants. Health standards may impose limits on the use of untreated outdoor air, which as a result, limits the effectiveness of natural ventilation techniques and influence comfort conditions in naturally ventilated buildings. Ventilating a space with polluted outdoor air can heavily impose on indoor air quality, which may result in occupant health problems. Alternatively, the use of mechanical ventilation and air conditioning systems can be used to clean the outdoor air from atmospheric dust. However, it is not possible to treat outdoor air for gaseous contaminants. In any event, the use of mechanical ventilation and air conditioning will increase the energy consumption and operational cost of the building. It is also essential that the filtering system is well maintained, to prohibit the growth of microorganisms which can even be fatal.

Increasing the ventilated air to maintain acceptable indoor air quality means that more outdoor air has to be heated during winter and cooled during summer, thus increasing the energy cost. The importance of ventilation, both as an indoor environmental quality issue and as the single largest heat loss/gain component, makes ventilation the most important design challenge for HVAC systems.

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Biographical Sketch

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