Green Building Handbook for South Africa
Chapter: Heating, Ventilation and Cooling

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The heating, ventilation and cooling loads of typical commercial office space can range between 30-50% of the total energy load of the building. However, this figure is highly variable due to the high variability in building design, the climate in which they are built and their quality. Typically, in South Africa the cooling load is the greatest and the reduction of this load should be one of the first targets when considering an energy-efficient building design.

Passive Strategies

Passive cooling strategies as discussed elsewhere in this book should be carefully considered for utilisation. Solar heat loading as well as internal heat loads should be minimised as much as possible as these two aspects of the building have a direct effect on the cooling load of the active air-conditioning systems.

Efficient Air Conditioners

When selecting an air conditioner for a building, care should be taken in regard to its energy efficiency. The energy efficiency of air conditioners are measured by its coefficient of performance (COP), and this value can typically range between 2 and 4. An air conditioner with a coefficient of performance of 3 will produce 3kWh of cooling with an energy input of only 1kWh, a higher coefficient of performance is desirable and indicates a more energy-efficient air-conditioning system.

Air-conditioning Control Systems

Appropriate controls for the HVAC systems should be properly implemented to ensure efficient and effective operation. Users within a building area need to have a level of control over the temperature and ventilation rates to ensure a comfortable environment. Green Star South Africa recommends a control point between every 15m^2 to 30m^2. Over cooling areas should be avoided as it both creates an uncomfortable work environment and it unnecessarily wastes energy.

For areas of the building that are used infrequently, such as boardrooms or lecture halls, automatic sensors linked to the HVAC systems should be considered. Automatic sensors can also be placed throughout the building in order to adjust the cooling from the HVAC system as occupancy levels within the building change.

Limiting Thermal Control

While it is of the utmost importance that building users have control over the thermal environment within the building, restrictions should be placed to ensure proper and efficient operation. The majority of people will be comfortable in the temperature range between 21° an d 26° at a humidity ratio of 0.004. The temperature at which an individual is comfortable is dependant on a large number of different variables including humidity, air speed, outside temperature, as well as the person's mass, metabolism and activity. Consequently, not everyone will feel comfortable within this temperature range; however, clothing can be adjusted to ensure comfort levels.

The air conditioners within a building can be restricted so that they can only operate within a specified temperature range and so that different air conditioners operating at large temperature differences can be avoided.

Ventilation Rates

The benefits of having high fresh air rates into a building and consequently a healthier, more comfortable working environment should not be underestimated. While difficult to quantify, benefits can include higher productivity, reduced absenteeism, increased employee health and increased employee retention.

However, increasing the fresh air ventilation rates is going to directly increase the energy load on the air conditioners as more air is requiring conditioning. SANS 10400-0 requires that 5ℓ/s/person of outside air is provided for office spaces, while Green Star South Africa recommends fresh air rates ranging between 7.5ℓ/s/person up to 12.5ℓ/s/person.

Exhaust Air Heat Recovery

In a well-sealed building where the air leaves in centralised locations, heat recovery systems can be installed. These systems can be as simple as air to air heat exchangers that allow heat to be transferred between the incoming and the outgoing air streams but do not allow them to mix.

If a building is being cooled, then the building's exhaust air is cool and it is effectively used to pre-cool the incoming warm air and thereby reducing the load on the building's air-conditioning system and energy is saved.

Heat Recovery Wheels

Heat recovery wheels allow sensible heat to be transferred between the incoming fresh air and the outgoing air with minimal mixing. The wheel rotates slowly between the different air streams and absorbs the heat from the warm air stream and transfers it to the cold air stream. Heat recovery wheels operate effectively when the building is either being heated or cooled.

The wheel is typically manufactured from a highly conductive material and incorporates many small channels where the air streams may flow through and thus the surface area in which heat transfer can occur is maximised.

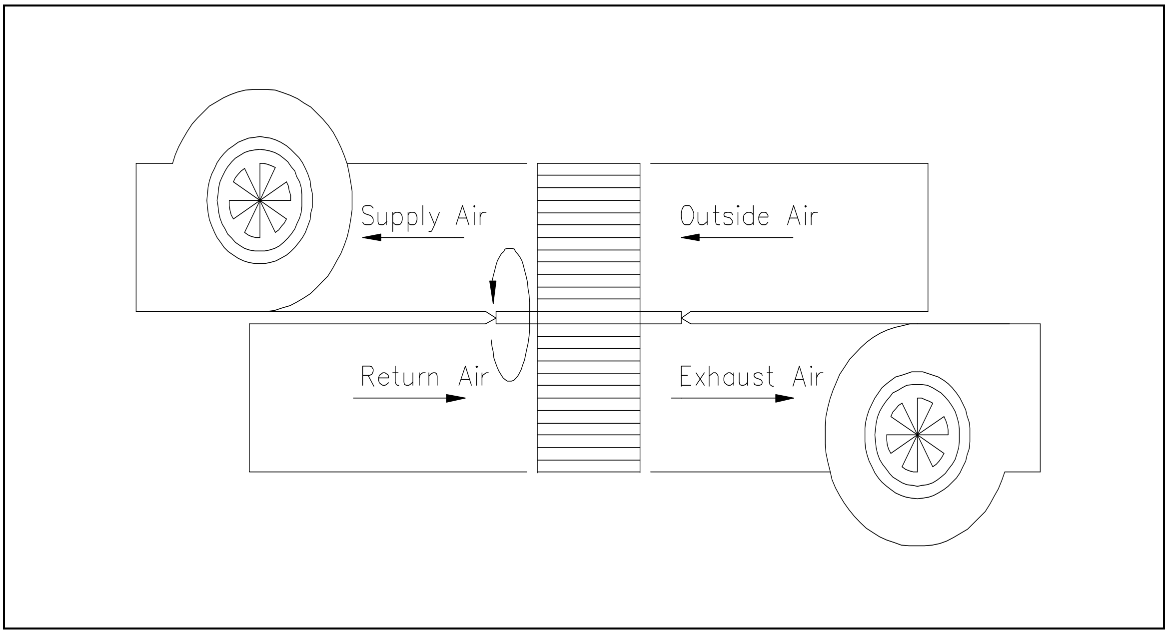

Figure 1: Diagram of a heat recovery wheel

Enthalpy Wheels

Enthalpy wheels are similar to heat recovery wheels with the notable difference that desiccants are included in the design. A desiccant is a substance that absorbs moisture from the nearby environment. They are used in enthalpy wheels so that the latent heat of the moisture in the air can also be transferred as well as the sensible heat.

Moisture is absorbed by the desiccant from the air stream that has the higher moisture content and is evaporated by the air stream with less moisture. Enthalpy wheels are more effective at transferring energy between the air streams as both sensible and latent heat is transferred.

Ground-Coupled Heat Exchanger

Ground-coupled heat exchangers (earth cooling tubes or earth warming tubes) are essentially a series of tubes that are laid in the ground through which air can be moved and heat is transferred between the ground and the air. The tubes can be laid either horizontally or vertically depending on space constraints. A few meters below its surface the ground has a very consistent temperature; however, the temperature of the ground will vary with depth, geography and season.

The ground-coupled heat exchanger can be used to either heat or cool the air as conditions allow and if required. Typically using the tubes for heating and cooling will not be sufficient on their own but they can be used to either pre-heat or pre-cool the air and thus save energy on either the heating or cooling load.

In Europe, America and Canada such tubes are used in order to pre-heat the air and thus save energy on the heating load. The tubes could be used for pre-heating in South Africa when the correct conditions exist; however, their potential within a South African context lies with their ability to reduce air-conditioning loads during the day when the air is warm and the ground is cool.

Night Flushing

Offices and other commercial buildings operate during the day and typically are unoccupied at night. During the day the building gets warm, both from the sun and internal heat loads, and active air-conditioning is required. Typically at the end of the day, office buildings are locked up and the heat remains trapped inside the building and it would still be warm at the start of the next day.

The concept of night flushing is to use the cool night air to cool down the building so that the building is cooler when it is occupied in the morning. Typically the night air is blown through the building for about an hour or two just before sunrise. This should delay the time in which active air conditioning is required and thus energy is saved. Night flushing is more effective in buildings with high amounts of thermal mass and when the thermal mass is exposed. The use of suspended ceilings and raised floors insulates the thermal mass both from being cooled by the night air and from the heat that is being generated during the day, both of which is undesirable.

Thermal Storage

Office buildings within South Africa typically require cooling during the day and are unoccupied at night, when the temperature is cool. The coolness of the night can be stored within a thermal battery and can be used to keep the building cool during the day.

The thermal battery should be a highly insulated room with a large amount of thermal mass with a very high surface area. Storing rocks within wire mesh columns fulfils the requirement of providing large amounts of thermal mass with a high surface area; however, alternate strategies should also be considered.

During the night, air is blown into the thermal battery reducing the temperature of the thermal mass to the night time air temperature. Then, during the day, fresh air is brought through the thermal battery and the air is cooled before it enters the building or it is drawn to the HVAC system for further cooling. Such a strategy can significantly reduce the energy load on the HVAC system and will be particularly effective in environments with high diurnal temperature variations.

Evaporative Coolers

Evaporative coolers work on the concept that the evaporation of water has a cooling effect on its immediate environment due to the latent heat that it absorbs in order to evaporate. It is exactly the same concept that human bodies use through the evaporation of sweat in order to keep the body cool.

Evaporative coolers are significantly cheaper than standard air conditioners, are cheaper to operate and are also significantly more energy efficient. However, there are very important considerations that need to be examined when considering the implementation of an evaporative cooler.

Increased Levels of Humidity

Evaporative coolers function by evaporating water in order to cool the air; consequently, the humidity of the air produced is very high and could be uncomfortably so. One method of overcoming this problem is to use the cool humid air from the evaporative cooler to cool the buildings air through a heat exchanger so that the coolness is transferred but the humidity is not.

Alternatively the evaporative cooler can be used as a humidifier to produce cool air at a comfortable humidity, either by controlling the performance of the evaporative cooler, mixing the cool humid air with outside air and diluting the humidity or mixing the cool humid air with the air from a conventional air conditioner.

Climate Specific

The performance of an evaporative cooler is highly dependant on atmospheric conditions. Evaporative coolers work best in hot and dry conditions but their performance is severely limited when operating under hot and humid conditions.

Evaporative coolers should only be considered within environments that are consistently hot and dry, with their performance degrading as humidity levels increase.

Water Use

Although evaporative coolers are significantly more energy efficient than other active air-conditioning options, they do however consume water in order to achieve this purpose. The ecological value of saving energy has to be weighed against the ecological value of using water for this purpose. A common approximation of water usage is 0.002ℓ/s per m^3/s of air flow for each 5^{o}C of wet bulb depression.

Operation and Maintenance

It is very important that an installed system is being maintained correctly by competent persons to ensure both smooth and efficient operation as well as to prevent mould growth. Legionnaires disease is a concern within evaporative coolers if it is not maintained correctly.

Combined System

Evaporative coolers can be used as part of an integrated system to provide air conditioning to a building alongside more conventional air-conditioning systems. Evaporative coolers cannot be relied upon to provide effective cooling under all conditions, so having a backup air-conditioning option would be wise. Additionally, evaporative coolers provide a level of humidity control than can be used to create a more comfortable working environment.

Solar Thermal Powered Air Conditioning

The heat from the sun can be used to operate absorption chiller air-conditioning units that can be run off of hot water. Efficient absorption chillers require water of at least 88℃. These chiller units absorb heat and are capable of producing cold air.

Solar hot water panels can be installed on the building site and the hot water produced during the day can be used to run the absorption chillers. The availability of the hot water produced coincides with the cooling load of conventional office buildings; therefore thermal storage is not required.

There are some difficulties in using such systems too, mostly connected to the space required for the installation of the solar collectors and the need for accurate flow calculations.

Solar Hot Water Panels

Flat-plate solar thermal collectors only produce about 70℃-80℃ water. Evacuated-tube solar panels are better suited for such applications. The hot water temperature could easily reach 120℃. Concentrating solar collectors are another option; however, they are best suited for dry areas. These collectors are less effective in hot humid, cloudy environments, especially where the overnight low temperature and relative humidity are uncomfortably high.

Power Requirements

A 100kW cooling capacity chiller will require around 40kW electrical power if the chiller is air cooled; if the chiller is water cooled then 25kW electrical power will be required. By comparison the entire system (chiller, pumps, cooling tower, controller) based on the absorption chiller will require around 10kW of electrical power.

Backup System

The use of a solar air-conditioning system should be always considered in conjunction with a compression air-conditioning system as a stand by, so that no interruption of service will be experienced if the weather conditions are bad or if air conditioning during the night is required.

References

Ashrae Standard, ANSI/ASHRAE Standard 55-2004.

Green Star SA - Office version 1.