Design of ventilative cooling systems using Ventilative cooling standards; design steps and corresponding flow diagram

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SUMMARY

Ensuring an indoor environmental quality that is acceptable to the majority of users, while also being energy efficient is a challenge. In addition, both user demands and the climate change are making it even more difficult to ensure good indoor environmental quality. One of the solutions to combat climate change is free cooling systems, such as ventilative cooling.

One of the challenges for the design of ventilative cooling systems in general has been the lack of technical documents, such as standards dealing with the design process for free cooling systems such as Ventilative cooling. Another challenge has been that HVAC engineers have to get used to dealing with natural ventilation and ventilative cooling, as these technologies are not (only) based on mechanical principles. They may be reluctant to use these technologies because they threaten traditional fixed-fee design services and this needs to be addressed.

Therefore this article presents eight design steps to follow as part of the new forthcoming European Technical Specification "Ventilative Cooling Systems – Design" for the holistic design of ventilative cooling systems in buildings starting from the definition of performance criteria and requirements to the final definition of controls and operations. This design process should be used by e.g. HVAC engineers or architects.

KEYWORDS

Design, ventilative cooling, performance-based, prescriptive, prevention, modulation, dissipation

1 INTRODUCTION AND BACKGROUND

Today's design processes are based on many years of experience with complex, multidisciplinary construction projects. The specialists involved are integrated sequentially. This makes it possible to implement classic core applications such as mechanical ventilation and/or mechanical cooling in a pre-defined design phase in any building.

90% of a person's life is spent in buildings, which account for 40% of primary energy consumption. At the same time, user requirements and the outside climate are constantly changing. Ensuring an indoor environment that is acceptable to the majority of users and can be provided in an energy efficient manner is a challenge. Reducing the primary energy consumption of buildings is a societal imperative.

The challenges described above are leading designers and system providers of HVAC solutions to offer their customers natural ventilation, hybrid ventilation and ventilative cooling. With these concepts, the building should provide the occupants with an acceptable and energy-efficient indoor environment. The building must therefore be able to respond to rapidly changing external climatic conditions with some delay.

Modern HVAC concepts do not start in the pre-project phase, but already in the feasibility study phase. The HVAC engineer therefore becomes part of an integral design team, involved from the start of the project according to the phases. This implies a holistic view of the building project, as the interaction with the building envelope is essential.

Knowledge of key terms such as thermal mass, solar shading, window area ratio and free-running temperature is essential for the HVAC engineer. Free-running temperature occurs when the building is occupied without heating or mechanical cooling.

Heating and cooling bring the room temperature into the contractually agreed comfort range. The HVAC engineer is used to assuming constant room temperatures over time, as this is the goal of conventional heating and cooling technologies. HVAC engineers need to adapt their thinking to variable temperature ranges rather than fixed values, and to dynamic rather than static processes.

They must learn to deal with uncertainty and combine it with criteria for acceptable deviations from target and contract values. In addition, the client needs to create a contractual framework that takes into account the fact that target values cannot be checked on the day the system is handed over.

The HVAC engineer needs to get used to dealing with natural ventilation and ventilative cooling, as these technologies are not (only) based on mechanical principles. They may be reluctant to use these technologies because they threaten traditional fixed fee design services. Furthermore, hybrid solutions are often the most energy efficient and cost-effective so a combination of ventilative cooling and mechanical cooling is a good solution for future buildings in the climate change scenarios we are looking at.

The effect of buoyancy and wind pressure, the daily variation of the external temperature, the overall dynamic processes and the handling of uncertainties are new challenges for HVAC engineers.

2 THE DESIGN PROCESS OF VENTILATIVE COOLING

The design process for ventilative cooling is iterative and integrative. In the forthcoming European Technical Specification called "Ventilative Cooling Systems – Design" the following design process for ventilative cooling is used:

1. Setting performance criteria and requirements
2. Specifying design assumptions, prevention and modulation strategies
3. Evaluate the ventilative cooling potential
4. Defining an ventilation principle and dissipation techniques
5. Develop a ventilation strategy (air flow distribution path) for ventilative cooling
6. Re-evaluate prevention and modulation interventions
7. Determine supplementary cooling for development during design
8. Defining controls and operation

The order of key decisions may depend on the building type or project specific requirements. Re-evaluate the thermal comfort performance of the building at each design stage. Once the ventilative cooling system has been designed, document the specifications and layout (e.g. drawings, plans). It is also important to define the project objectives in consultation with the client.

Below the eight design steps are detailed:

1. **Setting performance criteria and requirements**

Depending on the design assumptions the complexity level of the appropriate performance requirements might differ. In this point also the project objectives shall be defined in agreement with the client, together with the performance criteria and requirements.

- **Prescriptive approach** includes primary ventilation requirements expressed in the form of airflow rates and corresponding descriptive technical requirements (i.e. an air flow rate can be described/assessed by an opening area, fx. a window opening area)
- **Performance-based approach** includes primary ventilation requirements expressed in the form of airflow rates or in the form of thermal comfort criteria

Possible criteria for thermal comfort can be for example predicted mean vote and percentage of dissatisfied, exceedance hours or temperature ranges (weighted or non-weighted). Temperature ranges can be calculated using the adaptive comfort approach, which fully supports the use of ventilative cooling in buildings.

2. Specifying design assumptions, prevention and modulation strategies

Parameters designers should make assumptions about or collect information about:

- Building typography and surroundings
- Outdoor environment (soundscape, air quality)
- Weather data (current (design) and future scenarios): Wind velocity and direction, temperature, humidity, solar irradiation
- Occupancy (user, usage schedule)
- Internal and external heat loads (internal gains, External window solar shading)
- Building thermal inertia (thermal mass)
- Spatial considerations (floor space, ceiling height)
- (Unobstructed) airflow paths/pattern
- Space demand for installations

3. Evaluate the ventilative cooling potential

In the initial feasibility phase, the efficacy of ventilative cooling shall be evaluated. The design of a ventilative cooling system is an iterative process, and if the potential for ventilative cooling is limited and/or the thermal comfort requirements are not met, the initial design concept shall be reviewed in order to determine the optimal course of action prior to the installation of supplementary and/or mechanical cooling as part of the so-called cooling ladder, where passive measures are first explored before more energy-intensive active solutions are used.

4. Defining an ventilation principle and dissipation techniques

A variety of ventilative cooling systems can be employed, with either a natural or mechanical driving force, or a combination of the two (i.e., hybrid). Dissipation techniques at the building level can be either ventilative cooling or supplementary cooling. Dissipation techniques at the room level, with user control, are preferable, such as ceiling fans, table fans, and wall switches to control windows/louvres.

5. Develop a ventilation strategy (air flow distribution path) for ventilative cooling

The ventilation strategy is a comprehensive plan that defines the pathway of air within a building in order to achieve adequate ventilation and/or cooling. This is distinct from the field of hygienic ventilation. The aforementioned ventilation strategy is described in greater detail in the ventilation concept, which also outlines the potential ventilative cooling systems that could be implemented based on the specific requirements of the building in question. The ventilation concept is developed during the feasibility phase and presented to the client for discussion. In the subsequent design phase, the most suitable ventilative cooling system is selected in collaboration with the client.

6. Re-evaluate prevention and modulation interventions

Ventilative Cooling+ (or VC+) should be clearly defined and refers to additional passive interventions in the architectural design beyond those that have a direct capacity effect on airflow rates, i.e. the ventilative cooling system itself could be operable windows, exhaust stacks or fans. However, additional interventions that minimise the need for cooling in the first place may reduce the target airflow rate. When assessing the potential for passive cooling, a core set of design choices should be evaluated before adding complexity to the solution/strategy.

7. Determine supplementary cooling for development during design

The review should assess the need for interactions between ventilative cooling systems and other cooling systems, such as supplementary and/or mechanical cooling systems. This depends on an assessment of the cooling demand in a given building and the capacities of each type of cooling system. The number of cooling hours in a given building can be calculated using a simulation tool. If different types of cooling are designed in a given building, a combined control of all cooling systems is necessary. A priority list of cooling systems needs to be established for proper control.

8. Defining controls and operation

Reasons for controlling a ventilative cooling system may include

- To match the (often lower) ventilation airflow rate to indoor air quality to meet primary ventilation requirements.
- To adapt the ventilation airflow rate to mitigate low humidity (heating season).
- To adjust the (often higher) ventilation airflow rate to mitigate high temperatures - overheating (cooling season).
- To achieve low energy consumption in the heating or cooling season.
- To reduce the energy consumption of fans.
- To limit pollutant infiltration during outdoor pollution peaks.

- To limit the heating-up power in intermittently heated spaces.
- To protect against weather conditions (e.g. rain) (open windows).
- To adapt the draught rate.

3 CONCLUSION

Ventilative cooling design is a process that considers and investigates the cooling requirements of the building as a whole. Ideally, the free-running temperature of the occupied building should be within the contractually agreed comfort range of the room temperature. Architectural compromises and special use requirements can lead to an undesirable increase in the cooling requirements of the building. The design process for ventilative cooling using the proposed eight design steps can help to counteract and optimise this.

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5 REFERENCES

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