Adaptive comfort technology for temperature control in balanced ventilation systems

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ABSTRACT

Adaptive comfort technology is reflecting the fact that the human body adapts to changing temperatures. As such, the temperature level where people feel comfortable is not a constant value, but changes with the seasonal variations of indoor and outdoor temperatures.
In balanced ventilation systems, the desired indoor temperature can be changed by the occupant of a dwelling, to meet the personal demand on comfort. For balanced ventilation systems without postconditioning this indoor temperature setpoint regulates the use of the bypass, in order to temporarily reduce heat and moisture recovery partially or fully. For balanced ventilation systems with postconditioning, the desired indoor temperature does not only influence the bypass behaviour (passive cooling and heating) but also regulates the postheating and/or the postcooling of the supply air (active cooling and heating).
While occupants can set a fixed indoor temperature, adaptive temperature control is preferable. This method adjusts indoor temperature based on average outdoor temperatures, preventing excessive energy use for space cooling and consequently reducing costs. Moreover, the human body is still object to temperature changes during the year and therefore less sensitive to sudden temperature changes such as in heat waves.
This study describes the basic idea of the implementation of adaptive comfort technology in balanced ventilation units, with and without postconditioning. From monitored projects, examples are given how the indoor temperature setpoint of adaptive temperature control varies in time. Data is given how the bypass and the postconditioning react to changing indoor temperature setpoint. The combination of bypass and postconditioning influences the supply temperature of the fresh air, and ultimately influences the indoor temperature to comfortable levels.

KEYWORDS

Balanced ventilation, smart ventilation, postconditioning, passive cooling, adaptive comfort technology

1 INTRODUCTION

Adaptive comfort is regarded as a way to express the comfort of residents in a building. It reflects the fact that the temperature where people feel comfortable is not fixed during the year, but it changes with the seasonal variation in outdoor temperature.
The adaptive comfort model is mostly used to assess the comfort range of people, given a range of indoor temperatures during the year. Yet, it is rarely used to set temperature setpoints in balanced ventilation systems.
Figure 1 is a simplified graphical representation how the temperature setpoint would vary during the year with a fixed temperature profile and an adaptive temperature profile. In case of the adaptive temperature profile, outside the heating season the temperature setpoint is gradually increased to higher levels when outdoor temperatures rise. During the heating season, however, the temperature setpoint remains constant.

The use of the adaptive temperature profile serves three goals:

1. It avoids discomfort in summer when indoor temperatures remain at winter levels. Indoor temperatures should ideally be no more than 5°C below outdoor levels.
2. Van Marken Lichtenbelt (2022) has indicated that an adaptive temperature profile prevents the body from 'thermal boredom' and increases the resistance of residents to heat waves.
3. An adaptive temperature profile reduces unnecessary cooling energy and costs.

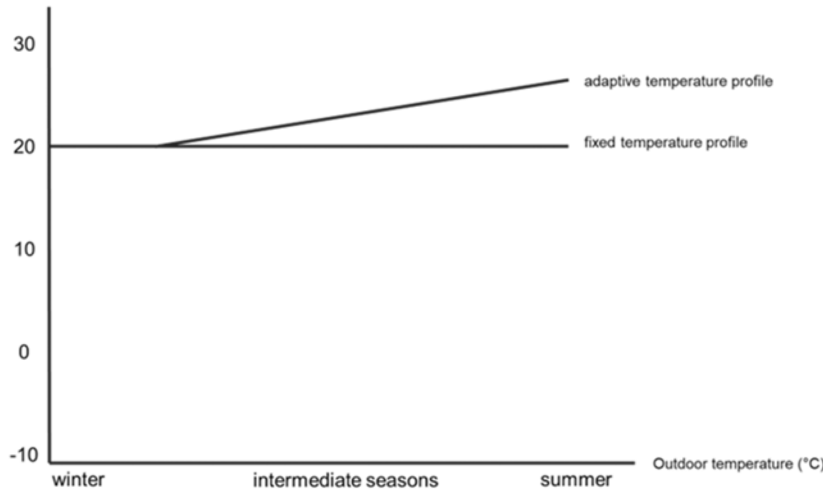

Figure 1: Schematic principle of fixed and adaptive temperature profile.

The theory and monitored results of the use of an adaptive temperature profile is explained in the next two paragraphs. Chapter 2 deals with balanced ventilation systems <u>without postconditioning</u> and chapter 3 describes balanced ventilation systems <u>with postconditioning</u>.

2 ADAPTIVE COMFORT TECHNOLOGY IN BALANCED VENTILATION SYSTEMS WITHOUT POSTCONDITIONING

2.1 Theory

Balanced ventilation systems bring filtered, fresh air into a building and extract stale air out of the building. The primary function is to refresh the indoor spaces for a healthy living and working environment. The secondary function of balanced ventilation systems is to bring in the fresh air in an energy efficient way and with comfortable supply air temperatures. Therefore, energy is transferred between the outgoing stale air and the incoming fresh air. When energy recovery is not needed, the recovery is temporarily reduced or switched off.

Figure 2 illustrates the basic principle of the control of a balanced ventilation system. The black sloping line is the indication of the indoor temperature setpoint, measured in the unit in the extract air. For warmer outdoor temperature, a warmer indoor (extract) temperature is accepted. A bypass for passive cooling is activated to reduce or switch off recovery when all of the following conditions are true:

1. Extract temperature is above the temperature setpoint (passive cooling is requested),
2. Outdoor temperature is below extract temperature (passive cooling is available),
3. Average outdoor temperature is above a threshold (no active heating in the house),
4. Supply temperature level does not lead to draughts and/or condensation on ducts.

In figure 2, this means that for low outdoor temperature heat recovery is used (supply temperature just below extract temperature). When outdoor temperatures are above a certain threshold, bypass can be activated to bring passive cooling to the house, but only when extract temperatures are higher than the temperature setpoint. When outdoor temperatures are above extract temperature, the bypass is deactivated again allowing cold recovery to supply fresh air while keeping most heat outside.

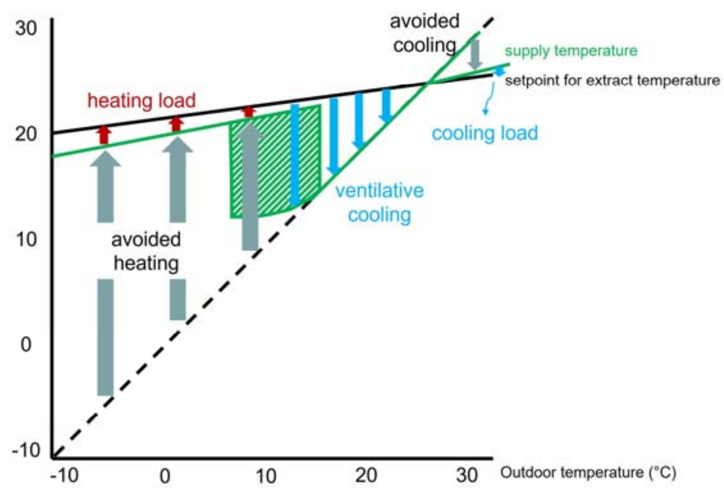

Figure 2: Schematic working principle of balanced ventilation system without postconditioning.

The extract temperature setpoint is the control parameter that decides how often the bypass is activated for passive cooling. For low setpoint, the bypass is activated more frequently than for a higher setpoint. The adaptive temperature control is implemented in balanced ventilation systems as indicated in figure 3. The default temperature profile NORMAL increases the extract temperature setpoint with running mean outdoor temperature. The end user has the possibility to change from the temperature profile NORMAL to temperature profiles COOL or WARM. This shifts the temperature setpoint below and above the default profile respectively. In all three profiles, the temperature setpoint changes with the average outdoor temperature, but the 'cooler' the profile, the more frequently the bypass will be used for passive cooling.

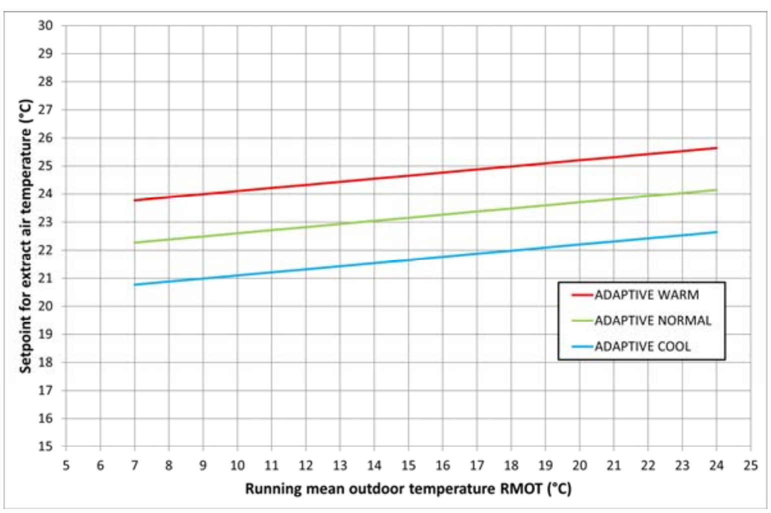

Figure 3: Adaptive temperature control as implemented in balanced ventilation system.

2.2 Monitored results

Figure 4 presents the result of the implemented adaptive temperature profile for a balanced ventilation system in a house in Switzerland. The graph shows the measured temperatures (measured in the unit) from January to July 2022. The outdoor temperature (light green) and the running mean outdoor temperature (dark green) are gradually rising from winter to summer. The running mean outdoor temperature rises in this period from 0□ to 24°C. The adaptive temperature setpoint (grey) in the normal temperature profile increases therefore in this period from 21.5°C to 24°C. The extract temperature (yellow) is also rising in this period from 22.5°C to 25°C. The supply temperature of the fresh air (red) shows that in January, February and March the heat recovery is maintaining a comfortable supply temperature which is just below the extract temperature. From April on, the bypass activation is allowed because the heating season has ended. Whenever the extract temperature is above the setpoint, and the outdoor temperature is below the extract temperature, the bypass is activated and the supply temperature will drop to levels close to the outdoor temperature, ensuring passive cooling. Please note that when the outdoor is warmer than the extract, the bypass does not activate, to keep the heat outside of the house.

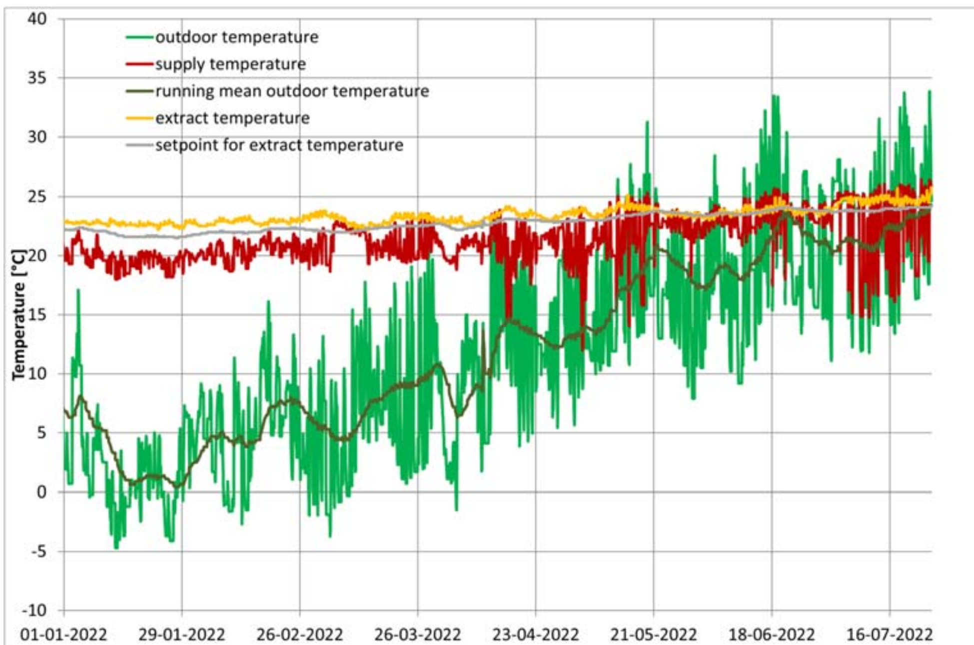

Figure 4: Monitored temperatures for a balanced ventilation system without postconditioning.

The measured extract temperatures rise when outdoor temperatures rise, because of transmission of heat through the construction, and solar gains through windows. For balanced ventilation without postconditioning, the bypass activation gives comfortably cool supply of fresh air, but mostly the amount of passive cooling is not enough to keep the house cool for a longer time.

Figure 5 shows another representation of the measured temperatures in the period January to July. As a function of the outdoor temperature, the extract temperatures (yellow) and the supply temperatures (red) are given for every hour in the relevant period. In this figure, the various modes of balanced ventilation can be observed: heat recovery, passive cooling with bypass and cold recovery. Note that the extract temperatures are slightly elevated in the warmer season with respect to the cooler season.

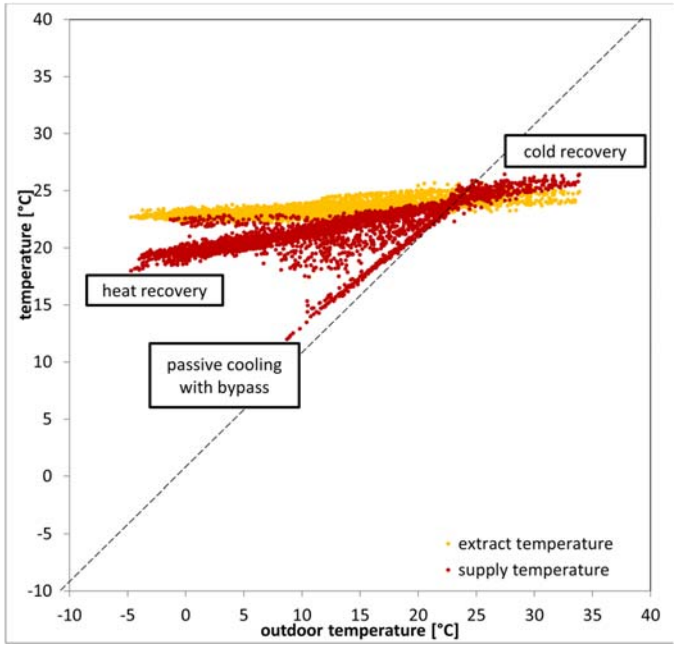

Figure 5: Correlation diagram of extract temperature (yellow) and supply temperature (red) as a function of outdoor air temperature for a balanced ventilation system without postconditioning.

3 ADAPTIVE COMFORT TECHNOLOGY IN BALANCED VENTILATION SYSTEMS WITH POSTCONDITIONING

3.1 Theory

For balanced ventilation systems <u>with postconditioning</u>, figure 6 shows the basic principle of control. The ventilation system supplies fresh air in an energy efficient way by first attempting to use heat recovery (saving on central heating system) in the heating season and cold recovery (saving on central cooling system) in the cooling season. In the intermediate season and the cooling season, the fresh air supply is kept comfortably cool by possible activation of the bypass, as explained in the previous chapter.

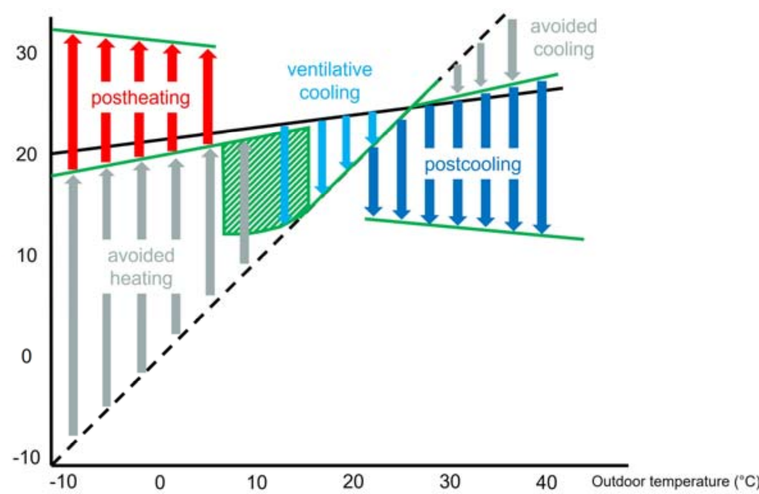

Figure 6: Schematic working principle of balanced ventilation system with postconditioning. Black line: extract temperature setpoint, green line: temperature of supply air.

Postconditioning is used to actively heat the ventilation air (in heating season) and actively cool the ventilation air (in cooling season) with the goal of maintaining a comfortable indoor temperature. The postheating and postcooling produces the energy needed to maintain the indoor temperature. Therefore, balanced ventilation systems with postcondition can really bring the indoor temperature to comfortable levels (as long as the specifications of the unit are sufficient for the thermal loads of the house). This technology is described in more detail by Cremers (2022).

3.2 Monitored results

Figure 7 shows the result of the implemented adaptive temperature profile for a balanced ventilation system with postconditioning in a house in Italy. The graph shows the measured temperatures (measured in the unit) from January to July 2022. The outdoor temperature (green) is gradually rising from -1°C in winter to 34°C in summer. The adaptive temperature setpoint (black) therefore increases in this period from 22°C to 26°C. The extract temperature (yellow) is also rising in this period from 23°C to 26°C (diurnal variation originates from nighttime relaxation of setpoint).

The supply temperature of the fresh air (red) shows that in January, February and March postheating is used for maintaining a comfortable indoor climate. From the end of March, the bypass activation is allowed and it is sufficient to keep the extract temperature close to the adaptive temperature setpoint. From the end of May onwards, the heat transmission and solar gains are higher than the passive cooling with bypass can bring, so that the control switches to postcooling. Even in this period the extract temperature is close to the setpoint indicating that the postcooling output is sufficient in this low energy house.

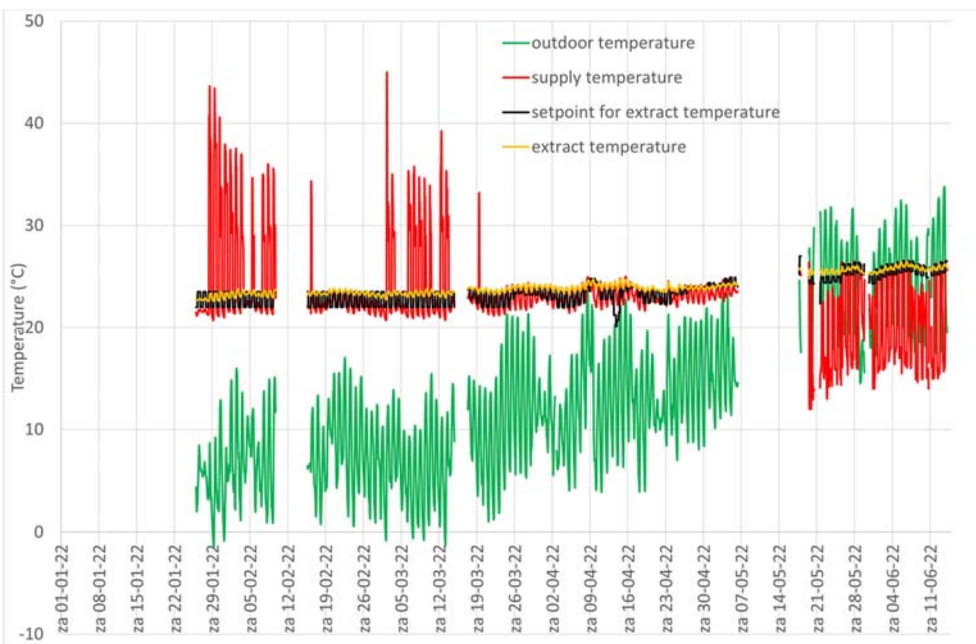

Figure 7: Monitored temperatures for a balanced ventilation system with postconditioning. Gaps in the chart are due to periods during which data transmission had failed.

Figure 8 shows another representation of the measured temperatures in the period January to July. As a function of the outdoor temperature, the extract temperatures (yellow) and the supply temperatures (red) are given for every hour in the relevant period. In this figure, the various modes of balanced ventilation can be observed: heat recovery (sometimes combined with postheating), passive cooling with bypass (sometimes combined with postcooling) and cold recovery (sometimes combined with postcooling).
Note that the extract temperatures are slightly elevated in the warmer season with respect to the cooler season.

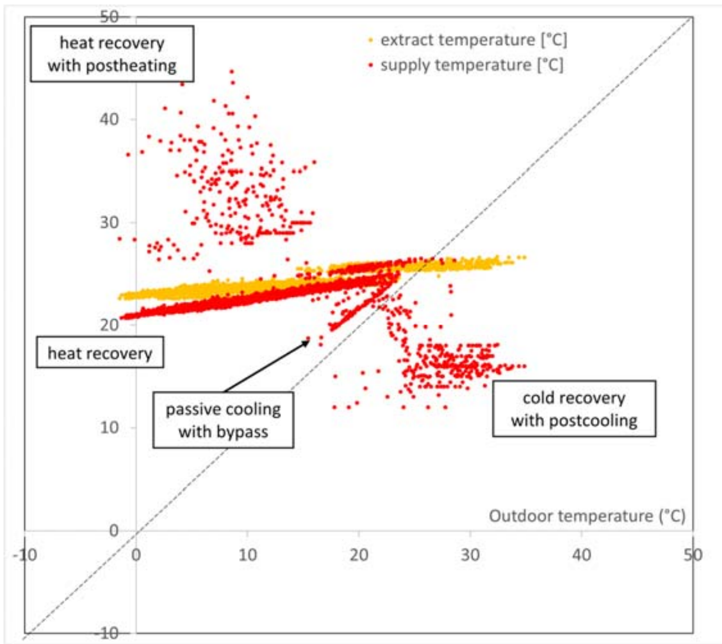

Figure 8: Correlation diagram of extract temperature (yellow) and supply temperature (red) as a function of outdoor air temperature for a balanced ventilation system with postconditioning.

4 DISCUSSION AND CONCLUSIONS

The previous two chapters have shown how adaptive comfort theory can be used to determine the extract temperature setpoint for balanced ventilation systems.

For balanced ventilation systems without postconditioning, the setpoint is a parameter that is used to define whether a bypass will be activated. As the passive cooling with a bypass often cannot be fully sufficient as cooling output for the house (only in nearly zero-energy buildings), the term 'setpoint' can be argued. It's not so much a temperature value that is attempted to be reached by the ventilation system, as there is no heating or cooling produced with a ventilation system, and the bypass activation cannot fulfil the cooling load. Rather than a setpoint it is a switch value for allowance of bypass activation. The term setpoint however, is maintained for similarity with the situation with postconditioning.
Even for a balanced ventilation without postconditioning, the adaptive temperature setpoint results in slightly lower comfort temperatures when outdoor temperatures are in the range of 10-17°C, and slightly higher comfort temperatures when outdoor temperatures are in the range of 17-23°C, when people are adapted to higher temperatures.

The result of adaptive temperature setpoint gets even more pronounced when postconditioning is used. In the algorithms of balanced ventilation systems with postconditioning, the temperature setpoint is kept fixed during the heating season. However, in the intermediate and cooling seasons, the setpoint is adaptive.
In this manner, the temperature setpoint during the warmer season is higher than during the intermediate season with mild outdoor temperatures. The resulting effect is that the comfort for residents is still good, but without too much (unnecessary) effort for the cooling system. Therefore, the cooling output stays within bounds which has benefits for a sustainable environment and for the costs for cooling for the residents. Moreover, the sound impact of the cooling system stays within bounds. In the long run, the variation in indoor temperatures also makes the human body more resistant to the impact of heat waves, as suggested by Van Marken Lichtenbelt (2022).

While the adaptive temperature setpoint generally offers advantages over a fixed setpoint, some occupants may prefer a fixed temperature. Therefore, the adaptive setpoint is the default option, but users can switch to a fixed setpoint if desired.

5 REFERENCES

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