Performances of new innovative domestic ventilation systems in combination with low temperature floor heating

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SUMMARY

In extended laboratory measurements, the combination of new innovative domestic ventilation systems with low temperature heating is investigated, using the advanced EnoTemp measurement equipment. These measurements took place in the framework of a large Dutch demonstration project for these innovative domestic ventilation systems. The main conclusion of the laboratory measurements is that self-regulating façade grilles form a good combination with low temperature heating in terms of thermal comfort. The air flow is regulated in such a way that moderate air velocities in the living zone are created with substantial lower air velocities in comparison with conventional grilles.

INTRODUCTION

Legislation and building regulations always have been the main driving force to stimulate innovations in domestic ventilation systems and especially for the development of advanced energy-efficient ventilation systems. The most recent developments of the European ventilation industry concern new systems and new principles have a certain meaning and impact for the EPBD[1]. In the long term sustainability will also feature in the housing sector, as well as for new as existing housing. Also indoor air quality, thermal comfort throughout the year and the acoustic environment play more and more an important role. In current practice conventional natural ventilation grilles in facades can cause complaints concerning thermal comfort, especially in combination with modern low temperature heating systems like floor heating. This results in reluctance by designers and real estate developers to apply either sustainable heating or certain types of ventilation techniques. This is a missed opportunity for sustainable development in general. However, in the most recent developments of domestic ventilation products all quality aspects are included. Next to it there are different alternatives for energy efficient ventilation, not only with regard to manufacturers but also with regard to ventilation principles. Both in terms of advanced natural ventilation as mechanical ventilation, there are solutions available and there are applications in all possible situations, both for new and existing housing. A number of these solutions have been developed within the European RESHYVENT project[2] (2002 -2004).

In practice, it has been noted that the combination of a decentralised, unheated air supply in combination with a floor heating system can lead to comfort problems with users. Draft with traditional air supply by grids in the facade in combination with radiator heating is a more or less accepted phenomenon. Older buildings in which this combination occurs generally have a large and continuous heat supply, which, to an extent, compensates for the draft that is created, by the convection and heat radiation of the radiators. However, in well insulated houses with a low heat demand and low system temperatures there is insufficient mixing of the incoming cold air with heated air. Particularly during strong winds on the facade large volumes of (cold) air enters the living zone, which can cause draft problems if there are no compensating measures.

Self regulating grids

Despite the extensive experience with natural air supply and floor heating, the level of discomfort has not been closely studied and quantified. This is why the level of thermal comfort with decentralised air supply was studied in a laboratory setting under controlled conditions. In a broader context, the research question was whether a good level of comfort can be achieved with the combination of low temperature heating systems with advanced (natural) ventilation systems, more particularly with self-regulating facade grids
The purpose of a mechanical self-regulating air supply is to provide a constant volume of air supply, regardless of the strength and direction of the wind (wind pressure on the facade). If there is no wind, the self-regulating facade grid (SR grid) is fully open and the nominal air flow taken in by the vent is delivered to the building. If the wind pressure increases, a flap in the grid will close mechanically which limits the increase of incoming air volume. This reduces unwanted, large (and in winter cold) air volumes. The required air volume can also be regulated electronically. By using servo steering in the grid and a control device in the vent the volume of air inflow and outflow can be adjusted. This device can control on:

- Time: ventilation will take place during specific time intervals based on a time schedule to be entered.
- Presence: ventilation takes place during specific time intervals based on the detected seizure.
- CO_2: ventilation takes place based on the level of CO_2, as a measure of indoor air quality.

Based on flow measurement in the grid, a servo-controlled flap can be positioned so that the exact required air volume is supplied. Using this technology a true horizontal pressure flow diagram can be realised. This method also reduces unwanted, large (and in winter cold) air volumes.

Low Temperature Heating and thermal comfort

A floor heating system was used as the main heating in the study. Rooms with floor heating as the main heating do not have convection. Floor heating does provide a significant radiation compensation for cold facade surfaces. Inflow of outside air via the facade, limited heating capacity per square metre of floor surface, low mixing in the air space and the determining factor of the air inflow, increase the chances of local discomfort. Comfort problems that may arise with (unheated) air supply via the facade in combination with floor heating as the main heating are:

- Draft, caused by high air supply volumes via the grid. Conventional configurations with an HT radiator under the window mix the convection air with the cold outside air, thus heating it.
- Down draft, convection of relatively cold air along glass surfaces in the facade, in particular with low supply speeds.
- Cold radiation, caused by relatively cold glass surfaces in the facade (radiation).

These three aspects are difficult to distinguish in practice and can occur simultaneously. It can therefore be difficult to determine the main cause of the comfort complaints, and it is easy to draw incorrect conclusions with regard to the role of the heating and ventilation system.
Down draft and cold radiation will occur in particular with facades with a lot of glass; natural air supply via facades with a high glass ratio is thus extra critical. The air permeability of the facade and facade elements is also important. Comfort/discomfort is determined using the Fanger equations and the dimensionless parameters PMV and PPD[3].

METHODS

The assessment of the thermal comfort with various types of natural air supply was done using the experimental setup in the climate room of Cauberg-Huygen RI bv, the Netherlands. A facade was simulated with an indoor and outdoor climate in the climate room, figure 1.


Figure 1: The climate room with test facade and measuring equipment.

The Dutch standard NEN1087:2001[4] provides a method for the assessment of thermal comfort. It includes the following:

- the air supply variation should not be greater than 10% of the nominal value;
- the air supply temperature should be 20 (± 2) K lower than the average air supply of the room;
- a three-dimensional measuring grid according to NEN1087:2001.

The outdoor air is simulated by cooling the room on the other side of the facade to 0°C. This simulates a winter situation where cool air flows into the heated room via the grids. This is done at an overpressure of 10 Pa (+/- 5 m/s wind speed) and 25 Pa (+/- 7.5 m/s wind speed). A wind pressure of 25 Pa was chosen to remain within the normal functional range (1..25 Pa) of SR grids. Temperature and air speed were measured using EnoTemp ClimaCubes. These measure in the x, y and z direction. What is special is that the temperature and air speed was measured using sound. The ClimaCubes emit short sound pulses between the sensors. This way, the temperature and air speed can be measured accurately and without contact based on the receipt of the sound in the sensors.

The ClimaCubes are fitted to a movable and height-adjustable measuring beam. A grid of 3 x 16 measuring positions was laid out on the floor. Measurements were taken at 12 different heights for each measuring point. Thus, there were a total of 576 measurements in a 3D grid with a mesh opening of 20 to 25 cm. The results were graphically represented in 2D and 3D graphs using appropriate software. The graphs represent temperature, air speed and air flow.

RESULTS

Table 1 contains a numerical overview of the results. The results are based on the total 3D measuring grid, i.e. including the measuring points outside the living area towards the facade, which in fact are outside of the assessment criteria of NEN1087. Table 2 shows the results for the measuring points inside the living area. Figures 2, 3 and 4 are graphic representations of the flow pattern. Next, the flow patterns have been converted into the Draft values and these are graphically represented in Figures 5, 6 and 7.

Table 1: Numerical overview of thermal comfort – total grid

Comfort criteria	Facade grid type	Standard	Passive mechanical self-regulating		Active / electronic self-regulating	
	Wind pressure on facade	10 Pa	10 Pa	25 Pa	10 Pa	25 Pa
Air speed	Average	0.24 m/s	0.08 m/s	0.10 m/s	0.05 m/s	0.06 m/s
	Maximum	1.77 m/s	0.56 m/s	0.69 m/s	0.38 m/s	0.31 m/s
Air temperature	Minimum	8.8°C.	17.5°C.	15.2°C.	19.9°C.	22.1°C.
	Average	16.7°C.	21.2°C.	21.3°C.	22.1°C.	23.9°C.
	Maximum	19.4°C.	22.9°C.	23.2°C.	23.2°C.	25.3°C.
PMV	Minimum	-5.5	-1.0	-2.0	-1.3	-1.0
	Average	-1.3	-0.1	-1.0	0.1	0.4
	Maximum	-0.6	0.7	0.3	0.4	0.7
Draft value	Average	45 %	13 %	17 %	6 %	6 %
	Maximum	100 %	87 %	100 %	82 %	76 %

Table 2: Numerical overview of thermal comfort – living area

Comfort criteria	Facade grid type	Standard	Passive / mechanical self-regulating		Active / electronic self-regulating	
	Wind pressure on facade	10 Pa	10 Pa	25 Pa	10 Pa	25 Pa
Air speed	Under 0.20 m/s	32 %	76 %	81 %	87 %	88 %
	0.20 to 0.24 m/s	12 %	7 %	2 %	6 %	5 %
	Over 0.24 m/s	56 %	17 %	17 %	7 %	7 %
PMV	Minimum	-3.4	-1.0	-1.3	-1.3	-0.5
	Average	-1.5	-0.1	-0.2	0.0	0.3
	Maximum	-0.7	0.7	0.3	0.4	0.7
Draft value	Average	62 %	11 %	13 %	7 %	8 %
	Maximum	100 %	64 %	75 %	82 %	76 %

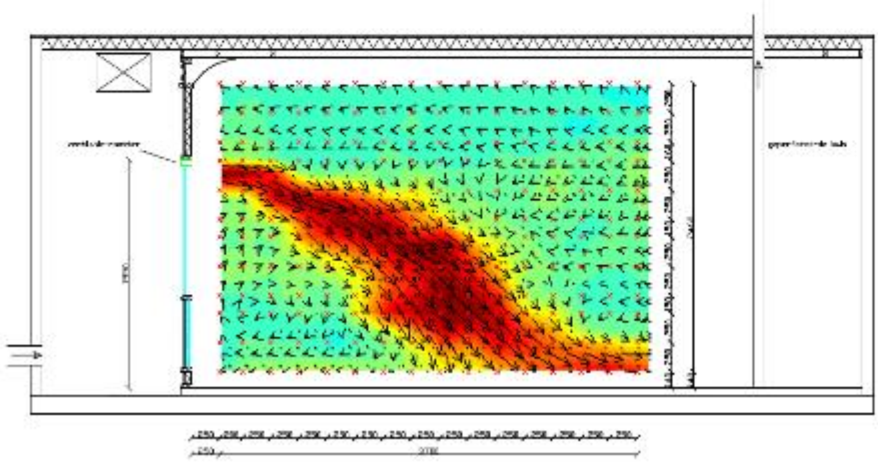

Figure 2: Flow pattern unregulated grid, pressure difference 10 Pa.

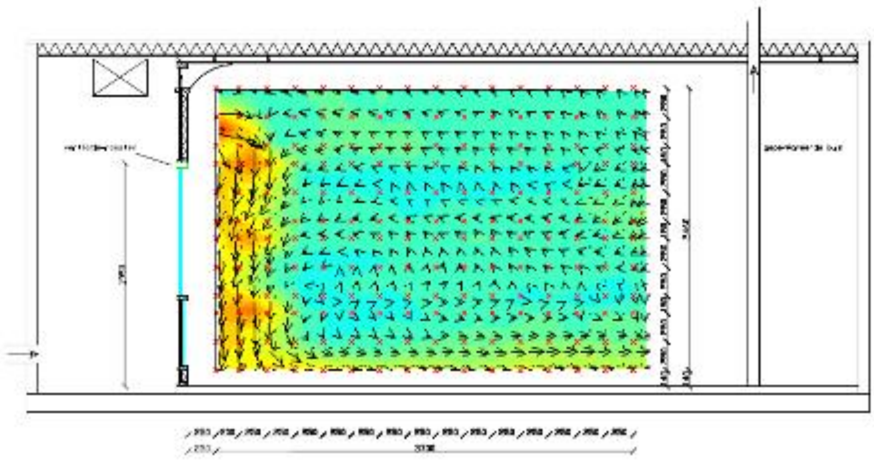

Figure 3: Flow pattern passive regulation, pressure difference 25 Pa.

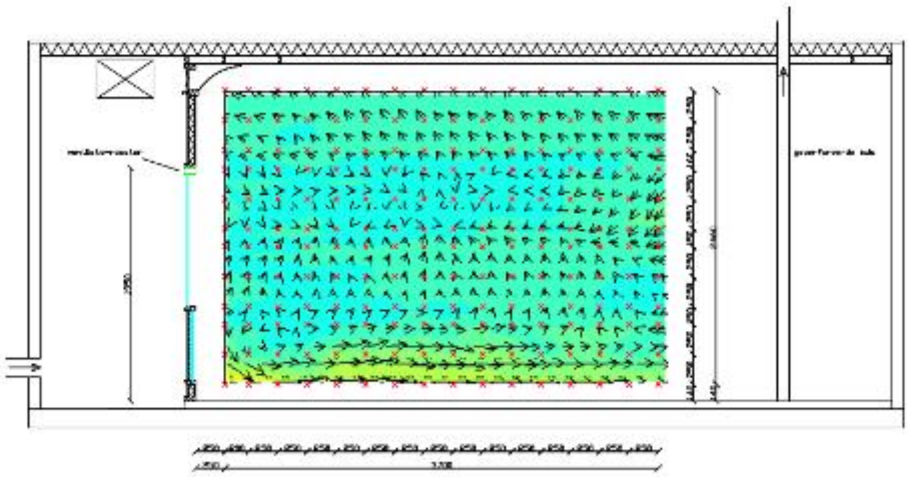

Figure 4: Flow pattern active regulation, pressure difference 25 Pa.

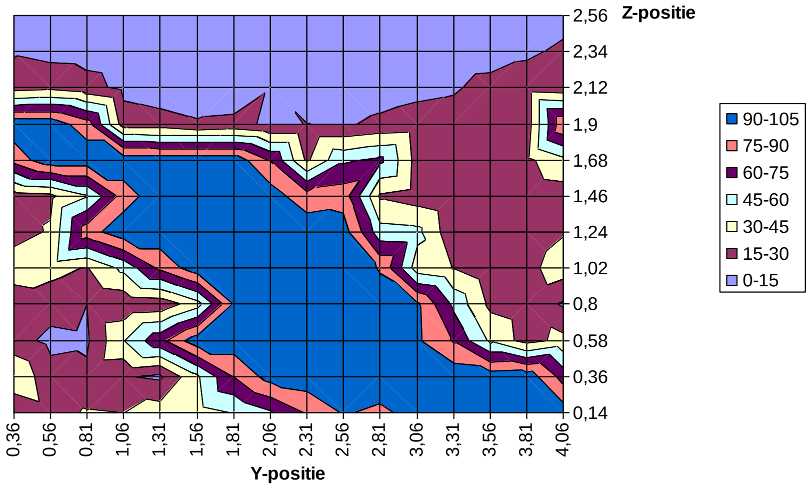

Figure 5: Draft value standard grid, wind pressure 10 Pa.

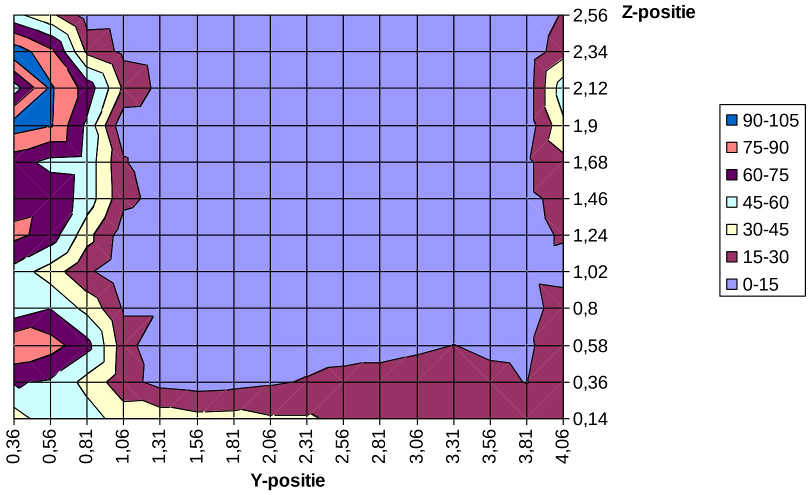

Figure 6: Draft value mechanical self-regulating grid, wind pressure 25 Pa.

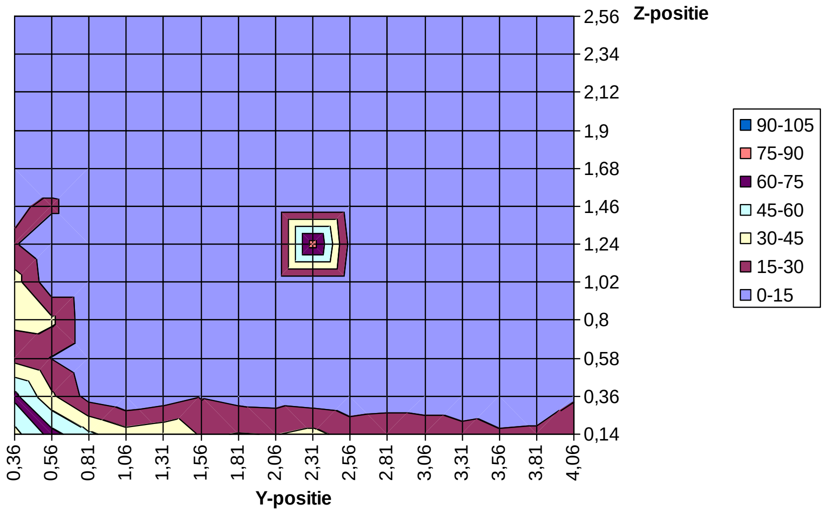

Figure7: Draft value electronic self-regulating grid, wind pressure 25 Pa.

From the figures and the table it can be concluded that with a standard facade grid air flows occur with high air speeds in the room as a result of the created pressure difference, causing local discomfort with, in particular, a high likelihood of draft complaints. With a passive (mechanical) self-regulating facade grid the average air speed is limited to 0.10 m/s, even

with a large pressure difference. With a pressure difference of 10 Pa the climate is almost thermal neutral (PMV ≈ 0). The chance of draft complaints is limited to less than 20%, even with a high pressure difference.
With an active (electronic) self-regulating facade grid the average air speed is limited (even with a high pressure difference) to 0.06 m/s, which is very low. With a pressure difference of 10 Pa the climate is almost thermal neutral (PMV ≈ 0). The chance of draft complaints is limited to less than 10%, even with a high pressure difference. With the self-regulating facade grid there is a limited disturbance of the indoor temperature, while with a standard ventilation grid there is so much inflow of cold air that space cools down noticeably. With all grid types air speeds of 0.20 m/s or higher are created at the outflow opening, but these are mostly outside of the living space.
Air velocity is particularly important for thermal comfort. As regards air speed, the electronic self-regulating grid has the best results and the number of measuring points with a high air speed is clearly lower than with the unregulated grid. The high air velocities occur mainly at a low height above the floor.

DISCUSSION

Using the innovative measuring equipment and the specially fitted climate room is possible to determine the air flows and the thermal comfort in a room with high accuracy. The collected data provide an insight into the effect of decentralised supply installations on thermal comfort. In line with practical experience, the climate room study shows a substantial chance of draft complaints with a standard facade grid. This is mainly due to the high air volumes at higher wind pressure on the facade. The self-regulating grids of Alusta that were studied limit the air volume to such an extent that comfort is average to good, also without radiator heating. In general we can conclude that self-regulating facade grids provide a clear advantage with regard to comfort. The difference between mechanical and electronic facade grids is particularly noticeable near the facade (outside of the living area). For this reason the difference between mechanical and electronic facade grids will mainly show in the form of energy savings. Dutch ISSO publication 92[5] provides general guidelines for the application of facade grids in houses.
This study shows that self-regulating facade grids also provide a good comfort with a wind pressure of 25 Pa. In practice, higher wind pressures can occur, in particular with high rise buildings and near the coast. The question is whether a self-regulating facade grid can control the air inflow sufficiently under such conditions and to what extent other air leakages in the facade will play a role. The innovative, acoustic measuring set allowed us to register even small air leakages in the regulating unit of the self-regulating facade grids. These measurements showed that the facade grids close to such an extent with high wind pressure on the facade that the outside air enters via minimal openings in the facade elements.

Possibilities for the future
The results of this study will allow improvements to be made at the product and project levels. Producers of ventilation and heating systems, but also project developers and designers, can, when in doubt, have the comfort level of a particular combination of facade design, heating and ventilation system measured before realisation of the project. This allows them to choose an alternative, if necessary. This will provide more security and will prevent unexpected results.
The main point of interest is that the pressure-air volume properties of an SR grid are really flat. There is now a requirement for self-regulating facade grids to have flat pressure-air flow properties up to a pressure difference of 25 Pa, while thermal comfort must also be guaranteed

with higher pressure differences. According to the manufacturer, electronic self-regulating grids offer the advantage at high wind speeds (100 Pa) that they can (actively) close completely; sufficient air inflow will remain through infiltration in the facade. Quality assurance and possible certification of the self-regulating properties are thus crucial for preventing complaints in the application of facade grids in critical situations. This study focused on a standard facade with parapet; further investigation with facades made entirely out of glass can provide new insights into the effects of cold radiation and ice-traps on the comfort level with all forms of decentralised air supply. The role of air permeability of the facade needs to be established in more detail. Natural air inflow must therefore always be seen in relation to the quality of the facade and the heating supply system.
The ventilation grids investigated here have a different inflow opening in the SR version than the standard grids, namely pointed upwards in relation to the standard horizontal air stream. The effect of this on the air streams due to improved induction and mixing has not been studied closely, but appears important in preventing draft complaints. Finally, the metadata can possibly be used as input for computer simulations (CFD computations) for validating the simulations and improving them where necessary.

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