Capture efficiency of air curtain assisted residential range hoods

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ABSTRACT

Air curtain assisted range hoods are very customary in large industrial kitchens. They allow to increase the capture efficiency of the range hood while lowering the net exhaust flow rate. For applications in residential settings, there is a lack of data on the performance of air curtain assisted range hoods, as well as a lack of information on the required settings and boundary conditions to come to the successful application of air curtain assisted range hoods. In this paper we present the results from an experimental test campaign in which we investigated the capture efficiency of a residential air curtain assisted range hood in comparison with a regular range hood, as well as the sensitivity of the capture efficiency to boundary conditions such as net exhaust flow rate, height above the range, enclosure etc. The results show that air curtain assisted range hoods are more efficient at lower flow rates, especially in non-enclosed settings, confirming the performance known from industrial kitchens, but are sensitive to higher mounting and on-going cooking activities.

KEYWORDS

Range Hood, Carbon Dioxide, Air Curtain, Efficiency

1 INTRODUCTION

The acoustic and airflow performance of range hoods has been captured by ISO standards 5167-1 (2003) and 10140-1 (2010), while the IEC 61791 standard (1997), discusses fat absorption and odor extraction performance. These aspects are also treated in the EN 13141-3 (2004) standard. There is, however, no mention of capture efficiency, the efficiency of the range hood to capture and exhaust the pollutants emitted by the cooking activities as is used for the testing of range hoods in commercial kitchens (CEN 2014). Test methods for this measure have been proposed and tested on residential range hoods available on the US market by Delp (2012) and Lunden (2014). On the other hand, air curtain assisted range hoods have been introduced and tested successfully in commercial kitchens where they reduce the exposure of the staff not directly working at the ranges. In this paper, we build on the methodological work done to define capture efficiency and compare the performance of air curtain assisted range hoods with that of normal direct extraction range hoods in residential kitchens in climate chamber experiments. In both cases, the range hood doubles as the kitchen ventilation vent hole.

2 METHODS

In this section, we will first discuss the experimental setup that was used for the experiments and then briefly introduce capture efficiency as the used metric to process the results.

2.1 Experimental setup

A test range was constructed within the hotbox of a hot/cold/hot box suite. The space measures 5 by 5 by 2,7 meters, dimensions that are fairly representative for a kitchen in Belgium. The height of the test range is adjustable, the height of the range hood is fixed. Two range hoods are mounted on either side of the setup, one standard residential range hood and one air curtain assisted range hood, so that they can be tested side by side. The enclosure of the range hood can be adapted from free hanging to enclosed in kitchen cupboards by adding or removing wooden paneling. The test setup is shown in figure 1 below.

Figure 1: The experimental setup with adjustable range height, electric range and air curtain assisted range hood in wall mounted non-enclosed mode.

2.2 Capture efficiency calculation

To process the measurements and calculate the capture efficiency, we use the 'indirect approach' put forward by Delp (2012) and Lunden (2014). Lab grade carbon dioxide is released at a constant rate above a boiling pot of water on the range. The carbon dioxide concentration is measured at 2 locations in the exhaust, at 2 locations in the room and in the fresh air intake as is shown in figure 2.

Capture efficiency is then defined as:

$$CE_{FP} = \frac{C_{hood} - C_{room}}{C_{hood} - C_{inlet}} \quad (1)$$

where CE_{FP} is the first pass capture efficiency, C_{hood} is the carbon dioxide concentration measured in the exhaust of the range hood, C_{room} is the carbon dioxide concentration measured in the test room and C_{inlet} is the carbon dioxide concentration measured in the inlet of the room. All measured concentrations are reported in parts per million (ppm).

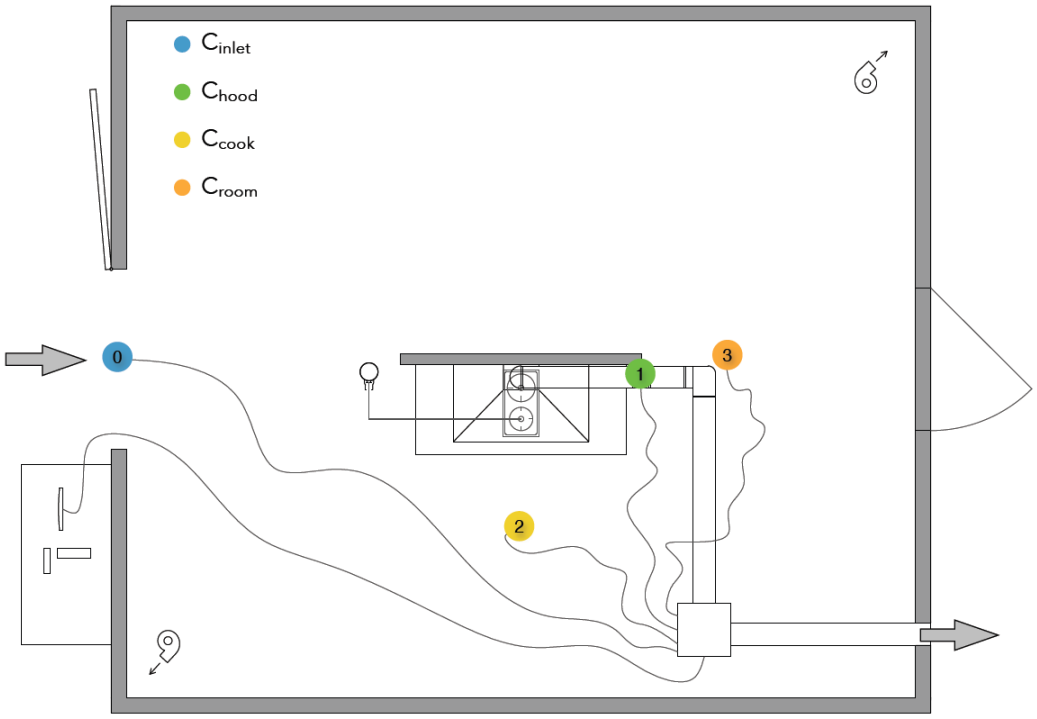

Figure 2: Scheme of the climate chamber with the location of the setup and the different sensors.

The concentrations measured during a 3 minute cooking event with the air curtain assisted range hood mounted at 0,75 meter above the range are shown in figure 3. The exhaust flow rate of the range hood during the test is 170 m3/h.

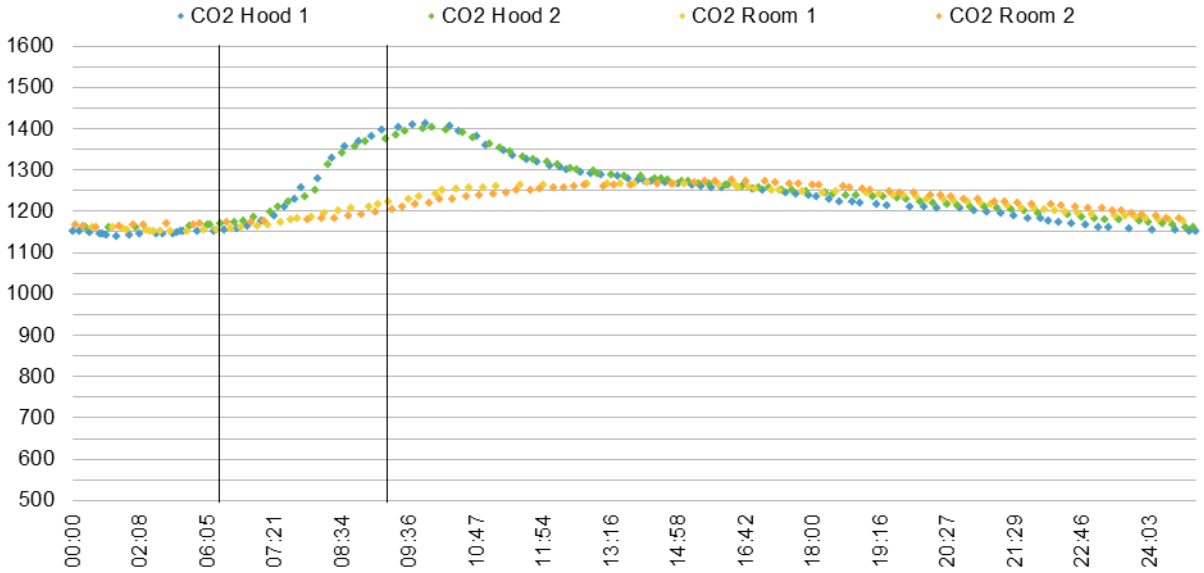

Figure 3: Measured carbon dioxide concentrations during a 3 minute cooking event with the air curtain assisted range hood and the cooking pot on the front burner.

Room and exhaust concentrations coincide in the pre-cooking phase of the test (minute 1-6), when no carbon dioxide is released. The concentration in the exhaust of the range hood rapidly climbs during the cooking event (minute 6-9, marked with the 2 vertical black lines in figure 3) while that in the rooms remains relatively low. This is, of course, the desired effect of the range hood and constitutes the effectiveness of the range hood. At the end of the cooking event, the momentary first pass capture efficiency is 77%.
23% of the emitted carbon dioxide, however, still escapes to the room. After the cooking event is stopped, the test is continued until all emitted carbon dioxide is exhausted and room as well as hood concentrations are back at inlet level (minute 9-25). The carbon dioxide concentration within the cooking zone decreases rapidly and becomes equal to the room concentration. The overall capture efficiency integrated over the total length of the test is only 30%. This metric, compared to the first pass efficiency, is not commonly used, but is more representative for the effectiveness of the range hood in reducing the total exposure of the occupants, especially since in Belgian kitchens, the kitchen tends to also be the dining area for family dinners, the dining room is usually only used for formal dinners.

3 RESULTS

The difference between the standard and air curtain assisted range hood become apparent when we compare the results of the test on both hoods under the same circumstances. For this test, we selected the same height between the range hood and the range as in the test shown in figure 3, 0.75 m, but instead of just having a pot on the front burner, 2 pots, one on the back and one on the front burner, were used. An summary of the test conditions and the measured capture efficiencies is given in table 1.

Table 1: standard vs. Air curtain assisted range hood performance
(experiment with pots on the front and back burner)

Range hood	Flow rate	Height	CE_{FP}	CE_{total}
Standard	170 m^3/h	0.75 m	0.85	0.52
Air curtain assisted	175 m^3/h	0.75 m	0.49	0.16
Air curtain assisted	250 m^3/h	0.75 m	0.50	0.16

At similar flow rates, the capture efficiency of the air curtain assisted range hood is better both during the cooking event (first pass) and over the complete period of exposure of the occupants.
The concentrations measured at each of the measuring points are shown in figure 4, for the test with standard and air curtain assisted range hoods both operating at approximately 175 m^3/h. Although they do both seem to function rather well during first few instances of the cooking event, the capture efficiency of the standard range hood plummets after about 2 minutes due to the turbulence induced by the pots of boiling water. While the capture efficiency of the air curtain assisted range hood also deteriorates at that point, it remains relatively high due to the containment of the pollutant above the range due to the air curtain. When the cooking event is stopped, the thermal plume created by the pots of boiling water disappears and the efficiency of both range hood worsens, but again, the containment achieved by the air curtain ensures a better endurance of the performance of the range hood.

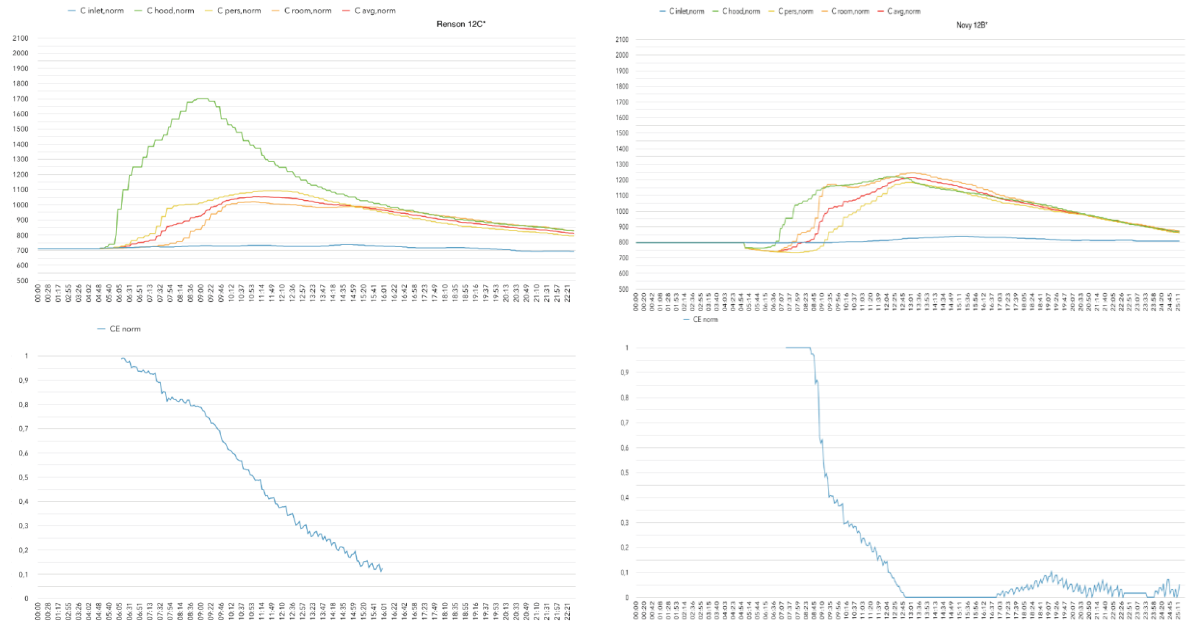

Figure 4: Measured carbon dioxide concentrations and capture efficiencies during a 3 minute cooking event with an air curtain assisted (left) and standard (right) range hood at 175 m^3/h and cooking pots on both burners

With the standard range hood, the concentration in the area near the range is almost immediately as high as above the range, effectively becoming a more or less well mixed environment.
With the air curtain assisted range hood, the excess concentration measured in the exhaust is nicely contained and exhausted, while the room concentrations, both near the range and further away, remain virtually constant and slowly go down.
The capture efficiencies and measured concentrations for the standard range hood remain virtually unchanged if the flow rate is increased by almost 50 %, as is shown in table 1.

4 DISCUSSION

The results clearly demonstrate that the 'post cooking event' period is characterized by reduced capture efficiency. In short cooking events, typical for example in frying events or reheating, this phase dominates the total capture efficiency. In the presented tests, no alternative room exhaust is used. This is rapidly becoming standard practice in kitchen ventilation in western Europe. The range hood is connected to the central exhaust ventilation unit and serves as both the ventilation vent hole and, when activated, as range hood. This configuration is a worst case scenario for the capture efficiency if the post cooking event period is taken into account.

5 CONCLUSIONS

Good capture efficiencies can be obtained with relatively small exhaust flow rates during cooking using air curtain assisted residential range hoods, where standard range hoods do much worse at the same flow rates and are virtually no better at 50% higher flow rates. Nevertheless, the post cooking event period has a large impact on overall capture efficiency in short cooking events regardless of the type of range hood that is used.

6 ACKNOWLEDGEMENTS

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