THERMAL CONDITIONS IN COMMERCIAL KITCHENS

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ABSTRACT

The aim of the research was to find out the indoor climate conditions in Finnish commercial kitchens by measurements and inquiries. Twelve kitchens were selected from the Helsinki metropolitan area. The measurements concentrated on thermal conditions.

On the average thermal conditions in measured kitchens are not fully satisfactory and they varied considerably between the kitchens. Thermal conditions within kitchens varied also depending on the workplace. Heat stress harmful to health was only found in two kitchens. According to measurements, ventilation rates in commercial kitchens should always be based on the loads caused by the cooking equipment.

The research pointed out that in addition to the air flows the supply air temperature also has a direct influence to the temperature of the indoor air in the workplace. To guarantee acceptable thermal conditions the air flow rates and the temperature of the supply air must be controlled.

KEYWORDS

Air conditioning, Air velocity, Kitchen ventilation, Temperature gradient, Thermal comfort

INTRODUCTION

In spring 1996, the Research and Development Project of Commercial Kitchen Ventilation (CKV) was started in Finland. The aim of the project is to improve indoor air quality, energy economy and occupational safety in commercial kitchens by creating new criteria for kitchen ventilation design. This paper is part of the first stage of this project, which objective was to collect basic information about thermal comfort and indoor climate in commercial kitchens.

METHODS

Measured kitchens

Twelve kitchens were selected from the Helsinki metropolitan area. The kitchens selected were situated in: two restaurants, four staff canteens, two kindergartens, two schools, one barracks and one hospital. The floor area of the kitchens varied between 28 and 234 m^2 and the number of the portions consumed daily between 85 and 1200. The amount of personnel in measured kitchens varied from one to over twenty persons.

The kitchens selected were quite new, or recently renovated, except in staff canteen 1, which was renovated in 1981. Modern kitchens were selected because they are likely to have been designed according to the current regulations and guidelines.

All the kitchens measured were equipped either with hoods, or with ventilated ceiling. Supply air devices were mostly of low-velocity type. Four out of twelve kitchens were equipped with a supply air cooling unit. Exhaust and supply equipment are introduced in Table1.

Table 1 Exhaust and supply equipment in the kitchens measured.

Kitchen	Exhaust equipment	Supply equipment
school 1	Hoods	L/H-c/h
staff canteen 1	Hoods	L/H-c
staff canteen 2	Ventilated ceiling	L-c, C
kindergarten 1	Ventilated ceiling	L-c
garrison	Hoods	L-h/f
restaurant	Hoods	L-c
kindergarten 2	Hoods	L-h
staff canteen 3	Hoods	L/H-c/h, C
fast-food	Hoods	L-h, C
school 2	Hoods	L-h/c
staff canteen 4	Hoods	L-c/f
hospital	Ventilated ceiling	L-c/f, C

L is Low-velocity equipment
H High-velocity equipment
c Air supply from ceiling
h Air supply from face panel of hood
f Air supply from floor level
C Cooling

Measurements

The measurements focused on thermal conditions. Air temperature in three different levels (0.1 m, 1.2m and 1.8 m), mean radiant temperature, natural wet bulb temperature and humidity were measured continuously. To define thermal conditions in commercial kitchens, WBGT-index and operative temperature were calculated. Normally one period of measurement continued for four days. Air flows, air velocity and turbulence, radiant asymmetry and surface temperature of the kitchen equipment were defined by measurements.

Inquiry

To define the employees' opinion on indoor climate conditions, employees from each kitchen filled in an indoor climate questionnaire. Indoor climate was evaluated in all kitchens and recommendations for renovation were developed for each of the kitchens measured.

RESULTS

Indoor air temperature and humidity

Average air temperatures in kitchens during working hours varied between 19.5 °C and 26.5 °C. McDonnell (1988) has proposed that a temperature of 30 °C should not be exceeded in kitchens. Air temperatures occasionally exceeded 30 °C in three kitchens. However, in many guidelines 28 °C is the highest acceptable indoor air temperature for commercial kitchens (Heinonen 1997). This temperature was exceeded in over 10 % of the working hours in three kitchens.

Table 2 Mean air temperature and vertical air temperature difference between 0.1 - 1.8 m.

Kitchen	Mean air temperature °C	Temperature difference °C/m
school 1	22.9	1.3
staff canteen 1	24.1	2.8
staff canteen 2	23.5	3.5
kindergarten 1	21.4	1.7
garrison	21.4	1.6
restaurant	26.4	7.4
kindergarten 2	25.7	1.1
staff canteen 3	23.7	2.1
fast-food	24.8	4.0
school 2	21.1	0.7
staff canteen 4	26.5	2.2
hospital	19.5	3.0

Vertical air temperature difference within the occupied zone, measured at the hight of 0.1 m and 1.7 m should not exceed 3 °C (ASHRAE 1992). The vertical temperature difference was measured in a slightly different way compared to the ASHRAE standard and in addition the standard does not directly cover the conditions in commercial kitchens. However, at least in the restaurant, the vertical air temperature difference will presumably decrease the thermal comfort.

There was only a small difference between the operative temperature and the indoor air temperature in most kitchens. However, the operative temperature was considerably higher than indoor air temperature in the restaurant and also in the fast-food restaurant. This was probably due to heavy use of the kitchen equipment including hot surfaces such as ranges, frying pans, fryers and grills.

The average value of the WBGT-index did not exceed 26 °C in any of the kitchens measured. However, in two cases the peak value of the WBGT-index occasionally exceeded 26 °C, which can be stated as a boundary value for heat stress harmful to health, when a person is not acclimatized to heat (ISO 1982).

According to the inquiry, personnel in kitchens with cooling were more satisfied with the thermal conditions than personnel in kitchens without cooling.

Figure 1 illustrates that the increase of the indoor air temperature follows quite accurately the increase of the supply air temperature. There was no change in the heat load caused by the cooking equipment between 9 am and 11 am according to the observation. Because cooling was not in use when the outdoor air temperature increased, the supply air temperature followed the outdoor air temperature with small delay.

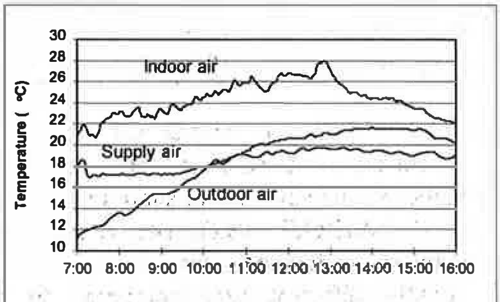

Figure 1 Indoor, outdoor and supply air temperatures in staff canteen 2.

According to the measurements, the most uncomfortable workplaces in kitchens are near a frying pan, a range or a grill. The prevention of the radiant heat load entering the kitchen space from such equipment can be a problem. Furthermore, they also cause large convective heat gain. Workplaces near frying pans and ranges are extremely problematical, because employees must usually work long periods continuously near the appliance. Figure 2 demonstrates the difference in thermal conditions between different workplaces in staff canteen 2, where both workplaces are under the same ventilation ceiling and therefore equally ventilated.

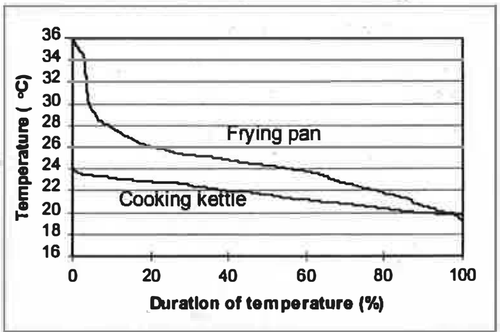

Figure 2 Duration of temperature during working hours in staff canteen 2.

The average values of relative humidity were under 50 % in the kitchens measured. According to the measurements, humidity is not a problem in commercial kitchens in Finland if the ventilation rate is adequate.

Air flow rates

Measured air change rates per floor area in dishwashing areas and in kitchens are presented in Tables 3 and 4.

Table 3 Measured air change rates in dishwashing areas.

Dishwashing area	Exhaust air flow rate L/s m^2	Exhaust air /Supply air
staff canteen 2	31.3	1.40
garrison	4.3	-
staff canteen 3	7.6	1.70
hospital	12.5	-

Table 4 Measured air change rates in kitchens.

Kitchen	Exhaust air flow rate L/s m²	Exhaust air /Supply air
school 1	30.8	1.99
staff canteen 1	14.1	1.17
staff canteen 2	35.2	1.26
kindergarten 1	34.8	1.44
garrison	21.5	0.78
restaurant	24.4	1.67
kindergarten 2	14.8	0.79
staff canteen 3	11.7	0.85
fast-food	87.1	2.86
school 2	33.3	1.08
staff canteen 4	22.2	1.36
hospital	25.6	-

Supply air flow rate in kitchen should usually be lower than the exhaust air flow rate. In three kitchens the supply air flow rate was nevertheless bigger than the exhaust air rate. Due to this, it is possible that emissions from the food preparation in kitchen can spread to other parts of the building.

Exhaust air flow rates varied considerably between kitchens measured. It was over seven times larger in the fast food restaurant than in the staff canteen 3. Exhaust air flow rates in some dishwashing areas were remarkably low.

Almost all of the kitchens measured fulfilled the minimum ventilation rates for commercial kitchens given in the Finnish building code (10 - 15 L/s m²). However the thermal conditions were not fully satisfactory. This indicates that the minimum ventilation rates given in the Finnish building code are not adequate to ensure acceptable thermal conditions in commercial kitchens.

Air velocity

Mean air velocities did not vary remarkably between the kitchens. Highest mean air velocities in all three levels (Table 5) were in the fast-food restaurant. This is quite obvious because exhaust air flow rate was over double in comparison with all the other kitchens in this study. The personnel in the fast-food restaurant did not, however, complain about the draught. One explanation for this is probably the quite high (on the average 21.1 °C) supply air temperature.

Table 5 Air velocities.

	0.2 m m/s	1.2 m m/s	1.6 m m/s	Mean m/s
school 1	0.36	0.22	0.23	0.27
staff canteen 1	0.33	0.22	-	0.28
staff canteen 2	0.29	0.24	0.24	0.26
kindergarten 1	0.22	0.25	0.29	0.25
garrison	0.35	0.25	0.26	0.29
restaurant	0.38	0.34	0.30	0.34
kindergarten 2	0.21	0.19	0.20	0.20
staff canteen 3	0.29	0.21	0.18	0.23
fast-food	0.47	0.36	0.54	0.46
school 2	0.23	0.24	0.29	0.25
staff canteen 4	0.42	0.26	0.28	0.32
hospital	0.27	-	0.27	0.27
Mean	0.32	0.25	0.28	0.27

According to the measurements, the highest air velocities occur at the floor level where the risk of draught is also greatest due to high air velocities, but also due to low temperature. The temperature gradient was positive from the floor level to head level in all the kitchens measured. According to the inquiry, most of the kitchen workers experienced draught at least from time to time.

DISCUSSION

On the average thermal conditions in measured kitchens are not fully satisfactory. Thermal conditions are rather good in some kitchens but not acceptable in some.

It seems that minimum or normative ventilation rates given per floor area are not adequate to ensure an acceptable indoor climate in commercial kitchens, due to the different loads caused by kitchen equipment. Ventilation rates in commercial kitchens should always be based on the load caused by the kitchen equipment. This should also be taken into account in building codes and guidelines.

Indoor climate should also be considered in kitchen layout design. For instance all cooking equipment and dishwashers should be placed under hoods or ventilated ceiling.

According to the measurements, if there is no control system of the air flows, the air flow rate in the kitchen is not suitable most of the time, because of the fluctuation of the heat, the moisture and the impurity load entering the kitchen. Because of this, the possibility of using demand based ventilation should be considered in commercial kitchens aswell.

The main needs in developing the ventilation of commercial kitchens are the improvement of ventilation design guidelines, as well as the development of control systems for ventilation.

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