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VENTILATION EFFICIENCY AND THERMAL COMFORT IN COMMERCIAL KITCHENS

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ABSTRACT

Thermal conditions and indoor air quality of the working environment in commercial kitchens can be unsatisfactory. With a properly operating ventilation system, it is possible to raise the level of quality of the indoor climate and, hence, increase working effectiveness and productivity.

This paper presents research that was conducted to study thermal comfort and ventilation effectiveness in commercial kitchens. Various methods for distributing the supply air and exhausting the kitchen air were investigated under laboratory conditions. Ventilation effectiveness was examined by marking the air with tracer gas and observing the concentration at different kitchen locations. Thermal conditions were metered with an indoor climate analyzer.

Ventilation effectiveness and contamination removal effectiveness were highest by the cooking appliances when the supply units were located on the floor. The best thermal conditions were found when the supply air unit was placed in the ceiling next to the exhaust hood.

INTRODUCTION

Commercial kitchens are working environments that can have indoor air problems. The indoor climate is often unsatisfactory and working conditions can have a significant effect on worker comfort and productivity.

Great amounts of impurities (grease, smoke) are released to the kitchen air during the food preparation process. Excessive heat created by the cooking equipment often causes a major problem in commercial kitchens. The impurities and a part of the heat load can be removed from the kitchen with an efficient ventilation system.

Airflows used to ventilate commercial kitchens are usually excessive. Still, supply and exhaust airflows are only two factors affecting ventilation effectiveness or quality of air in different parts of a kitchen. Besides airflows, local ventilation rates depend on (1) the positioning of supply and exhaust air units, (2) the efficiency of the exhaust units, (3) the air distribution method, and (4) the temperature difference between the supply and room air.

TESTING

Testing Setup

The operation of various air distribution and exhaust methods and their effect on ventilation effectiveness and thermal comfort were studied under laboratory conditions. The test configuration was built in a special model kitchen. Two different methods of supplying and four methods of exhausting air were used. The volume of the model kitchen was approximately 70 m^3 (5,900 mm × 4,000 mm × 2,900 mm).

A frying pan and an oven range were used as cooking appliances in the test. Their added average power consumption varied between 6.5 and 6.8 kW. The convective heat developed by the equipment was estimated to be 2.0 kW. The convective flow was evaluated to be 280 L/s at the lower edge of the hood (2.0 m from the floor) (Pfeiffer and Augustin 1982). Both the exhaust and supply airflows used during the tests were 360 L/s, which was 30% higher than the calculated convective flow. The ventilation rate was 18.5 air changes per hour (ach).

One ventilation arrangement was also investigated with supply and exhaust airflows at 600 L/s. Six different air distribution and exhaust combinations were studied. In every case the air was introduced to the kitchen with low-velocity supply air units. These units were installed either on the floor or in the ceiling.

There were four separate ways for exhausting the air:

1. Conventional (exhaust-only) hood (3,000 mm long by 2,000 mm wide by 800 mm high—see Figure 1c).
2. General exhaust from the ceiling, see Figures 1d and 1f.
3. Special hood (no. 1) with an air jet to capture the convective flow (3,000 mm long by 1,200 mm wide by 570 mm high—see Figures 1a and 1e).
4. Special hood (no. 2) with a capture air jet (2,000 mm long by 1,000 mm wide by 570 mm high—see Figure 1b).

Different system variations are presented in Figure 1. It should be noted that no system configuration used traditional ceiling diffusers for supplying the air.

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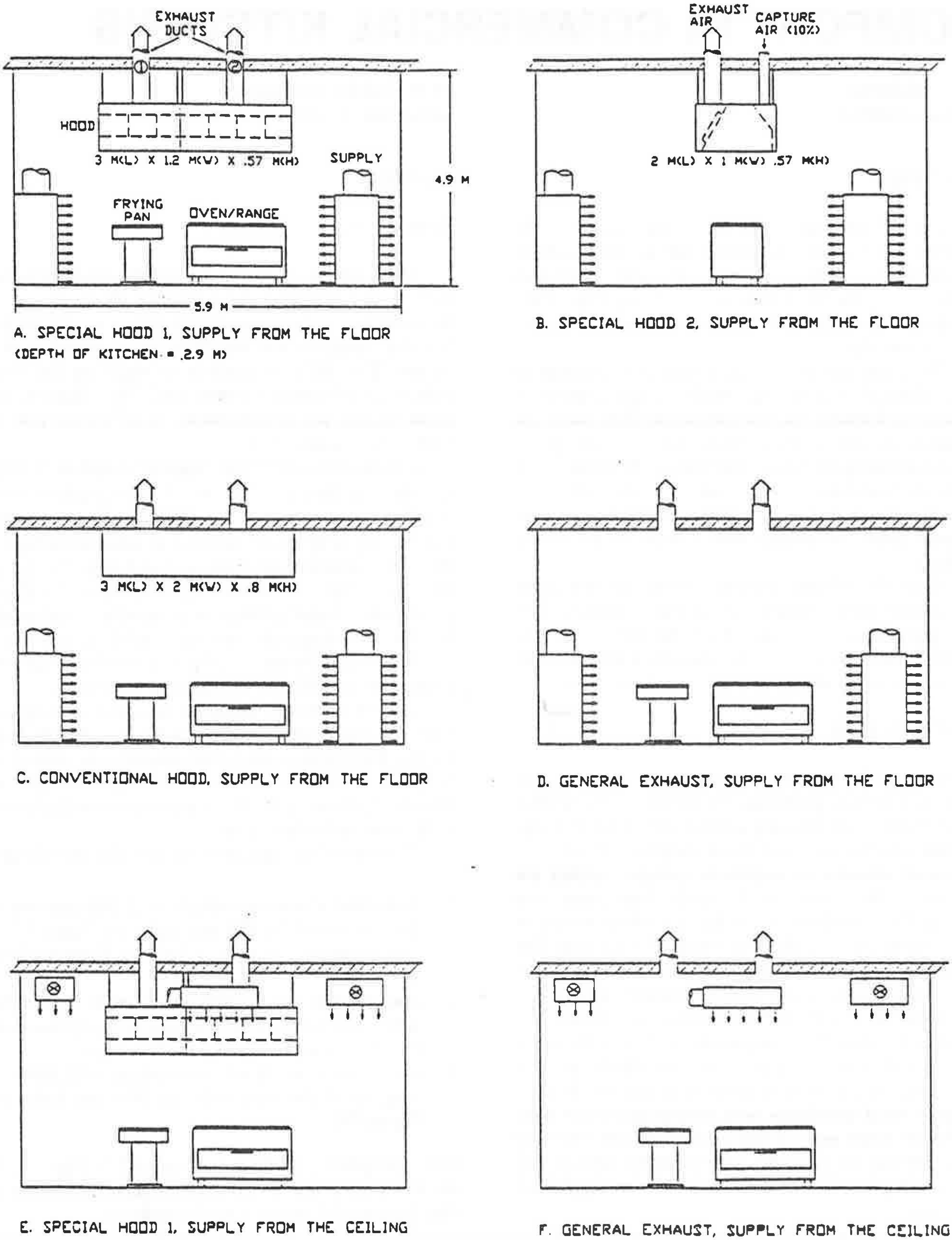

***Figure 1** Model kitchen system variations for supply and exhaust combinations.*

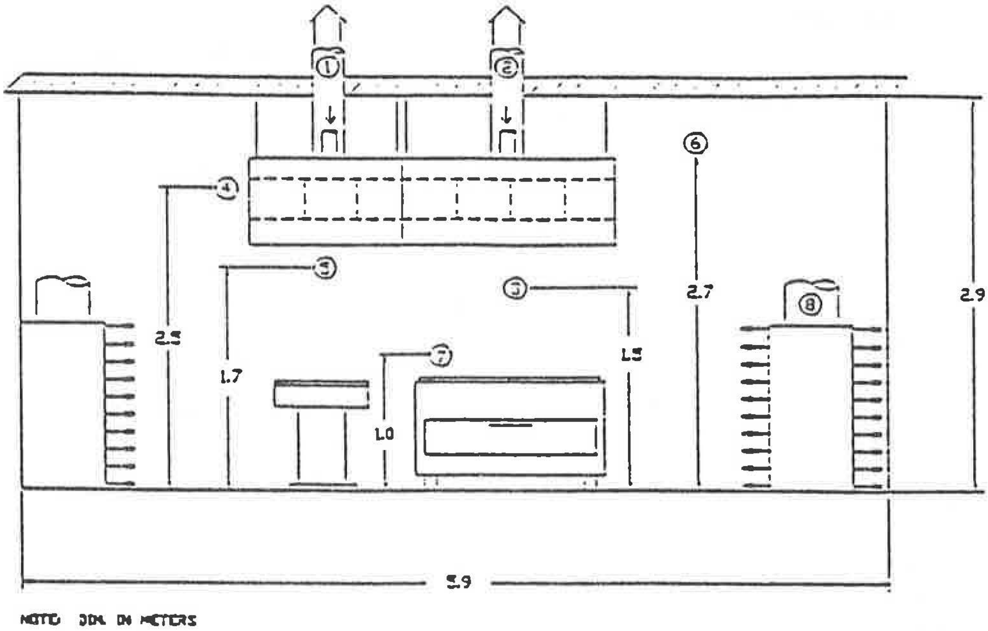

Figure 2 *Tracer gas concentration measuring locations.*

EXAMINING THE VENTILATION EFFECTIVENESS

Local Ventilation Rates

The model kitchen ventilation rate was studied by using a tracer gas technique. The supply air was marked with N_2O (nitrous oxide) tracer gas. Gas concentrations were followed with a computer-driven data logger in eight locations (Figure 2). When the steady-state concentration was achieved, the tracer gas was shut off. The subsequent decrease at various locations was observed.

Local ventilation rates were calculated from the digression curves by dividing the steady-state concentration by the area that lies under the curve. An example of a local ventilation rate measurement is shown in Figure 3.

VENTILATION EFFECTIVENESS

Ventilation effectiveness is the ability of a ventilation system to remove impurities from indoor air:

$$\epsilon = C_e/C_i \tag{1}$$

where

ϵ = ventilation effectiveness coefficient (-),
C_e = concentration in exhaust duct (ppm),
C_i = average occupant breathing zone concentration (ppm).

Tracer gas was released at the rate of 0.065 L/s through a perforated copper ring located on the range. Concentrations were observed in locations presented in Figure 2.

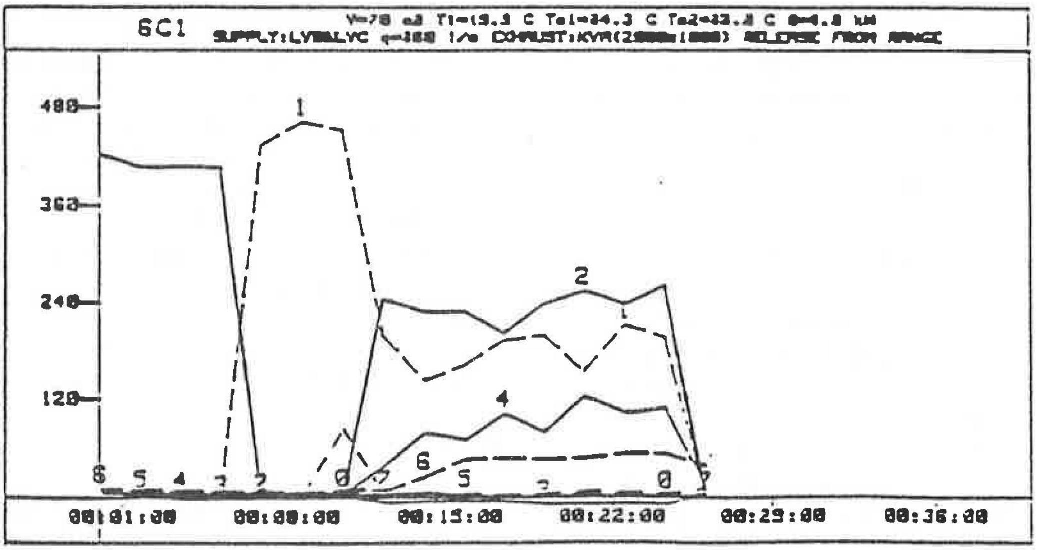

Figure 3 *Example of tracer gas concentration curves.*

Examining the Thermal Comfort

Thermal comfort was measured using an indoor climate analyzer located by the range. Evaluated were thermal radiation, air temperature, air velocity, and humidity.

RESULTS

Local ventilation rates that were calculated from the tracer gas digression curves are presented in Table 1. System letters (A-F) are presented in Figure 1 and measuring locations in Figure 2. These results indicate that

- supplying air from the floor (systems A, B, C, and D) generally leads to higher local ventilation rates than with ceiling distribution, and
- increasing the exhaust airflow by 1.7 times (system A2) did not affect the individual local ventilation rates in the same ratio.

Results of exhaust effectiveness metering are shown in Table 2. These results indicate that

- generally, the concentrations were higher by the hood edge and near the ceiling than in the occupancy zone, and
- concentrations with a conventional hood and general exhaust were much higher near the ceiling than with the special hoods.

Comparing the results of metering thermal comfort with the various installations was difficult. Heat accumulated by the surrounding structures could not be measured or considered in results for different examination days. Some factors can be noted:

- greater airflows did not noticeably affect indicators of thermal comfort;
- air velocity in the working zone (by the range) was highest with supply air units located in the ceiling, which provides necessary local cooling.

CONCLUSIONS

This study showed that the best results in ventilation effectiveness and thermal comfort were not achieved with the same exhaust and supply air system configuration. The main purposes of commercial kitchen ventilation are removal of odors and removal of grease from exhaust air and providing thermal comfort to the workers in the kitchen. Using effective hoods, the main criterion of design should be thermal comfort because the airflow rates are adequate to provide satisfactory air quality in the breathing zone. This is due to the extreme working conditions, especially near the cooking appliances.

TABLE 1
Local Ventilation Rates (L/h)

System	Location 1	2	3	4	5	6	7
A1	26	23	33	14	28	19	31
A2	48	29	30	20	65	15	63
B	25	26	34	16	13	9	25
C	21	20	30	8	21	7	14
D	18	22	33	12	20	15	14
E	22	21	19	19	15	14	22
F	21	19	17	13	16	17	12

TABLE 2
Exhaust Effectiveness Factors

System	Exhaust duct 1	Exhaust duct 2
A1	126	12
B	66	50
C	35	19
D	8	5
E	8	3
F	2	2

Distributing supply air from units located on the floor leads to better ventilation efficiency than with supply units in the ceiling. An unwanted result with this installation is a vertical temperature gradient.

Distributing air from the ceiling near the hood with low air velocity provides local cooling that is a necessity because of the strong radiant heat created by cooking appliances. Increased airflows did not raise metered indicators at the same ratio, which proves that good results in kitchen ventilation can be achieved with careful design and efficient equipment without excessive airflows.

Based on the results of the study, the following are some basic principles of commercial kitchen ventilation.

1. Impurities and excess heat should be removed with efficient local exhaust.
2. Supply air, at the correct temperature, should be brought to the working area in such a way that it first refreshes workers and then replaces convective flows.
3. In cases where workers are subjected to large heat radiation, supply air should be introduced directly to the working space (local cooling).
4. The permitted supply air velocity varies in different kitchen areas between 0.3 and 0.5 m/s. Velocity for local cooling can be as high as 0.8 m/s with a supply air temperature of 18°C.
5. In addition to local exhaust, general exhaust is required. General exhaust should be at least 10% of the total kitchen exhaust flow.

REFERENCE

Pfeiffer, W., and S. Augustin. 1982. *Absaugluftmengen von Erfassungseinrichtungen offener Bauart*. Staub-Reinhalt. Luft 42(8).