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VENTILATION FOR KITCHENS IN A BIG HOTEL

H.H. Wu [1] and W.K. Chow [2]

[1,2] Department of Building Services Engineering,
The Hong Kong Polytechnic University,
Hong Kong, China

ABSTRACT

Indoor environment required for kitchens in a big hotel in Hong Kong was described. Local regulations and design guides for ventilation systems in kitchens including exhausts were briefly reviewed. In addition, effluents from cooking were discussed. Environmental parameters including air temperature, air speed and relative humidity in the kitchen of a coffee shop in a hotel were studied. Better ventilation designs for the kitchens are proposed. Further, immediate actions to be taken are recommended.

INTRODUCTION

Under the local regulations (Provisional Urban Council, 1992), the kitchen area can only be 21% of the total food and beverage area. Comparing with other countries including China Mainland, this value is much smaller. Therefore, the occupancy loadings of commercial kitchen are very high, bearing in mind that there are lots of equipment inside the kitchen. As a result, the kitchen environment is often crowded with kitchen personnel and 'smoky' with slippery floor.

A commercial kitchen is also viewed as a dangerous location because occurrence of fire is high. Statistically, for those 27,000 restaurant fires occurred annually in U.S.A., 30% originated in the kitchen (Conover, 1992). The fire protection system should be capable of not only extinguishing the fire on the cooking surface, but also preventing fire spreading to the exhaust duct and other adjacent areas.

At the moment, designing a ventilation system in commercial kitchens relies on past experience in operation. This is because there are not yet good understanding on indoor aerodynamics, heat transfer and environmental control for local kitchens. A typical application may involve many variables, some of which may be virtually unknown and difficult to estimate. Engineering judgment is a common practice in kitchen ventilation engineering and design. Therefore, it appears that different components of the ventilation systems are just put in the kitchen without considering the thermal comfort, system effectiveness and safety. This paper emphasises those key issues so that a platform for further investigation can be identified.

KITCHEN VENTILATION DESIGN

Kitchen ventilation is a vital component of the huge service industry, affecting building air balance and energy efficiency. If it is not working properly, malfunctions of the entire kitchen would halt the operation of the whole restaurant. This topic covers a number of factors or considerations that combine to form the basis of a system that will perform satisfactorily, cost-effectively, and comply with applicable codes. These factors (e.g. Black 1989) include smoke capture, grease extraction and disposal, fire protection, and the maintenance of acceptable air quality and temperature in the kitchen space. Modern systems may also include air pollution control and heat recovery equipment.

The most prominent component of a kitchen ventilation system is the exhaust hood. The primary function of the hood is to capture and exhaust smoke, grease vapors, and other contaminants generated in the cooking process. The volume of air required to accomplish this must be determined. It is important that this volume be kept to the minimum possible since it must be replaced by make-up air, which usually requires heating or cooling.

Efficient grease extraction is extremely important. Grease that is not extracted will accumulate in the ductworks, leading to higher occurrence of fire. To such areas, the difference between 90% and 95% efficiency is not 5% but rather 100% (Conover, 1992)! Centrifugal grease extraction has proved to be highly effective and is currently employed in most leading designs of exhaust hoods. Many such hoods are also equipped with internal wash systems using hot water with detergent injection to automatically dispose the extracted grease.

What is so special about kitchen contamination?

- First, the contaminants are emitted with high concentration over a short time.
- Second, there are a variety of contaminants involved, including particulate matter, moisture, heat, odors and gases; all produced by different chemical mechanisms.

Therefore, good indoor air quality is difficult to maintain in commercial kitchens. The indoor climate is usually unsatisfactory, giving poor working conditions to the kitchen personnel concerned. For example, grease and combustion products are released to the kitchen air while cooking, especially when using Chinese 'wok'. Heat emitted by the modified gas stores (a common practice in Chinese restaurants!) gives problems. Therefore, an efficient ventilation system must be provided.

Both solid and liquid particles can be formed in several ways while cooking (Wolbrink and Sarnosky, 1992). The solid particles are usually formed by burning the food to generate carbonaceous particles. Vegetables in particular are of a cellulose nature, and they readily form these solid particles when burned. The "burning" incidents might be infrequent for western style of cooking; but very usual in cooking Chinese food with a 'wok'!

LOCAL CODES AND DESIGN GUIDES

According to the local building planning regulation (BPR - clause 3 of the Buildings Department, 1991), the air exchange rate per hour for kitchen should not be less than five. This value basically refers to natural ventilation. But from the Urban Services Department codes, the mechanical ventilation per person should not be less than 17 m^3hr^{-1} and must fulfill USD codes chapter 132 (Provisional Urban Council, 1992). Furthermore, all kitchen exhausts have to satisfy the codes as laid down by the Environmental Protection Department. Various grease removal devices need to be installed, such as grease filter, vent wash system, electronic precipitator or even water scrubber system.

The kitchen ventilation design in Hong Kong follows:

- CIBSE recommendation (CIBSE, 1986)
- ASHRAE recommendation (ASHRAE, 1995)
- Local design experience

Mechanical ventilation and fresh air make-up provision for kitchens, including duct risers, external exhaust and fresh air intake lourves, will be based on 60 air changes per hour. Moreover, air-conditioning or pre-treated primary air at 28°C to 30°C supply air temperature will be provided to the hotel kitchens in summer.

CASE STUDY

The kitchen of a coffee shop in a hotel is taken as a case study. This is a western style kitchen located at the ground floor of the hotel. Both town gas and electricity are provided for the appliances. The kitchen is of length 16 m, width 12 m and height 3 m with false ceiling as shown in Figure 1. It is the busiest kitchen in the hotel with heavy customer circulation and maximum daily production. The current installed ventilation system is shown in Figure 1 as well. Tpical characteristics of the ventilation system are:

- Kitchen exhaust system with 38 air changes per hour (or 7.5 m^3s^{-1} at 500 Pa).
- Primary air unit with fresh air supplied to suit local regulation, i.e. at a rate of 6.75 m^3s^{-1} at 375 Pa; and supply air temperature at about 14°C.
- Fan coil unit system to provide spot cooling to the kitchen staff.

Indoor temperature, air velocity and relative humidity at different positions inside the kitchen were measured in winter. Results are shown in Figure 2. Further, kitchen personnel were interviewed on their subjective feelings. The ventilation system was also inspected.

In general, the indoor environment is considered to be acceptable. However, the air speeds measured were low and people might feel stuffy inside. Note that the measurements were made in winter. Even so, unsatisfactory air motion due to low speeds were reported, confirming that there are serious problems on thermal comfort in summer.

Therefore, problems identified in the ventilation system from this environmental field measurement and interview survey are:

- Indoor temperature was high, acceptable in winter by taking off some clothes, but unacceptable during summer.
- Complaints on feeling stuffy.
- Smelly during peak food production time.
- Insufficient exhaust at peak production time due to poor workmanship on design and installation.
- Water leakage in the exhaust ductworks for dishwasher and vent-wash.

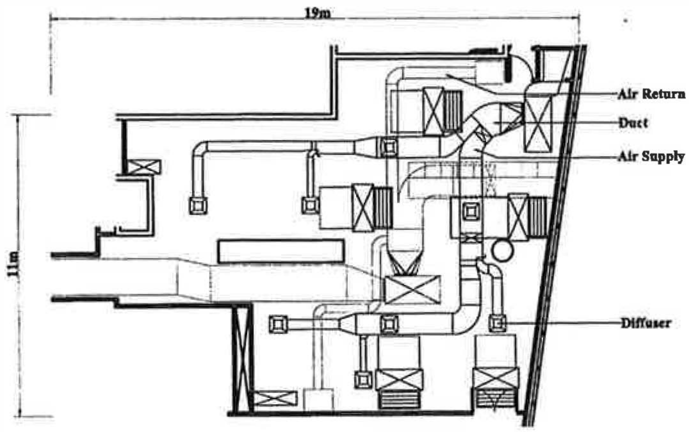

Figure 1: Layout of the kitchen

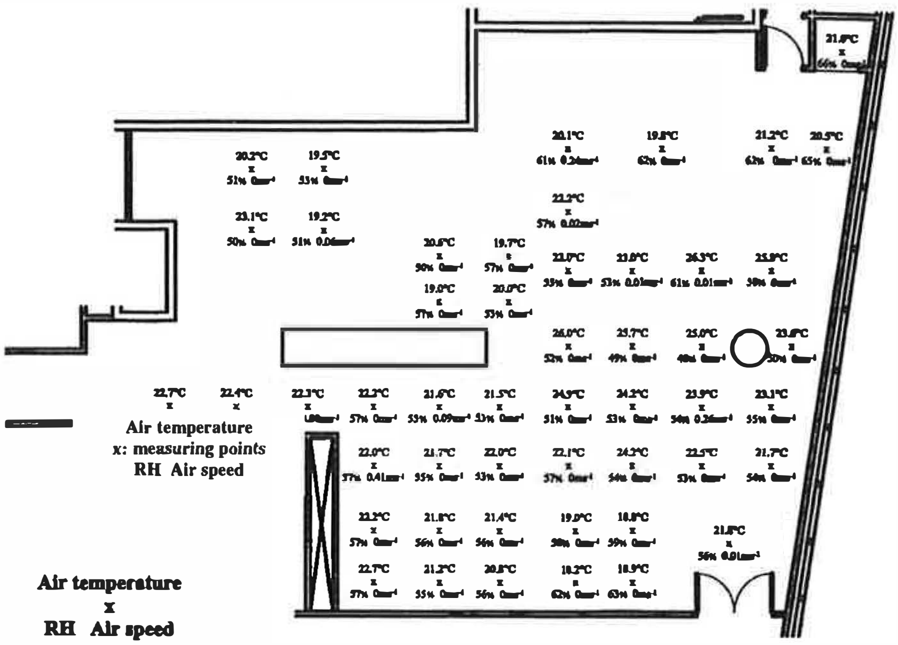

Figure 2: Measured environmental parameters

IMMEDIATE ACTIONS

Based on the above field measurement, immediate actions to be taken are:

- Put in portable fans to increase the local air speed and turbulence intensity, as elevated air speed is believed to be important from a thermal comfort study (Chow and Fung 1994) under local hot and humid climate.
- Put in portable dehumidifiers to reduce the humidity.
- Consider installing spot cooling systems for positions with unsatisfactory environmental performances.
- Apply for further support funding to replace a better system.

FURTHER DESIGN CONSIDERATIONS

Kitchens are always designed with the cooking appliances arranged in a line. It is difficult to determine the operating conditions (flow rates and pressure) of the exhaust system catering for the contaminants produced. Factors to be considered should include the amount of heat, grease and smoke produced by the cooking equipment; code requirements; room draughts; Heating, Ventilation and Air-conditioning (HVAC) system design; and hood design. It is observed that these were not considered in the current design as illustrated by the above case study. A more accurate method (Fritz, 1989) for determining the exhaust required to ventilate a particular line of cooking equipment is by estimating the amount of heated air produced by each piece of equipment.

Supply and exhaust airflows are the two key factors affecting the performance of the ventilation system and hence the air quality in different parts of a kitchen. It was concluded (Pekkinen and Takki-

Halttunen, 1992) that the best results in ventilation effectiveness and thermal comfort were not achieved with the same exhaust and supply air system configuration.

Reduction of commercial kitchen exhaust rates is generally viewed as leading to reduced energy use and cost (Horton et al. 1993). The presumption is that less energy is required to heat and cool the correspondingly reduced amount of make-up air.

CONCLUSION

This performance evaluation on ventilation system is based on the thermal comfort survey. The parameters measured are related to the design criteria practised. Comfortable ranges of air temperature and relative humidity were surveyed by interviewing with the kitchen personnel. These subjective responses can be compared with the design criteria. Air movement in kitchen is important as reflected in the poor response to the low air velocity measured. Moreover, current design criteria might not be suitable in local kitchen ventilation design.

Ranges of thermal comfort parameters for kitchen ventilation design should be identified. The results are significant for a crowded kitchen with lots of cooking activities. The conclusion is simple but provides a platform for further research in kitchen, laundry and workshop.

Thermal comfort is critical to the kitchen personnel and cooking activities but is neglected previously. The conclusion clearly demonstrates that a lot of aspects need to be considered in the kitchen ventilation design, in particular, energy consideration which related to the exhaust/test air flow rate. Current design codes or rules of thumb are definitely insufficient. From operational experience, the loosely established ventilation design criteria would lead to poor indoor environment in the kitchen, spoiling cooking activities and fire hazard in the kitchen.

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REFERENCES

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) (1995). Handbook - Application, Chapter 28: Kitchen Ventilation, *ASHRAE*, p. 28.3-6.

Black D.K. (1989) Commercial Kitchen Ventilation – Efficient Exhaust and Heat Recovery. *ASHRAE Transactions* CH-89-9-6, 780-786.

Buildings Department (1991). Building Planning Regulation Clause 3. *Government of the Hong Kong Special Administrative Region.*

Conover D.R. (1992) Building Construction Regulation Impacts on Commercial Kitchen Ventilation and Exhaust System. *ASHRAE Transactions: Symposia* AN-92-16-5, 1227-1235.

Chartered Institution of Building Services Engineers (CIBSE) (1986). Ventilation and Air-conditioning (System, Equipment and Control). *CIBSE Guide B2/B3*, p. B2-7, B2-11 and B3-7.

Chow W.K. and Fung W.Y. (1994). Investigation of the subjective response to elevated air velocities: Climate chamber experiments in Hong Kong. *Energy and Buildings* 20(3), p. 187-192.

Fritz R.L. (1989) A Realistic Evaluation of Kitchen Ventilation Hood Designs. *ASHRAE Transactions* CH-89-9-5, 769-779.

Horton D.J., Knapp J.N. and Ladewski E.J. (1993) Combined Impact of Ventilation Rates and Internal Heat Gains on HVAC Operating Costs in Commercial Kitchen. *ASHRAE Transactions: Symposia* DE-93-13-1, 877-883.

Pekkinen J.S. and Takki-Halttunen T.H. (1992). Ventilation Efficiency and Thermal Comforts in Commercial Kitchens. *ASHRAE Transaction* AN-92-16-3, 1214-1218.

Provisional Urban Council (1992). Application for a Restaurant License. *Government of the Hong Kong Special Administrative Region*, p 6-7.

Wolbrink D.W. and Sarnosky J.R. (1992) Residential Kitchen Ventilation – A Guide for the Specifying Engineer. *ASHRAE Transactions: Symposia* AN-92-16-1, 1187-1198.