FIRE SAFETY CONCERN ON OPEN KITCHEN IN SMALL RESIDENTIAL UNITS OF TALL BUILDINGS

W.K. Chow
Research Centre for Fire Engineering, Department of Building Services Engineering
The Hong Kong Polytechnic University, Hong Kong, China

(Received 3 May 2011; Accepted 8 July 2011)

ABSTRACT

Open kitchens have been designed for many small residential units in tall buildings in Southeast Asia. This open design, without enclosing the kitchen with fire resisting walls has failed to comply with building fire safety codes in places like Hong Kong. Performance-based design was adopted to determine fire safety provisions. Gas cookers with flames are not allowed. Additional fire protection systems such as water mist suppression or dry powder systems have to be provided above the stoves, though studies on kitchen fire physical hazards with and without fire resisting walls were not reported in the literature. A survey on fire load density indicated that large amounts of combustibles are stored in small residential units. Experiments with electric induction cookers indicated that the cooking oil in a frying pan can be ignited within ten minutes. Fire would spread out from the open kitchen to burn up all stored combustibles in the residential unit to give a big fire. There are queries on whether such open kitchens in tall buildings are really safe when there is an accidental fire.

Aspects of big open kitchen fires both with and without fire resisting walls in small residential units of tall buildings should be further explored. Fire dynamics must be applied to study the possibility of onsetting flashover upon igniting the cooking oil and burning adjacent combustibles. There might be new fire phenomena such as the air pumping effect of the plume and flame whirling motion in an open kitchen to give big disasters. Full-scale burning tests should be carried out to confirm identified scenarios; to justify the model predictions; and to observe any new physical fire phenomena. Performance of the specified suppression systems including water mist and dry powder suppression systems in big fires must be evaluated.

1. INTRODUCTION

Many tall residential buildings over 200 m in height with small units of floor area less than 30 m^2 have been built in dense urban areas in Southeast Asia [1,2]. Fire resisting walls are required to enclose the kitchens. To utilize space more effectively in such a small residential unit, open kitchens have been designed. Although this design failed to comply with the usual building fire safety codes, some projects have been approved by virtue of a performance-based design (PBD) [3,4], known as fire engineering approach in Hong Kong [5].

Three conditions are commonly imposed in the associated PBD design for open kitchens. Firstly, gas cookers cannot be used, and only flameless electric induction cookers are allowed. Secondly, additional fire suppression systems including water mist [6] or dry powder [7] systems are specified for installation. The systems are supposed to act on the stove fire and prevent it from growing large. The residential unit owner cannot take out the system, nor change the cooking stove without approval from the government. Thirdly, the estate management office has to sign an undertaking to implement the approved fire safety management procedures [4,8] specified in the performance-based design report. Open kitchen is included in the new code [9] with additional fire safety provisions on fire detectors, sprinklers and fire resistance walls proposed by the Authorities.

However, the performance of open kitchen fires in small units of tall buildings were not studied in detail using fire dynamics tools. Kitchen fire physical hazards with and without fire resisting walls were not even compared [10]. Only the spread of smoke from the open kitchen to areas outside the residential unit was predicted by fire models [11,12]. Results on carbon monoxide concentration, heat flux and visibility were used to justify the available and required safe egress times only as far as the staircase. The provision of additional water mist suppression or dry powder systems targeted to suppress small fires at an early stage might not work as expected if the fire grows big. No experimental data from full-scale burning tests has been made available to support the above specifications.

Survey [13] on the fire load density in Hong Kong indicated that large quantities of combustibles are stored in residential units. As surveyed by Chow and associates earlier [14,15], the fire load density is particularly high for small units of floor area less than 30 m^2. More combustibles are stored by stacking the stuff up. A very high fire load density above the upper limit of 1135 MJm^{-2} specified in the local code [16] results. Further, cooking oil can be ignited easily even when using induction cookers [17]. The burning of all combustibles in a big post-flashover fire needs to be studied. There are deep concerns on fire safety for open kitchens in tall residential buildings. Some citizens in such existing buildings with open kitchens are worrying about having big accidental fires if the fire installation systems cannot suppress the small stove fire at the early stage.

New fire issues applying to open kitchen fires and the associated protection required for small units in residential buildings should be studied [18].

2. LITERATURE REVIEW

Although there has been much work on kitchen ventilation, thermal plumes, exhaust hoods and fire detection [e.g. 19-23], very little concerns kitchen fires. A fire originating from kitchen stoves in a two-storey duplex house was studied by fire models [24]. The critical event was the onset of flashover in the kitchen. Fire spread to the entire house within one minute. In addition, a workshop [25] on residential kitchen fires was held at the Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology (NIST) in USA in 2007. Over 30 participants from professional societies, research laboratories, fire departments, insurance companies and others attended to discuss the existing test methods, technologies, and research and development on residential fire protection. Statistics for kitchen fires in USA was reported. An average annual value of 125,500 home fires started in the kitchen, including confined cooking fires from 1999 to 2002, leading to an average of 460 deaths per year. Although 9% of the fires extended beyond the kitchen, 70% of fatalities were due to this small percentage of kitchen fires. This gives a warning signal to residential units with open kitchens. Fire officers then summed up their firefighting experience, and suggested that installing a single sprinkler would control kitchen fires effectively. Residential range-top fire suppression systems have been proposed and tested by the Underwriters Laboratories Standards UL 300A [26]. Studies on hazard mitigation of kitchen fires at BFRL, NIST were then reported [24]. Kitchen fire hazard characterization and the protection of typical cooking oil fires on stoves by both active and passive fire systems were studied using limited full-scale burning tests. Two points for further research were identified in this workshop : protecting the kitchen fire from spreading; and suppressing the kitchen fire. These two conclusions support in-depth study on open kitchen fires.

General fire safety of kitchens in restaurants and hotels and associated fire safety systems has been studied [27-31]. Fire load density for kitchens in residential buildings, hotels and restaurants has been surveyed. Regulations, codes, design guides, practices and safety requirements on fire and ventilation in kitchens have been reviewed thoroughly. Fire safety in Chinese kitchens was studied with fire models. Kitchen fire safety in a hotel group in Hong Kong was studied. As most kitchen fires started from Chinese ‘woks’ on the stoves, heat release rates in burning such ‘woks’ in accidental fires have been measured by the oxygen consumption method. Performance of sprinkler and water mist system in kitchens with ‘woks’ under small fires were evaluated preliminarily. Results of this project were applied to the design of fire safety provisions in the kitchens of large hotel groups in the Far East. However, such results cannot be applied to open kitchen fires in small residential units in tall buildings.

Possible ignition of cooking oil while using the specified electric induction cookers in kitchen was studied [17]. However, the study only measured flame temperature, flame shape and flame length. The heat release rate of the cooking oil was not measured and the effect of fire suppression systems was not evaluated. Some of the observed phenomena, such as the ignition of cooking oil within 10 minutes by the electric induction cooker, need to be further justified. Note that similar tests [25,26,29-31] showed that the ignition of cooking oil by gas cookers took 75 to 180 minutes.

3. HAZARDOUS SCENARIOS

The fire scenario [32] in a residential unit depends on the amount of fuel, materials stored, storage arrangements and ventilation provisions. An earlier survey showed that the fire load in a small residential unit can be very high. Typical fire scenarios are proposed to be worked out by first understanding the combustibles content. Ignition possibilities, including frying food with electric induction cookers, will then be investigated.

Bench-scale experiments studying cooking oil fires should be reviewed [17,24-26,29-31].

The possibility of the onset of flashover in residential units can then be analyzed based on empirical expressions reported in the literature [33,34]. Fire behaviour of combustibles under post-flashover fires [35] in a small residential unit is suggested to be burnt by imposing a high thermal radiation heat flux on all combustibles. An open kitchen design would provide sufficient air for combustion, and possess no fire resisting walls to block heat and mass transfer. Air pumping action [36], in addition, would give higher air rate leading to sustained combustion of the ignited objects.

4. HAZARD ASSESSMENT

Hazard assessments based on the identified scenarios will be carried out with empirical formula derived from analytical study of the fire scenarios and fire models. Some cases will be backed up by full-scale burning tests to justify the model predictions. Literature [e.g. 33,34,37,38] on modelling heat release rates for kitchen arrangements will be taken as the starting point. The total heat release rate in a kitchen is first estimated using the principle of superposition [37,38] in combining the heat release rates curves of the furnishings and finishes deduced from a cone calorimeter. The results from full-scale burning tests will then be used to model overall heat release rates when those kitchen combustibles are burnt. A scenario based on common geometry of the open kitchen in Hong Kong should be considered. The electric induction cooker with cooking oil will be taken as the fire source. A fire will be started from the burning of cooking oil in a wok with reference to UL300A [26].

5. PERFORMANCE EVALUATION OF INSTALLED SYSTEMS

Performance of the permitted water mist and dry powder systems [16,17] in controlling flashover big fires must be evaluated. Experiment is suggested to be carried out in a room calorimeter with heat release rate measured [11,12]. A big fire scenario in a typical open kitchen arrangement without fire suppression system operating would be burnt first. Operation of the adopted water mist system [16], and the dry powder system [17] in this fire scenario are then tested. For each test, gas temperature distributions and heat fluxes at the floor levels are measured first. The key fire parameters of burning duration, peak heat release rates and maximum heat flux can then be deduced.

The effects of water sprays and dry powder on the burning objects can then be studied from the measured air temperatures, heat fluxes and heat release rates in a similar fashion to other reported work [11,12,38]. Reductions in peak heat release rates due to the suppression system, and maximum heat flux can be assessed. The extinguishing time, if any, will be measured. Fire spread from the open kitchen to the residential unit will be studied numerically.

6. CONCLUSION

All concerns raised above on open kitchen fires should be considered. More importantly, the effect of a fire resisting wall for enclosing the kitchen and the degree of protection provided by the current suppression system must be further justified with full-scale burning tests. Appropriate design guides and fire safety management procedures promoting adequate fire safety for open kitchens in small units of tall residential buildings can then be recommended. Note that there are on-going researches on kitchen fires all over the world [39].

ACKNOWLEDGEMENT

This work described in this paper was supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China for the project "Aspects of Open Kitchen Fires in Tall Buildings and Protection Alternatives" (PolyU 5136/11E) with account number B-Q27R.

REFERENCES

1. W.K. Chow, "Several points to note in performance-based design for fire safety provisions in Hong Kong", Plenary talk, The National Symposium on Fire Safety Science and Engineering, China Fire Protection Association, Beijing. China, 14-16 October (2010).
2. Centaline Property, http://hk.centanet.com/icms/template.aspx?series=1
3. W.K. Chow, "A preliminary discussion on engineering performance-based fire codes in the Hong Kong Special Administrative Region", International Journal on Engineering Performance-Based Fire Codes, Vol. 1, No. 1, pp. 1-10 (1999).
4. CIBSE, Guide E: Fire engineering, The Chartered Institution of Building Services Engineers, London, UK (2010).

5. PNAP 204 Practice note for authorized persons and registered structural engineers: Guide to fire engineering approach, first issued in March 1998. (Re-issued under new categorization in August 2009 as Practice note for authorized persons, registered structural engineers and registered geotechnical engineers), Buildings Department, Hong Kong Special Administrative Region, April (2009).

6. The Guardian III, Owner's manual for installation, operation and maintenance, Model G300-A Wet chemical extinguisher unit, G310A-A (2007). http://www.vulcanfiresystems.com/getdoc/359c1d07-5caf-4636-8a72-52096402cb72/G3-manual.aspx

7. The Guardian, Owner's manual for installation, operation and maintenance. Model 1384-A Wet chemical extinguisher unit. NO 71758-S. (2000). http://www.vulcanfiresystems.com/getdoc/1719fefe-5979-4b17-a9da-b2ef63021706/Guardian-I-Manual.aspx

8. W.K. Chow, "Building fire safety in the Far East", Architectural Science Review, Vol. 48, No. 4, pp. 285-294 (2005).

9. Draft Code of Practice for Fire Safety discussed in the 13th Steering Committee Meeting held on 6 May 2011, Clause C13.4 for the requirements on open kitchen design. Fire Safety Committee and Advisory Committee for the Fire Safety (Buildings) Ordinance and the Fire Safety (Commercial Premises) Ordinance, Buildings Department, Government of the Hong Kong Special Administrative Region.

10. W.K. Chow, "Assessing construction elements with lower fire resistance rating under big fires", Journal of Applied Fire Science, Vol. 14, No. 4, pp. 339-346 (2005-2006).

11. W.W. Jones, R.D. Peacock, G.P. Forney and P.A. Reneke CFAST – Consolidated Model of Fire Growth and Smoke Transport (version 6) - Technical reference guide, NISTSP 1026, National Institute of Standards and Technology, US Department of Commerce, May (2008).

12. K.B. McGrattan, S. Hostikka, J.E. Floyd, H.R. Baum and R.G. Rehm, Fire Dynamics Simulator (version 5): Technical reference guide, NIST special publication 1018-5, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland, USA, October (2007).

13. Arup research brochure, Ove Arup Hong Kong, December (2010).

14. W.K. Chow, Carmen C.S. Fong and Kenny S.M. Kong, "Fire load survey for offices in a university", International Journal for Housing Science and Its Applications, Vol. 30, No. 3, pp. 159-172 (2006).

15. C.L. Chow and W.K. Chow, "Fire safety aspects of refuge floors in supertall buildings with computational fluid dynamics", Journal of Civil Engineering and Management, Vol. 15, No. 3, pp. 225-236 (2009).

16. Code of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment, Fire Services Department, Hong Kong Special Administrative Region, July (2005).

17. A.K.K. Wong, Experimental study of induction cooker for fire hazard, MSc dissertation, The Hong Kong Polytechnic University, Hong Kong (2009).

18. W.K. Chow, "Points of concern in performance-based design for fire safety provisions in Hong Kong", Talk at Nanjing University of Technology, Nanjing, Jiangsu, China, 13 April (2011).

19. R.M. Kelso and C. Rousseau, "Kitchen ventilation", ASHRAE Journal, Vol. 37, No. 9, September (1995).

20. Che-Ming Chiang, Chi-Ming Lai, Po-Cheng Chou and Yen-Yi Li, "The influence of an architectural design alternative (transoms) on indoor air environment in conventional kitchens in Taiwan", Building and Environment, Vol., 35, No. 7, pp. 579-585 (2000).

21. Q.Y. Xie, H.Y. Yuan and H.L. Guo, "Experimental analysis on false alarms of fire detectors by cooking fumes", Journal of Fire Sciences, Vol. 22, No. 4, pp. 325-337 (2004).

22. Risto Kosonen, Hannu Koskela and Pekka Saarinen, "Thermal plumes of kitchen appliances: Cooking mode", Energy and Buildings, Vol. 38, No. 10, pp. 1141-1148 (2006).

23. J.A.T. Halls, "Ultra low resolution thermal imaging for kitchen hazard detection: A technology feasibility study", 4th International Conference on Smart Homes and Health Telematics, 26-28 June 2006, Belfast, Ireland, Smart Homes and Beyond, Assistive Technology Research Series, 19, pp. 231-238 (2006).

24. D. Madrzykowski, G.P. Forney and W.D. Walton, "Simulation of the dynamics of a fire in a two-story duplex – Iowa, December 22, 1999", NISTIR 6854, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD, USA, January (2002).

25. D. Madrzykowski, A. Hamins and S. Mehta, Residential kitchen fire suppression research needs: Workshop proceedings, NIST Special Publication 1066, US Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD, February (2007).

26. UL300A Outline of investigation for extinguishing system units for residential range top cooking surfaces - Issue 3, Underwriters Laboratories Inc., Northbrook, Illinois, USA (2006).

27. W.K. Chow, "Zone model simulations of fires in Chinese restaurants in Hong Kong", Journal of Fire Sciences, Vol. 13, No. 3, pp. 235-253 (1995).

28. W.K. Chow, "Use of the ARGOS fire risk analysis model for studying Chinese restaurant fires", Fire and Materials, Vol. 19, No. 4, pp. 171-178 (1995).

29. H.H. Wu, W.K. Chow, G.W. Zou, H. Dong and Y. Gao, "Performance evaluation of fire services installation in kitchens of big hotels", BUEE2006, 8th International Symposium on Building and Urban Environmental Engineering, held at Tokyo Institute of Technology, Tokyo, Japan, 10-13 July 2006, p. 226-231 (2006).

30. H.H. Wu, "A critical study on the fire safety for big hotels in Hong Kong", PhD thesis, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong (2006).

31. W.K. Chow and H.H. Wu, "Measured heat release rate in Chinese kitchen 'wok' fires", Poster paper at 10th International IAFSS Symposium, University of Maryland, College Park, Maryland, USA, 19-24 June (2011).

32. G.V. Hadjisophocleous and E. Zalok, "Development of design fires for performance-based fire safety designs", Invited Lecture, Fire Safety Science - Proceedings of the Ninth International Symposium, 21-26 September 2008, Karlsruhe, Germany (2008).

33. W.K. Chow, "Review on heat release rate for fires in small retail shops", Journal of Applied Fire Science, Vol. 10, No. 2, pp. 157-178 (2001).

34. F.W. Mowrer and R.B. Williamson "Methods to characteristic heat release rate data", Fire Safety Journal, Vol. 16, No. 5, pp. 367-387 (1990).

35. W.K. Chow, "Necessity of testing combustibles under well-developed fires", Journal of Fire Sciences, Vol. 26, No. 4, pp. 311-329 (2008).

36. T.Z. Harmathy, Fire safety design and concrete (Concrete design and construction series), Longman Scientific & Technical, Essex, England (1993).

37. B. Sundström (editor), "Fire safety of upholstered furniture", Final report on the CBUF Research Programme, Interscience Communication Ltd, London, UK (1995).

38. W.K. Chow, "Combining heat release rates of combustibles", Journal of Applied Fire Science, Vol. 17, No. 3, pp. 251-260 (2007-2008).

39. K.H. Almand, Fire Protection Research Foundation, National Fire Protection Association, Quincy, MA, USA - Private communication, July (2011).