ESTIMATION OF HEAT RELEASE RATE FOR GASOLINE POOL FIRES

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ABSTRACT

The heat release rate of liquid pool fires in full-scale burning tests and field tests were commonly adjusted by using different square trays of size 0.5 m. The heat release rates of gasoline pool fires under different ventilation factors were measured by the oxygen consumption method. Experimental data on the heat release rate of those gasoline fires were used to deduce empirical correlations. Results will be reported in this paper.

Heat release rate per unit area of liquid gasoline was estimated to be 1670 kWm^{-2} in a room calorimeter. For tests with a square tray of 0.5 m by 0.5 m, the volume of gasoline was 58 litres for a burning duration of half an hour. The heat release rate was about 400 kW per tray.

1. INTRODUCTION

Heat release rates have to be adjusted in full-scale burning tests [1] for different objectives such as investigating the conditions to onset fire whirls [3,4]. Results on the heat release rate per tray are also useful on field tests [2] such as hot smoke tests. The heat release rate will be adjusted by varying the number of square trays.

Full-scale burning tests on gasoline pool fires of different sizes were carried out by the principal author [7] in collaboration with the Harbin Engineering University since 2002. The site was located at a remote town Lanxi in Harbin, Heilongjiang, China. The calorific value of gasoline tested was 43.7 $MJkg^{-1}$. The heat release rate of those pool fires were measured in a room calorimeter with different ventilation arrangements or in an open space under an exhaust hood as shown in Fig. 1.

Pool fires were set up with circular pans of diameters 0.2 m, 0.46 m, 0.5 m, 0.6 m, 0.81 m and 1.0 m and square pans of sizes 0.25 m and 0.35 m. Volumes of gasoline burnt varied from 0.1 litre to 23 litres.

Correlation expression will be deduced from those experimental data. Results are useful in adjusting the heat release rate in full-scale burning tests.

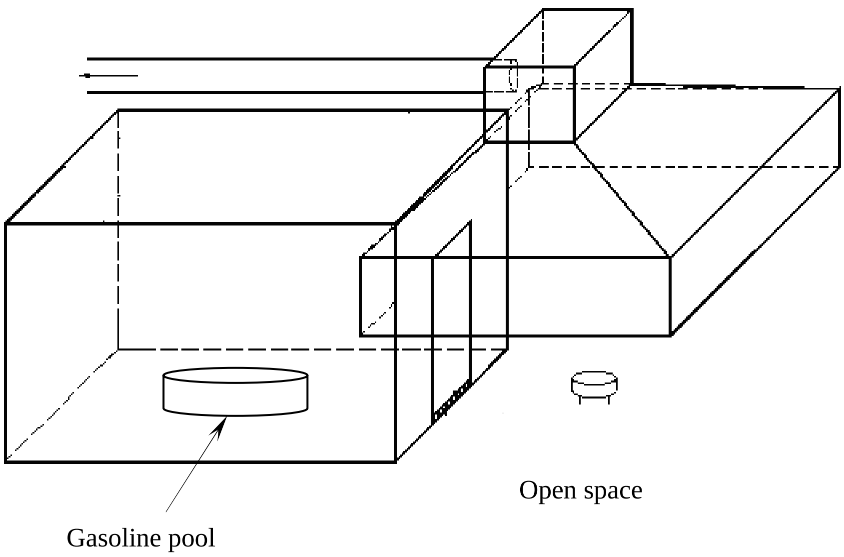

Fig. 1: The room calorimeter of gasoline fire tests

2. VENTILATION CONDITIONS

It is obvious that different ventilation arrangements would give different air intake rates, hence affecting the burning of liquid fuel.

An important parameter, the ventilation factor, V_f, is given by the area A_o and height H_o of opening as:

$$V_f = A_o\sqrt{H_o} \quad (1)$$

Full-scale tests on gasoline pool fires with different ventilation arrangements achieved by shielding part of the door as in Fig. 2 were carried out. Values of V_f varied from 0.3 $m^{5/2}$ to 2.2 $m^{5/2}$. Different heat release rates would be achieved.

Under such ventilation conditions, heat release rate curves were measured. The volume of gasoline used per tray was deduced to be 58 litres from a typical curve as in Fig. 3.

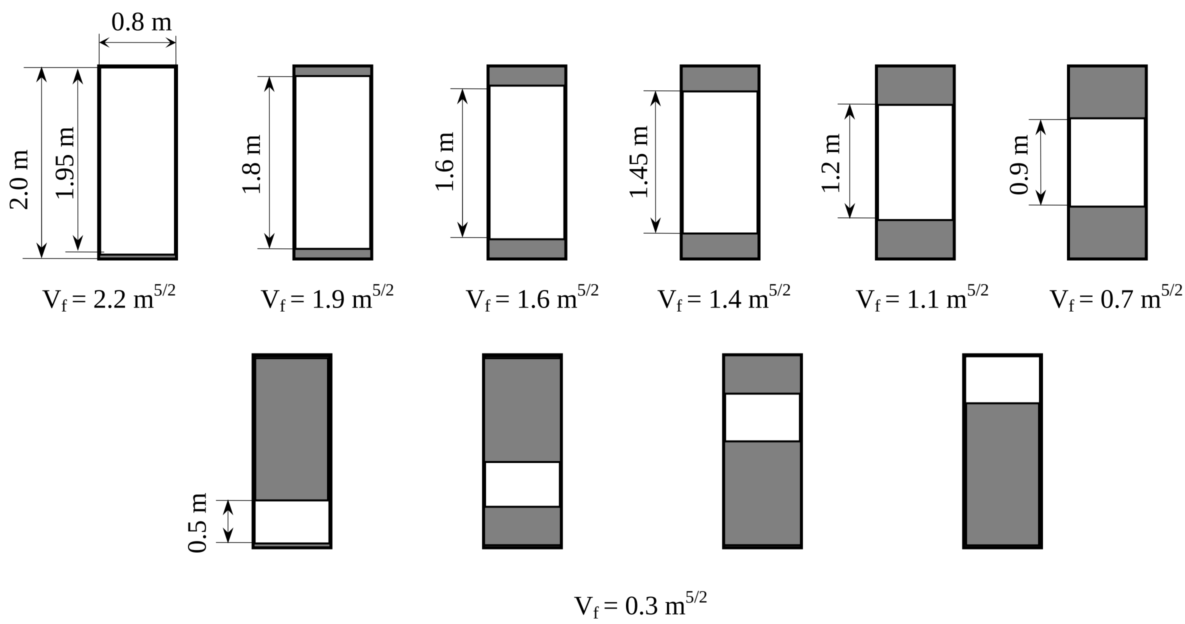

Fig. 2: Different ventilation factors

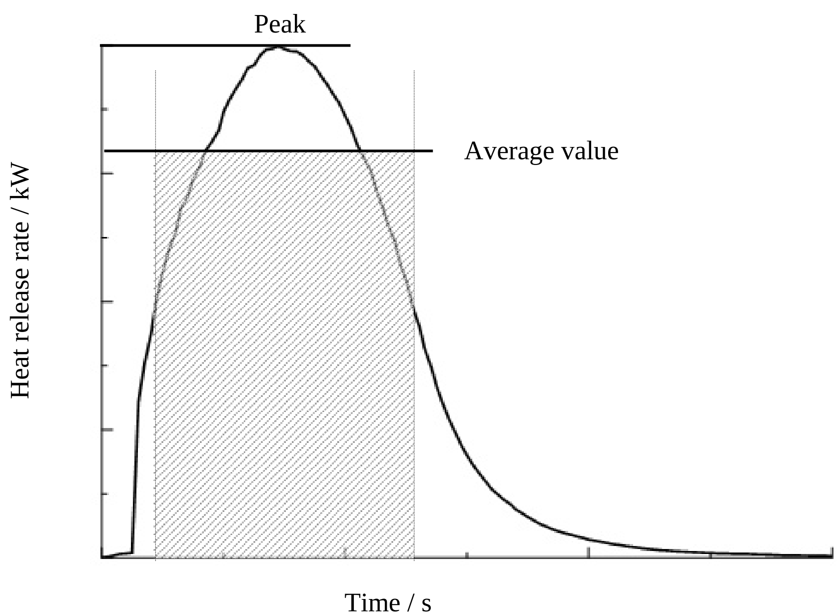

Fig. 3: Typical example on gasoline fire

3. FITTED HEAT RELEASE RATES

Heat release rates were measured by the oxygen consumption method. The pool fires were observed to burn steadily with a typical example shown in Fig. 3. From such curves, the average heat release rate during the burning period was estimated. A summary on the data is shown in Table 1.

A correlation between the average heat release rate (over the burning period as in Fig. 3) per unit area Q_A (kWm^{-2}) with pool area A (in m^2) was fitted by all those data [5-7] as shown in Fig. 4:

$$Q_A = 2818(1 - e^{-0.81A}) \quad (2)$$

Results can be divided into five groups of better fitted heat release rates for different ventilation factors:

- For $V_f = 2.2\ m^{5/2}$:

  $$Q_A = 1670\ kWm^{-2} \quad (3)$$

  The correlation coefficient r^2 was 0.4 and results are shown in Fig. 5.

- For V_f from 1.5 to 2 $m^{5/2}$:

  $$Q_A = 2466\ kWm^{-2} \quad (4)$$

  Results are shown in Fig. 6.

- For V_f from 1 to 1.5 $m^{5/2}$:

  $$Q_A = 1450\ kWm^{-2} \quad (5)$$

  The correlation coefficient r^2 was 0.8 and results are shown in Fig. 7.

- For V_f less than 1 $m^{5/2}$:

  $$Q_A = 508\ kWm^{-2} \quad (6)$$

  Results are shown in Fig. 8.

- For open space,

  $$Q_A = 678\ kWm^{-2} \quad (7)$$

  The correlation coefficient r^2 was 0.5 and results are shown in Fig. 9.

Table 1: Heat release rate per unit area of gasoline under different ventilation conditions

Ventilation factor / $m^{5/2}$ — Pool area / m^2	Heat release rate per unit area / kWm^{-2}							
	2.2	1.9	1.6	1.4	1.1	0.7	0.3	Open space
0.03								469,613,684, 694,901
0.06	590							345, 484
0.12	802,921							
0.17	1583				857 977 1384			
0.20	1386,1259,1372 1556,1401,1265 1137,1216,1124 1479,1399,1497 2047,2230,2230 2230							1227
0.28	1627,481							
0.52	1623,2443,1527							
0.79	2818,2690,2602 1076,2602,2185 2051,1932,2395	2614 2603	2254 2394	2072 1979	1445 1434	1055	639,491 448,555 377,525 440,443 299,312	

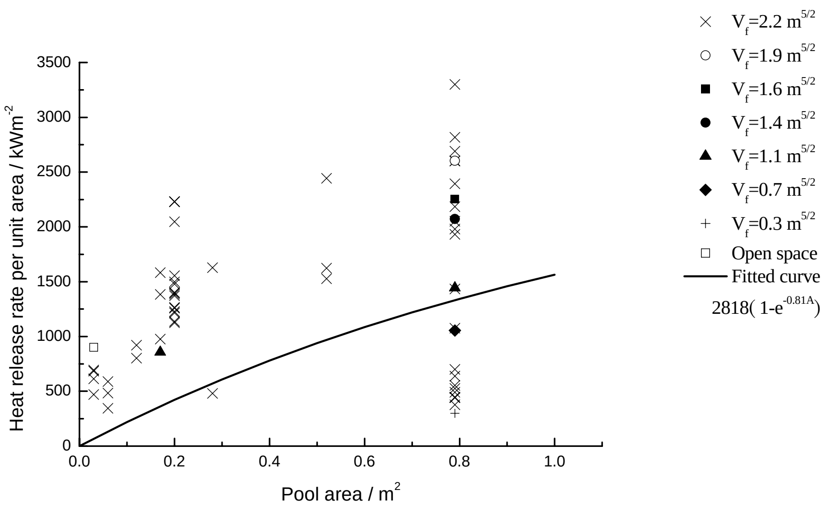

Fig. 4: Average heat release rate per unit area against pool area of gasoline fuel

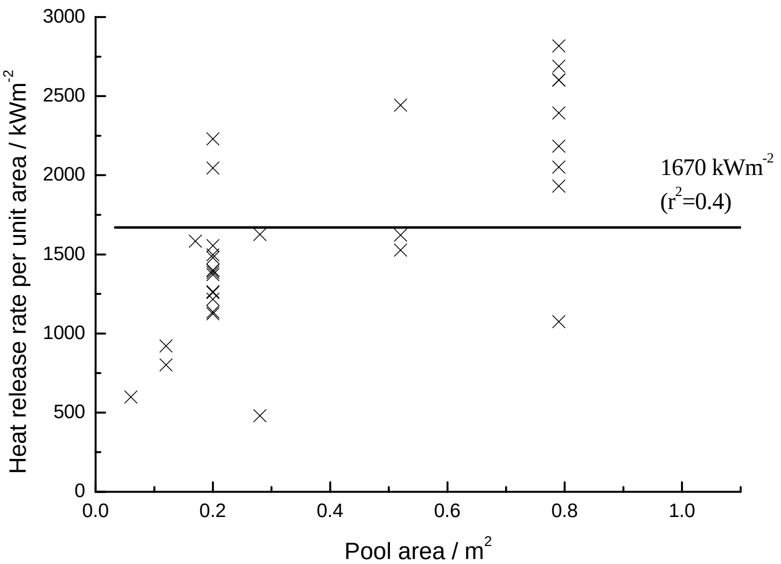

Fig. 5: Heat release rate for ventilation factor of 2.2 m$^{5/2}$

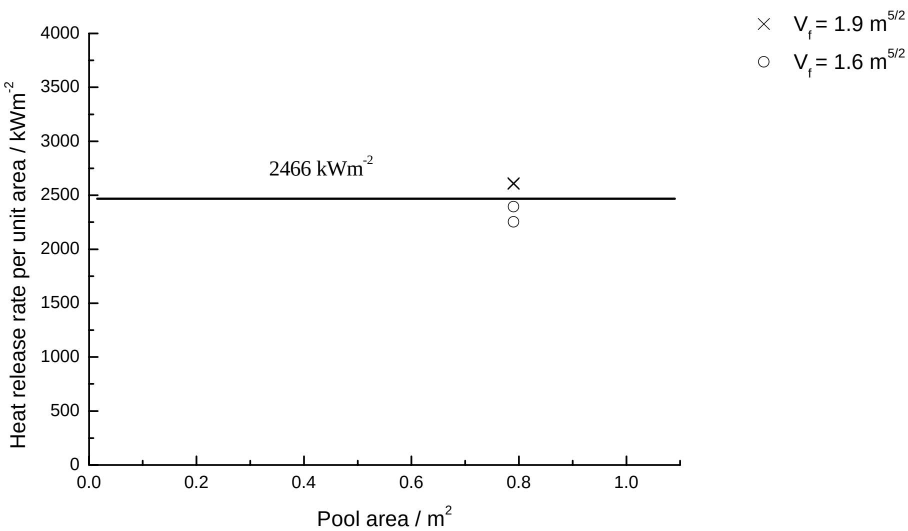

Fig. 6: Heat release rate for ventilation factors from 1.5 to 2 m$^{5/2}$

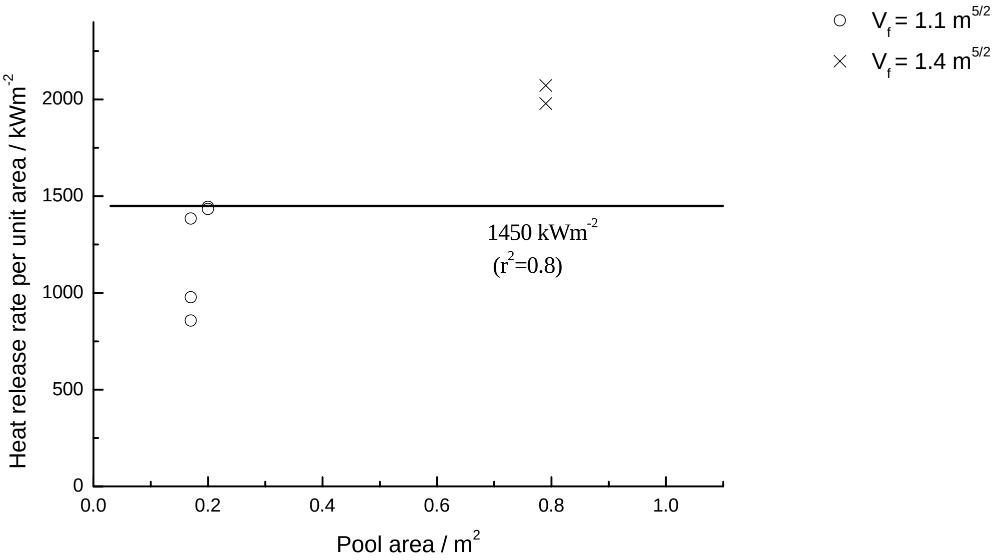

Fig. 7: Heat release rate for ventilation factors from 1 to 1.5 $m^{5/2}$

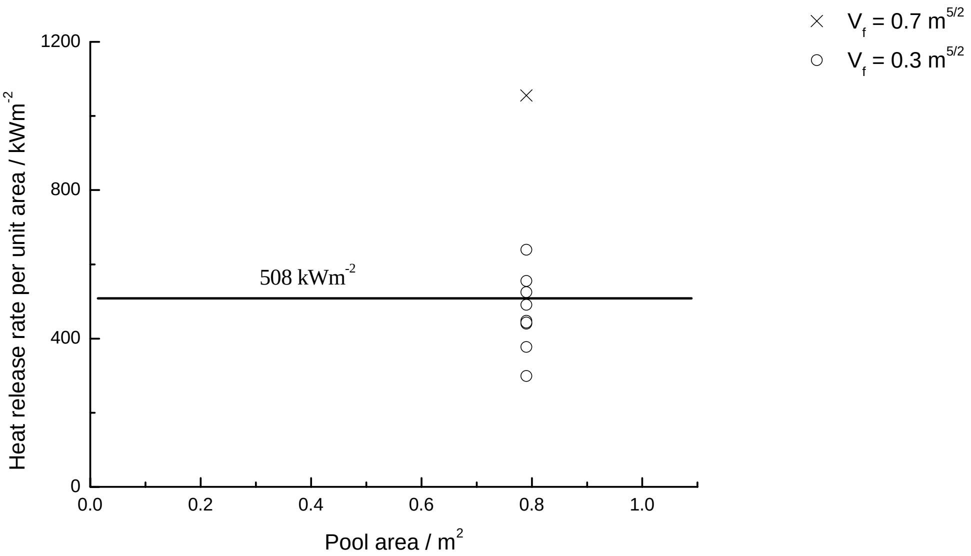

Fig. 8: Heat release rate for ventilation factors less than 1 $m^{5/2}$

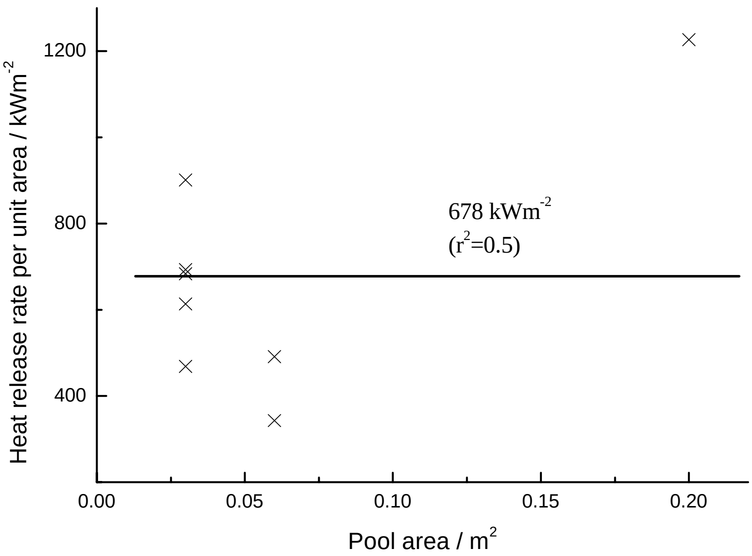

Fig. 9: Heat release rate for open space fire

4. DISCUSSIONS

Full-scale burning tests are proposed to judge the total heat release rate by changing the number of square trays. If the ventilation factor of a room is close to 2.2 $m^{5/2}$, the average heat release rate per unit area is 1670 kWm^{-2}. The average heat release rate per 0.5 m square tray will be 418 kW, rounding off to about 400 kW. This value is proposed for fine tuning in actual tests with similar ventilation factors, such as the room calorimeter tests with bigger fires on assessing fire resistance construction [8].

5. CONCLUSIONS

Based on experimental data from full-scale burning tests, the heat release rate per square tray of 0.5 m was estimated to be 400 kW in a room calorimeter. The amount used was 58 litres deduced from transient curves such as Fig. 3 to give a burning period of 30 minutes. Such results are useful for adjusting heat release rate in full-scale burning tests [1] on studying onsetting of fire whirls [3,4] and atrium hot smoke tests.

ACKNOWLEDGEMENT

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REFERENCES

1. ISO 9705: 1993(E), Fire tests – Full-scale room test for surface products, International Standards Organization, Geneva, Switzerland (1993).
2. W.K. Chow, “Atrium smoke exhaust and technical issues on hot smoke tests”, ASME 2005 Summer Heat Transfer Conference, 17-22 July, 2005, Westin St. Francis, San Francisco, CA, USA, Paper HT2005-72412, 4 pages (2005).
3. H. Satoh, S. Osami, K. Kurioka and T. Wataru, “Plume behavior in confined tall and narrow space- as one of sub-model of plume for an atrium fire”, Fire Safety Science – Proceedings of the Fourth International Symposium, Ottawa, Ontario, Canada, pp. 551-562 (1994).
4. D.H. Evans, “Fire protection aspects of the luxor hotel and casino: A performance-based approach”, Proceedings of the Second Performance-Based Design and Fire Safety Design Methods Conference, 3-9 May 1998, Maui, Hawii, USA, by Society of Fire Protection Engineers, May (1998).
5. W.K. Chow, Y. Gao, H. Dong, G. Zou and L. Meng, “Full-scale burning tests on heat release rate of gasoline fire with water mist”, Journal of Applied Fire Science, Vol. 11, No. 1, pp. 21-40 (2003).
6. W.K. Chow, Y. Gao, H. Dong, G. Zou, Z. Luo and L. Meng, “Experimental studies on minimum heat release rates for flashover with oxygen consumption calorimetry”, Architectural Science Review, Vol. 46, No. 3, pp. 291-296 (2003).
7. W.K. Chow, “Necessary of carrying out full-scale burning tests to measure the heat release rates of combustibles”, International Journal on Engineering Performance-Based Fire Codes, Vol. 6, No. 3, pp. 88-93 (2004).
8. W.K. Chow and J. Zhu, “Full-scale burning tests on fire resistance Construction”, Unpublished report, The Hong Kong Polytechnic University, May (2007).