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:

$$V_f = A_o \sqrt{H_o}$$  \hspace{1cm} (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 $0.3 \ m^{3/2}$ to $2.2 \ m^{3/2}$. 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 $Q_A$ (kW/m$^2$) with pool area $A$ (in m$^2$) was fitted by all those data [5-7] as shown in Fig. 4:

$$Q_A = 2818(1-e^{-0.814A})$$  \hspace{2cm} (2)

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

- For $V_f = 2.2$ m$^{5/2}$:
  $$Q_A = 1670 \text{ kW/m}^2$$  \hspace{2cm} (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$^{5/2}$:
  $$Q_A = 2466 \text{ kW/m}^2$$  \hspace{2cm} (4)
  Results are shown in Fig. 6.

- For $V_f$ from 1 to 1.5 m$^{5/2}$:
  $$Q_A = 1450 \text{ kW/m}^2$$  \hspace{2cm} (5)
  The correlation coefficient $r^2$ was 0.8 and results are shown in Fig. 7.

- For $V_f$ less than 1 m$^{5/2}$:
  $$Q_A = 508 \text{ kW/m}^2$$  \hspace{2cm} (6)
  Results are shown in Fig. 8.

- For open space,
  $$Q_A = 678 \text{ kW/m}^2$$  \hspace{2cm} (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

<table>
<thead>
<tr>
<th>Ventilation factor / m$^{5/2}$</th>
<th>Heat release rate per unit area / kW/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool area / m$^2$</td>
<td>2.2</td>
</tr>
<tr>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>0.06</td>
<td></td>
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<tr>
<td>0.12</td>
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<td>0.17</td>
<td>1583</td>
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<tr>
<td>0.20</td>
<td>1386,1259,1372</td>
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<tr>
<td>0.28</td>
<td>1627,481</td>
</tr>
<tr>
<td>0.52</td>
<td>1623,2443,1527</td>
</tr>
<tr>
<td>0.79</td>
<td>2818,2690,2602</td>
</tr>
</tbody>
</table>
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 $2.2 \, \text{m}^{5/2}$, the average heat release rate per unit area is $1670 \, \text{kW/m}^2$. The average heat release rate per 0.5 m square tray will be $418 \, \text{kW}$, rounding off to about $400 \, \text{kW}$. 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 $400 \, \text{kW}$ 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.

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**REFERENCES**