AN EXPERIMENTAL STUDY ON THE COMBUSTION BEHAVIOR IN COMPARTMENT FIRE WHEN THE FUEL GAS ARE EXCESSIVE

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ABSTRACT

When a building is on fire, a large quantity of fuel gas can be produced. If the air supply is insufficient, these excessive fuel gas will be accumulated in the room. Once they are mixed with fresh air, a strong combustion can take place. The characteristics in such fire were studied in a single reduced scale room. It is found that this kind of combustion can appear periodically. The appearing conditions are discussed too.

KEY WORDS: Building Fire; Compartment Fire; Combustion; Excessive Fuel Gas; Periodical Detonation.

INTRODUCTION

Building fire happens very commonly. Every year, it can cause thousands of people died and injured, and billions dollars of property loss. Actually the total costs of building fire is hard to estimate. In order to avoid and reduce fire loss, it is important to understand the processes occuring in a building fire.

There are always many different sorts of combustible materials in buildings, such as furniture, cloth, ornament and so on. Sometimes there are also combustible liquids in it. When a fire takes place in the building, a large amount of fuel gas can be produced because of the decomposition of solid or the evaporation of liquid. If the doors and windows are closed , air supply is insufficient. The fuel gas can not be burned completely. These excessive fuel gas will rise up to the ceiling with other combustion productions because of buoyancy. Once they are mixed with fresh air which enters during the fire, they can be burned again. Some one called this type of combustion 'flameover', 'flashback' or 'detonation'. In this paper, we use the word 'flmaeover'. The temperature in the fire room is much higher than usual when flameover happens. It has serious effects to the fire spread in the building.

Flameover in fire has been noticed by several researchers. After studied the additional vents formed in the fire, Bullen pointed out this can allow the fire to increase in its intensity. Under certain conditions, the room can erupt into flame. Quintiere and his co-workers have studied the smoke movement along a corridor, they found fuel-rich smoke can burn vigoriously when they mixed with fresh air, and perhaps at a point remote from the room of origin. Zokoski etc. found the heat release rate can change significiently when they study the species produced in fire burning in the vitiated

environment. The author also found the flame can even spread out the ventilating open when flameover took place.

In this paper, the emphasis is put on the combustion phenomena when the fuel gas is excessive. The experiment were made in a single reduced-scale room model. It is found that the excessive fuel gas can change the temperature profile in the room, and flameover can appear periodically. The appearing condition of this kind of combustion is also discussed.

EXPERIMENTAL ARRANGEMENT AND PROCEDURE

Figure 1 illustrated the experimental arrangement. The size of the combustion box is 0.60m* 0.60m* 0.60m. Its wall is made of kao wollon plate which thickness is 35mm. There is a ventilating open on one side wall to simulate a door, its widthis 0.18m, while its height is adjustable. In this experiment, it is about 0.15m to 0.20m. A burner is set in the center of the floor, the height of burner outlet is 0.15m. Methane is used as fuel. Eight pairs of thermocouples are set vertically beside the fire plume to measure the temperature. For the special phenomena, some photographs were taken. The combustion situation are discussed mainly according to the temperature-time curves which were got in the experiment.

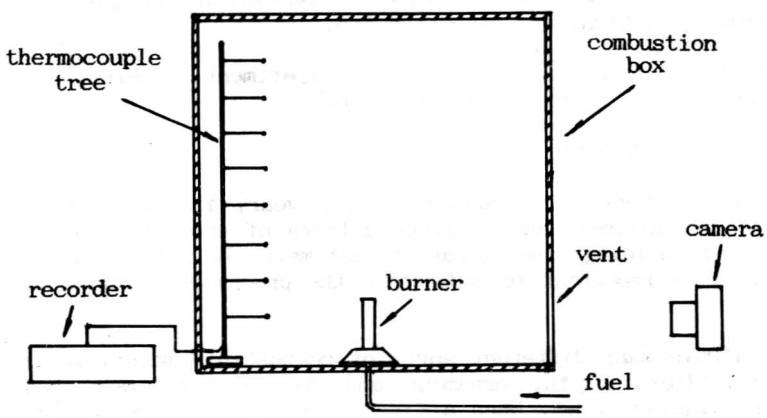

Fig.1 The experimental arrangement

RESULTS AND DISCUSSIONS

1. Growth of the hot gas layer

In analysing compartment fires, Kawagoe suggested the two layers model. It is assumed that the volume of the room is divided into two layers, the upper hot gas layer, and the lower cool air layer. Every property is uniform in each layer. This model is used widely. But many people also pointed out that its application is limited. It is not suitable in some stage of the fire developing process. When the fuel gas are excessiv,some special situation can happen. these will be discussed according to figure 2.

When a room is on fire,the smoke plume rises up and imping on the ceiling with

a certain velocity, then some smoke gas are bounced from ceiling and flow down, but because of buoyancy, It will float again after a while. It is called anti-buoyancy jet. In the same time, most of the smoke gas will spread horizontally. When they touch the side wall, they will flow down too. With the same reason it will flow upward in a moment. These flowing condition make the lower surface of smoke very irregular. In other words, there is not a clear interface between the hot smoke and the cool air layer. It is hard to devided the room into two layers at the starting stage of the room fire.

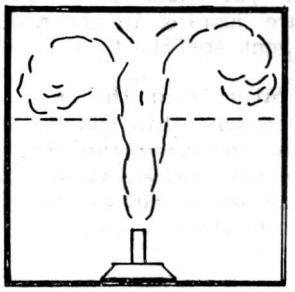

Fig. 2 The developing process of hot gas layer

As the burning continues, a certain quantity of hot gas will be collected in the upper part of the room. When the thickness of the hot gas layer is thicker than that of the anti-buoyancy jet, the interface between the two layers becomes clear and clear, except at the fringe of the flame plume. When the thickness of hot gas layer is nearly twice of the height of anti-buoyancy jet, two layers assumption is quit well.

If the flow rate of fuel gas is too large, flameover will happen in the adjacent area of the interface. It can cause that area very chaotic, and no interface can be distinguished. So two layers model is not a good approach for this stage too.

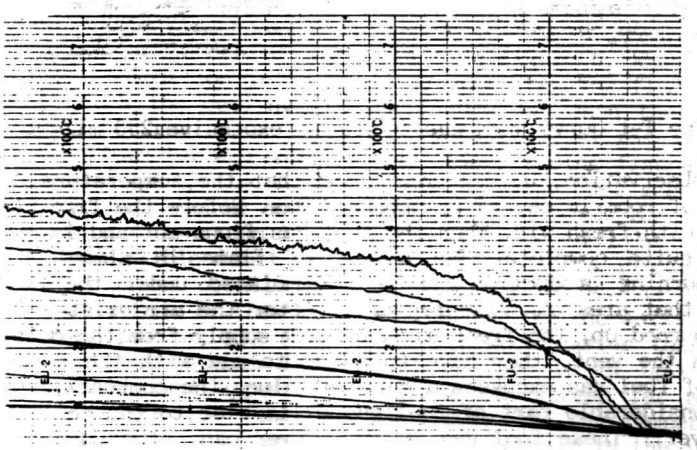

Fig.3 the T-t curves when gas flow rate is lower

2. INFLUENCE OF THE FLOW RATE OF FUEL GAS

As the fire last, air supply become the control condition of the combustion. All the fresh air will come from the outside and can only enter through the vent. The vent area used here is big enough, if the flow rate of fuel gas is not too large, a strong diffusion flame can be formed at the outlet of the burner and the combustion is quite complete. The temperature profile in the room is shown in figure 3. It can be seen that the temperature increases rapidly at first, and then becomes smoother gradually. It is relative to the

heat losing condition. We can also see that the temperature difference between the upper part and lower part of the room is very large. There is a temperature jumping in the middle of the room. Its height is a little lower than the vent soffit, this is just the location of the interface.

The temperature near the ceiling will change while the flow rate of fuel gas is large enough, this can be seen in figure 4. At first the temperature near the ceiling increases rapidly, seeing No.1 and Nc.2 thermocouples. When it is up to a certain value, it will descend a little. After several minutes, it can rise slowly again. But at the lower part in the room, the temperature does not have such changes.

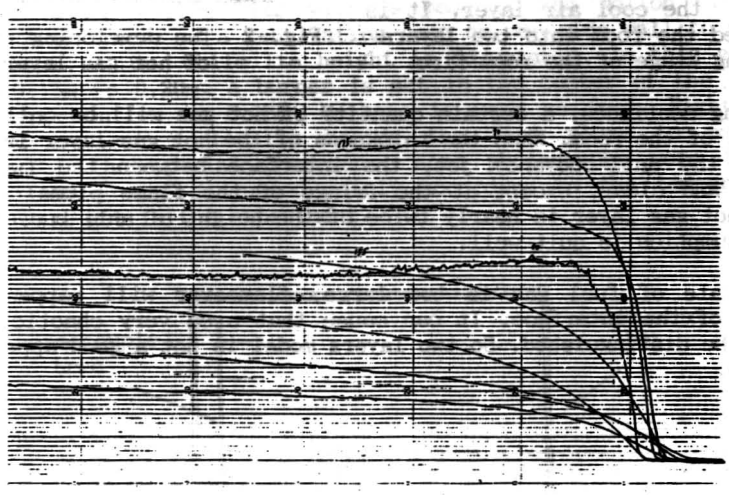

Fig.4 The T-t curve when gas flow rate excessive 250 ml/min

After lots of observation, we can understand that the temperature decrease at the upper part of room is caused by unburned gas. Before the fire starts, the room is filled with fresh air. When the fuel gas flows out and is ignited, the combustion is quite complete. The height of flame is almost touched the ceiling. The burning production can be accumulated under the ceiling. The temperature in that area can rise rapidly . After the air existed in the room originally is burned up, the fresh air can only supply from the outside. After passing through the vent, they have to go up to mix with the fuel gas. When the flow rate of fuel gas excesses a certain value, the combustion will not be completed. A considerable part of fuel gas will rise to the ceiling and form the hot gas layer. These fuel gas in this layer can notbe burned because of the lack of air. So the temperature there descends a little. While the temperature rise again is because of the total temperature in the room rising.

If the flow rate of fuel gas is increased continuously, the thickness of the hot layer including the excessive fuel gas is thicker. The area where the temperature decrease is larger. Moreover when the upper hot gas layer is thicker enough, the mixing of unburned fuel gas with the air coming from the lower part of the room becomes easier. Some premixed combustion can takes place, and the temperature will change a lot. This will be discussed below. When the up layer mixed with fresh air, some premixed combustible gas is

produced, flameover would appear in the room which will be discussed below.

3. FLAMEOVER IN THE FIRE ROOM

When the flow rate of fuel gas is larger than 450 ml/min, the temperature profile in the room begins to fluctuate. Along with the increasing of flow

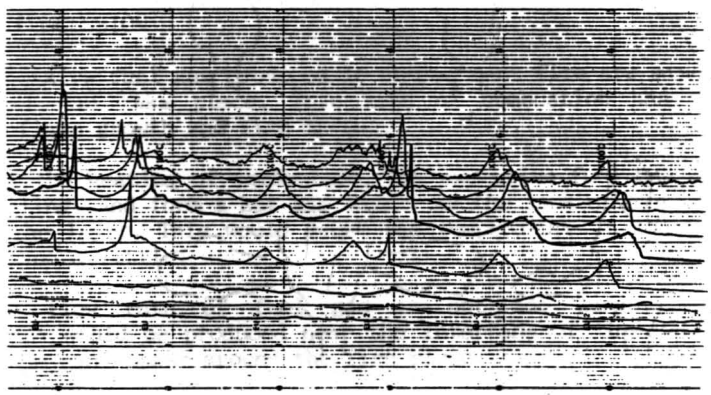

Fig.5 The T-t curve when the flameover takes place

rate, the fluctuation appears periodically, seeing Figure 5. This is caused bythe flameover in the fire room. Flameover is a kind of premixed combustion. The forming process of it can be explained with figure 6. When the flow rate is not too large, combustion in the room is complete. The flame is long, its top can almost touch the ceiling, seeing figure 6a. When the fuel gas flow rate increases, a hot gas layer including excessive fuel gas is formed under the ceiling. The flame becomes shorter and wider, seeing figure 6b. When the flow rate increases more, the thickness of hot rich fuel gas layer becomes thicker. Its lower part can be easily mixed with the fresh air coming from the vent. A pre-mixed gas zone can be formed. This zone will be ignited by the flame when the combustible limit is reached. At first, a ringlike flame will appear around the flame occationally, seeing figure 6c. As the flow rate increasing, the interface of the two layers descend to the soffit of the vent. The excessive fuel gas can mix with fresh air much easier than before. The amount of premixed gas is much larger either. Once it is ignited, a strong burning in the whole zone appears. The flame can spread far away from the burner even go out from the vent, seeing figure 6d. The temperature in the room will increase suddenly after the flameover, the air in the interface zone exhausted. The temperature in the room descends. But the excessive fuel gas can be accumulated in the room again. If the fuel gas supply does not stop, this kind of flameover will appear periodically.

When the flow rate of fuel gas is greater than 520 ml/min, the hot rich fuel gas layer increases too faster. It can even reach the outlet of the burner. A few minutes later, a very strong flameover happens. Then the whole flame is put out, seeing figure 6e. The temperature change when the flame died can be seen in figure 7. It can be thought that the extinguish of the flame is caused by the lack of fresh air even near the burner outlet.

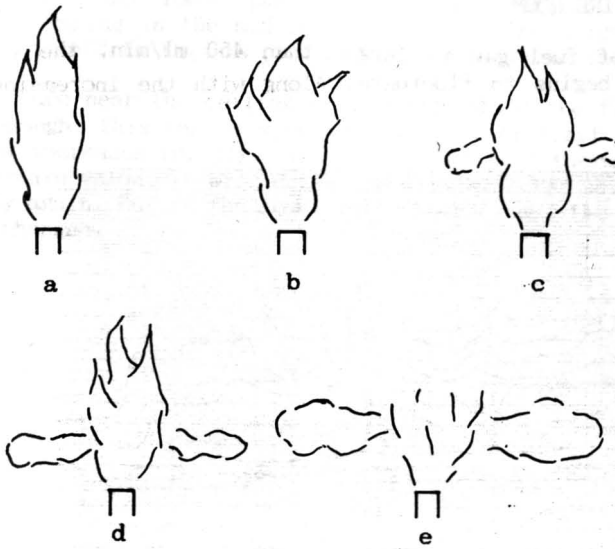

Fig.6 The forming process of flameover

When flameover happens, the temperature can reach to a very high value. In this small scale experiment, the peak temperature is nearly 1000k, it is reasonable to consider it will be much higher in the full scale fire. In such situation, almost every thing in the room can be ignited even it is hardly combustible.This can promote the flame growth in the fire room. If the wall materials in the room are demadged, the fire can even spread out off the room and cause more destruction.

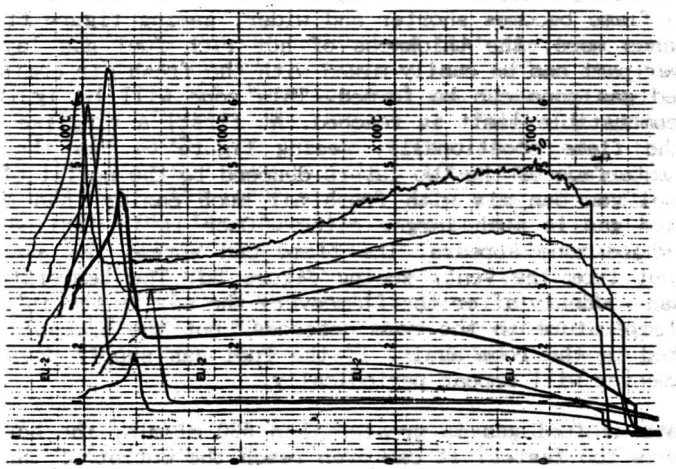

Fig.7 The T-t curve when the flame is put up

In order to prevent flameover in the compartment fire, reducing the production of fuel gas and air supply are important. For the first aspect, the

using and storage of combustible material should be controlled, non-burned or retarded material should be encouraged to use. But it is difficult to achieve recently because many things used in rooms are still made of combustible material. So reducing the fresh air supply in fire is a very practical method. If it is found that a large quantity of fuel gas formed in the fire room, it should be careful to let fresh air in .First thing first is to put down the fire source, and push the combustible gas to the no flame area, and then open the vent.

CONCLUSION

1. If the excessive fuel gas produced in compartment fire are mixed with fresh air, flameover can take place. This kind of combustion has significant influence to flame growth and fire spread.

2. Because of the heating of combustion, the excessive fuel gas are collected under the ceiling, and form a hot gas layer. As the lack of air, these gas can not burn in the layer. This would cause the temperature in the upper part of the room descend a little.

3. When the flow rate of fuel gas is not too large, some premixed combustible gas would be produced near the interface of the two layer. A ring like flame can appear around the fire plume.

4. If the flow rate of fuel gas exceeds a certain value, the thickness of hot layer will increases rapidly. The mixing of unburned fuel gas with fresh air becomes easier and stronger. And the periodical flameover would appear if the supply of fuel gas is not stopped.

5. When flameover takes place, flame can spread out for a long distance from the fire source. This is very dangerous. In order to stop this kind of combustion, it is important to control air flowing into the fire room.

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