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# An Analysis of Compartment Fire and Induced Smoke Movement in Adjacent Corridor

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## Abstract

The analysis of large fire incidents indicate that most of fire casualties occurred during fire evacuation pass out to death by the smoke rather than fire itself. The purpose of this study is to investigate the characteristics of smoke movement in office building, and to analyze the influence of fire-induced toxic gas on the building occupancy involved in the fire evacuation.
For this purpose, five compartment rooms and the adjacent corridor which is 20[m] long are built up. Fuels such as kerosene, polyurethane foam, unsaturated polyester and mixing of these fuels, are burned in the compartment room.
The characteristics of smoke movement, such as the velocity of heat flow and time-dependent densities of the products, produced by the compartment fire are measured and analysised.
In order to observe the pattern of smoke movement in detail, reduce-scale experiment (1:0.15) was tried. Also a transient numerical analysis of smoke movement was conducted by using commercial CFD software package.

## 1. Introduction

In recent years there has been considerable research activity in the area of smoke movement in multicompartment structures. Because of the analysis of large fire disasters indicates that most of fire casualties were not caused by the fire itself, but resulted from the inhalation of toxic gases contained in the fire-induced smoke during the fire evacuation process. Therefore, the rapid and successful evacuation is critical to ensure the life safety of occupants in fire emergency.

In this study, Speed of smoke front and concentration of combustion gas influencing occupants are tested by burning kerosene poolfire (pool fire + light polyurethane foam, and pool fire + Unsaturated PolyEthylene). Usually spread

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speed of smoke front, descending speed of smoke in corridor and movemet pattern of smoke are dependent on type / amount of combusion materials and structure of compartment construction. Moreover, Smoke flow influencing evacuee at 1.5~1.8m height from the bottom come back from corridor door to burn room in the reverse direction of evacuation route.

## 2. Experimental setup and procedure

### 2.1 Real-scaile experiment

Fig 1. shows the layout of basic construction of test building. The layout shows two burn rooms, three rooms and a corridor with an exit

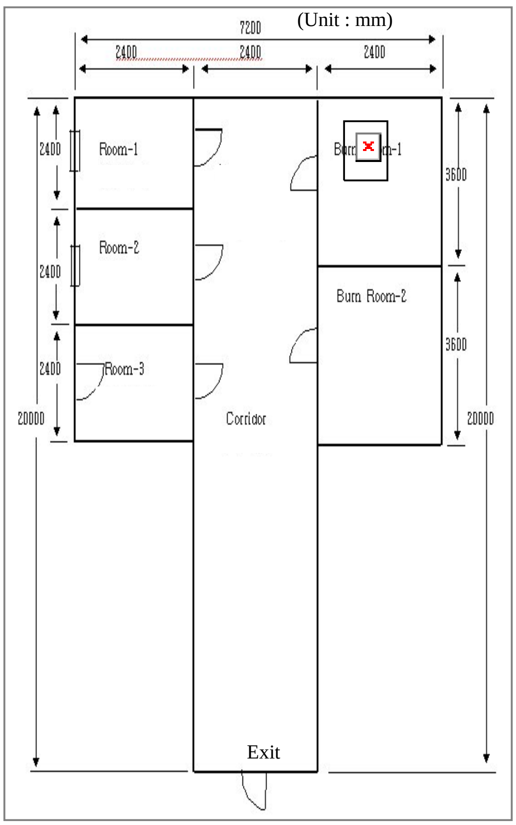



**Fig 1. Schematic diagram of experiment Building**

The fuel burning room built up by ISO Room size (2.4m x 3.6m x 2.4m) and also made of insulation blocks, and the adjacent corridor which is 20(m) long and vertically connected to the burn rooms and 3 rooms as shown in Fig 1.

The walls and ceiling have an inner iron plate of 3mm thickness. Fig. 2 is the picture of this facility, the door size of corridor is 0.8m x 2.0m and was opened during the experiement for suppliment of air to burn room

**Fig 2. Photograph of the test facility**

Fig 3. shows the layout of sensors in the corridor in order to monitor the pattern of the smoke movements.

There are totally 16 positions (2 rows with 8 columns) of the detecting points along the corridor. Five different kinds of detecting sensors (temperarue, CO, $CO_2$, $O_2$, and ionization smoke sensor detecting visibility range) are respectively installed at theses 16 positions to quantitatively measure these parameters of smoke movements.

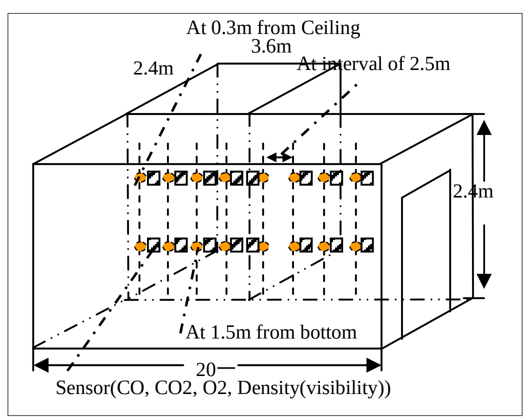



**Fig 3. schematic of the experimental test facility**

The basic fuels was kerosene and other various materials such as polyurethane foam and Unsaturated Poly Ethylene were mixed up with the basic fuel. The result in this paper is obtained through the 30cm dimeter poolfire with polyurethane foam. This kind of fuel mixture usually shows similar effect when interior upholster are burned in the compartment room.

### 2.2 Reduce-Scaling experiment

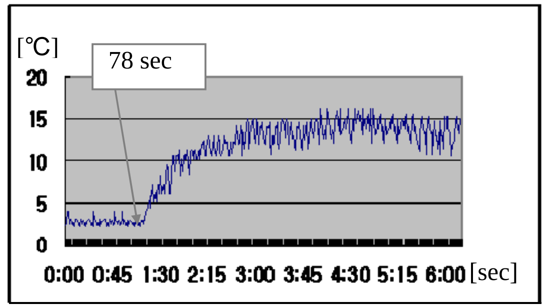
**Fig 4. Photograph of reduce-scale experiment**

Fig 4. shows the reduce-scale model ( 1:0.15 ) which was used to observe the smoke patterns in detail. The scaling experiment was installed with transparent grass at one side and 16 thermocouples inside.

## 3. Experimental results

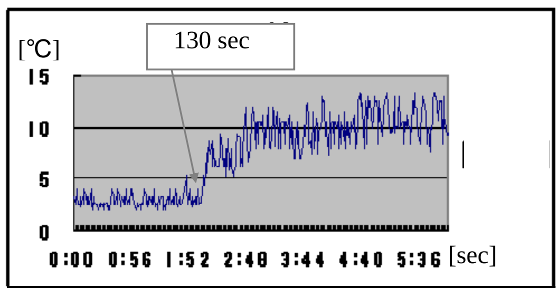
In real-scale experiment results, 16 measuring points consist of 2 horizontal array with 8 measuring points of same height. One array is near ceiling and the other is adjusted for the breath height of evacuee, 1.5m apart from bottom. To calculate the smoke front velocity, the difference of temperature rising time between a) and b) in Fig. 5 is used.

Fig 5. shows the temperature variations of smoke front from the sensor that is located 30cm away from ceiling. The two graphs in Fig 5. are typical examples of temperatue plots which make us know the passage of smoke. Similar plots are obseved from the CO concentration and visilbility plot. Smoke movement dectected at 1.5m array shows no time difference which means




that simultaneous descending of smoke layer.

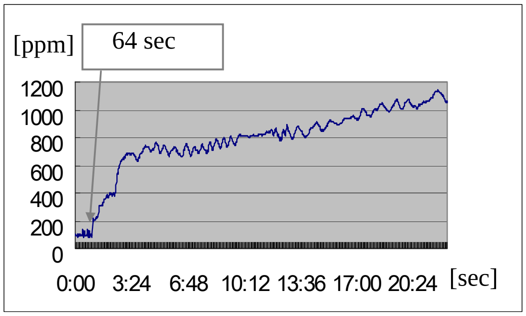
**a) Temp. at 4th sensor near ceiling**



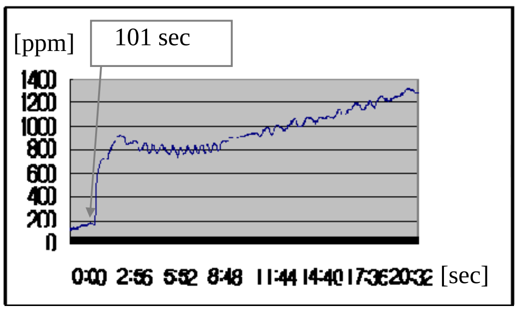

**b) Temp. At 8th sensor near ceiling**

**Fig 5. The temperature graph of ceiling in corridor**

As the show Fig. 5, The distance between 4th and 8th sensor is 10m. and rising time difference is 52sec. Therefore the horizontal velocity of smoke front is estimated as 0.19 m/sec (10m/52sec = 0.19m/sec).




**a) CO consentraiotn. at 4th sensor near ceiling**




b) **CO consentraiotn. at 8th sensor near ceiling**

**Fig 6. The CO concentration graph of ceiling in corridor**

As the show Fig. 6, The distance between 4th and 8th sensor is 10m. and rising time difference is 37sec. Therefore the horizontal velocity of smoke front is estimated as 0.27 m/sec (10m/37sec = 0.27m/sec).

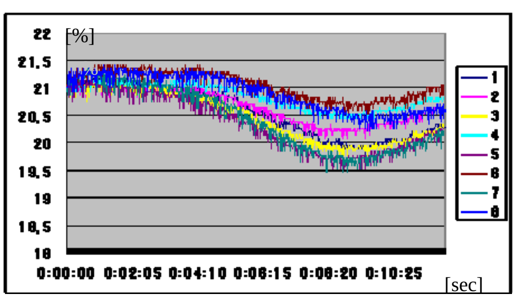



**Fig 7. The $O_2$ concentration graphs at 1.5m from bottom with closed door**

The concentration of $O_2$ shows no change with time (every 16 positions in corridor). But when the door of corridor closed, the fig. 7 shows change at 1.5m from bottom.

## 4. Analysis of experimental results

A transient numerical analysis of smoke movement was conducted by using CFD software package simultaneously. The results obtained from simulation and experiments are compared for clear understanding. There are some noticable charateristics. smoke propagation sequence the near the ceiling shows turbulant flow. The downward movement of smoke layer was detected synchronously only after smoke front reach the end of corridor.

The different smoke velocity shows a little variation due to ambient temperature and the air current in/out of corridor's door in spite of same fuel and amount.

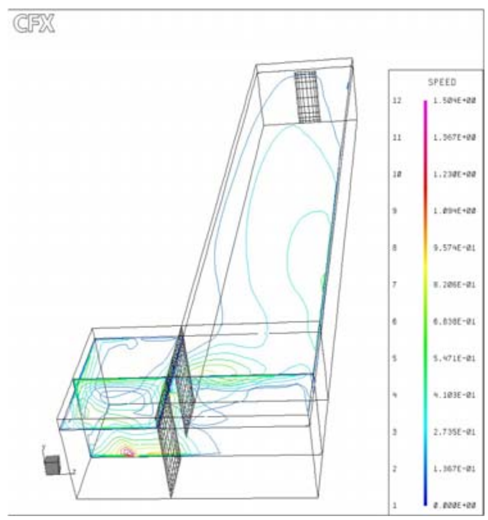
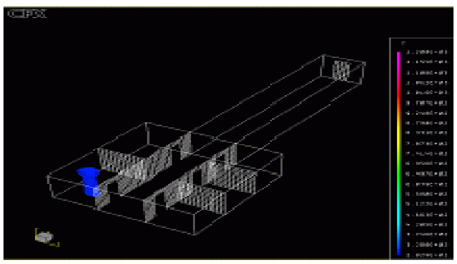


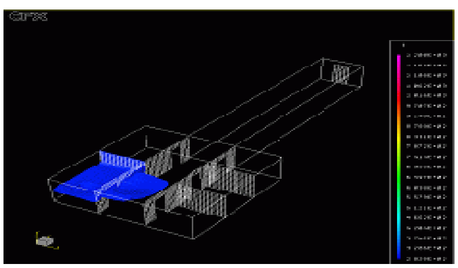

**Fig 8. Speed stream line**

The experiment and calculation data show the existence of turbulent range in corridor at 30cm from ceiling as in Fig. 8. The turbulant range is located near burn room door. Fig. 9 is the diagram of smoke movment. The sequce of detection is as follows .①,③,④,⑤,⑥,②,⑦,⑧. The route of this turbulant flow just looks like an elliptic circle. The wider becomes the corridor width, the longer becomes the diameter of the elliptic circle. We happened to observe this turbulant smoke behaviour at different width of corridor. In Fig. 11 in case of wider width of the corridor, the sequence of reponse of the temperatue sensor is as follows ①,④,⑤,⑥,⑦,②,③. This kind of pattern has close relationship with efficacy of smoke detctor.

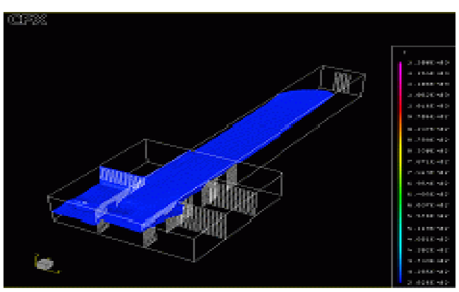
The experiment data and Fig 9 show a general smoke movement character that is first to reach the corridor end and then descends until a boundary lay between smoke and air.



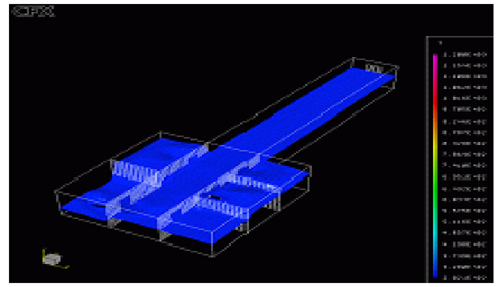
**a) After 3 sec**



**b) After 30 sec**



**c) After 70 sec**



**d) After 120 sec**

**Fig 9. Isothermol transient analysis at 5C**

The velocity of same smoke movement detected by different kind of sensor shows some discrepancy. Fig. 10 show the variation of velocities obtained by three different methods

| Measurement | Velocity |
|---|---|
| Tempature | 0.19 m/sec |
| CO concentration spread | 0.27 m/sec |
| FPETool corridor program | 0.25 m/sec |

**Fig 10. The various smoke front velocity**

## 5. Conclusions

1. The structure of facility which makes orthogonal contact of moving smoke and corridor axis cause a turbulant flow. The wider becomes the corridor width, the longer becomes the diameter of the turbulant circle under the same fire source. This kind of pattern shold be considered in case of design process of the detector layout.

2. The downward movement of smoke layer was detected synchronously only after smoke front reach the end of corridor.

3. The definition of smoke velocity can not be taken for granted by temperatue only in the view of evacuee. Other parameters

such as various gas concentration should be considered together, when we estimates the safe egress time by the criterion of descending smoke

## References


1. Drysdale, D.D., An Introduction to Fire Dynamics, Wiley, 1990.
2. Karlsson, B., Quintiere J.G, Enclosure Fire dynamics. CRC Press.
3. Baum, H.R, and Rehm. T. G., Calculation of Three Dimentional Buoyant Plumes in Enclosures, Combstion Science and Technology, Volume 40, 55-7, 1984
4. Jones, W.W., " Multi- compartment Model for the Spread of Fire, Smoke and Toxic Gases" Fire Safety Journal, Vol 9, 55-79. 1985
5. NFPA2-3, "Toxicity Gases of generator in fire", 1996
6. Harland, W. A. and Anderson, R. A., Causes of Deah in Fires Proceedongs Smoke and Toxic Gases from buring plasics, Vol. 15, London, 1982
7. Coundil on Tall Buildings and Urban Habitat Committee 8A, Fire Safety in Tall Buildings, p128, 1992

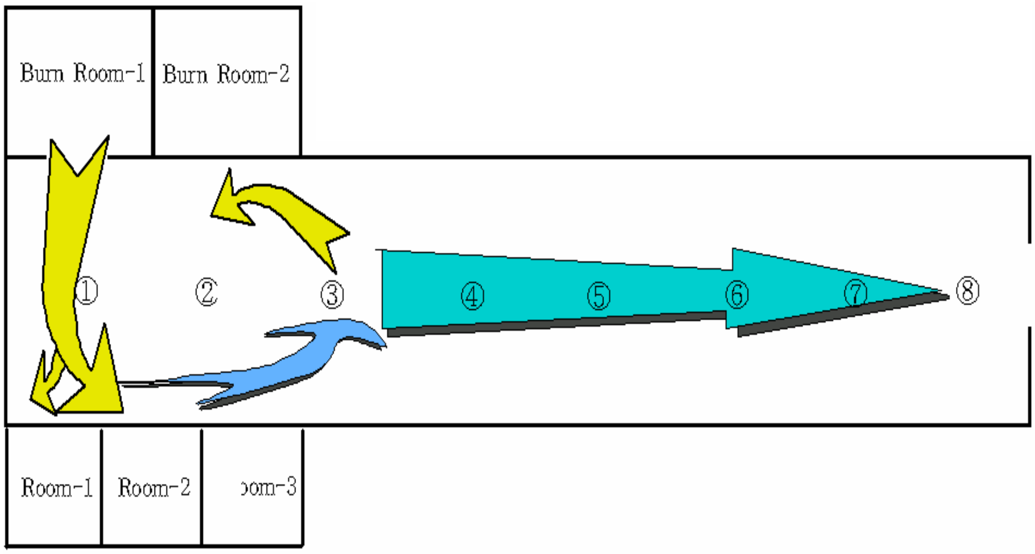



**Fig 11. Schematic of CO concentration spread sequence at 30cm parts from ceiling**

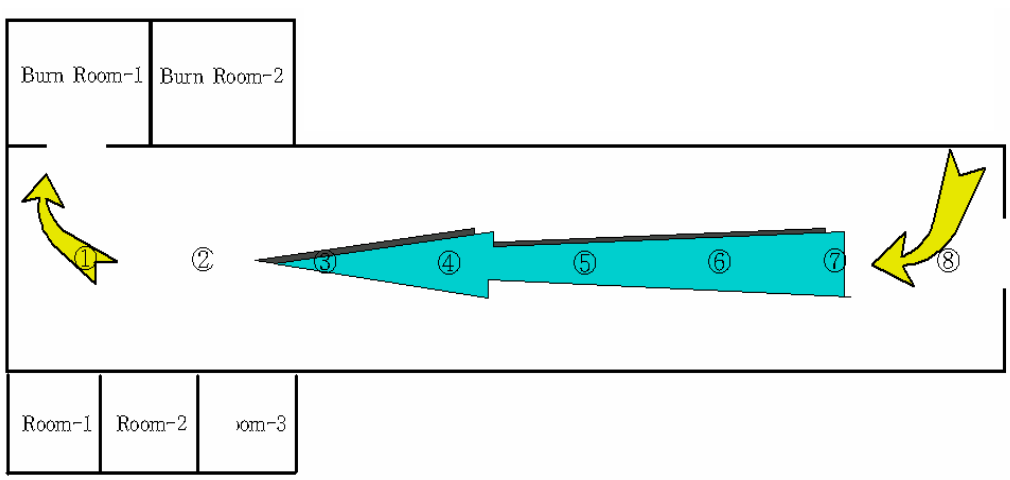



**Fig 12. Schematic of CO concentration spread sequence at 1.5m parts from bottom**