INFLUENCE OF AERIAL FIRE FIGHTING ON INTENSITY OF RADIATION FROM FIRE

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ABSTRACT

A large scale fire experiment was conducted through the collaboration between the Tokyo Fire Department and the National Research Institute of Fire and Disaster (NRIFD) for the purpose of studying the effectiveness of aerial fire fighting against urban fire. Ten model houses and ten collapsed model houses were arranged in an area of about 2,000 m^2. Water was dropped totally fourteen times by helicopters onto the model houses. In order to know influence of water drop, radiation was measured by four radiometers and four IR (Infrared) cameras, which were set around the burning area.

In this report, the influence of aerial fire fighting on fire was discussed in terms of irradiance and IR images. Data of irradiance, flame temperature and flame area showed that influence of each water drop continued only at most a minute.

INTRODUCTION

When a large earthquake happens in a major city, huge amount of fires may occur and expand. If the hydrant using water supply system is destroyed and fire fighting is restricted by an traffic obstacle, aerial fire fighting by helicopters may be considered as one of the measures to cope with this serious situation. It is important to study the effectiveness of aerial fire fighting. There are a lot of hurdles which must be overcome, for example protection of helicopter from fire and so-called downwash. Downwash is a down air flow which is produced by helicopter. The National Research Institute of Fire and Disaster (NRIFD) had done large aerial fire fighting experiments [1, 2], but we believed to do test more for clarifying there problems. Therefore a large scale fire experiment concerning aerial fire fighting was conducted in Hachiouji City in a suburb of Tokyo through the collaboration between Tokyo Fire Department and NRIFD. Water was dropped fourteen times by helicopters onto the model houses.

In this experiment, temperatures of the burning area and inside the burning houses were measured to study the influence of water drop. The influence of downwash by helicopter on the burning area was examined because there might be possibility that fire expand due to downwash by helicopter in aerial fire fighting. These results will be reported in another paper. The results and discussion of the radiation and the IR image was reported in this report.

EXPERIMENT

The burning area was about forty meters times fifty meters. All model houses and collapsed model houses were arranged in four lines, and in five rows. Each house was expressed as 1-1 to 5-4 in this paper. The arrangement of the houses and the collapsed houses is shown in figure 1. The houses in line 1 and line 3 were ignited using kerosene. The weight of combustibles was about 80 kg/m^2 in each house.

Radiation from fire was measured by four radiometers around the burning area. IR images of fire were taken by four IR cameras around the burning area. The arrangement of the radiometers and the IR camera is shown in Fig. 2. Because there was the bank in front of the radiometer on the north side, was set on a tripod of about 1.2 m height. The other radiometers were fixed using the stand of about 0.3 m height. The radiometers faced to the center of the burning area to obtain the maximum radiation. One of four IR cameras was used in the analysis of this paper. This IR camera was set away from the burning area in the direction of south-west. The influence of the burning houses on the circumference was examined by the radiometers and the IR camera. The outputs of the radiometers were recorded by every 10 seconds using a data acquisition system with a personal computer.

The temperature of flame was analyzed in terms of the IR images. IR camera had small time constant and narrow angle, though radiometers had large time constant and wide angle.

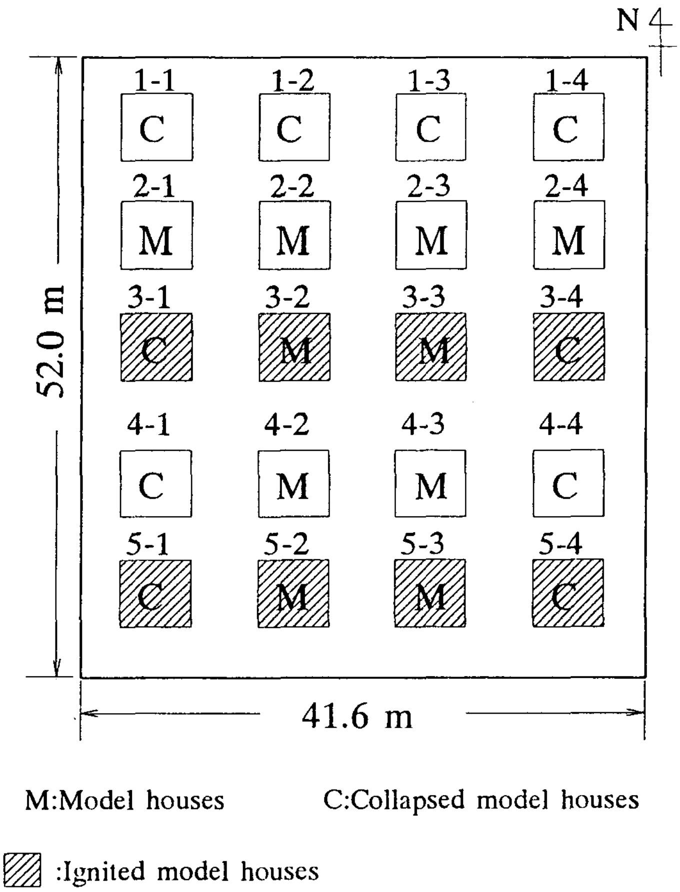


Fig.1 Positions of model houses and collapsed model houses.

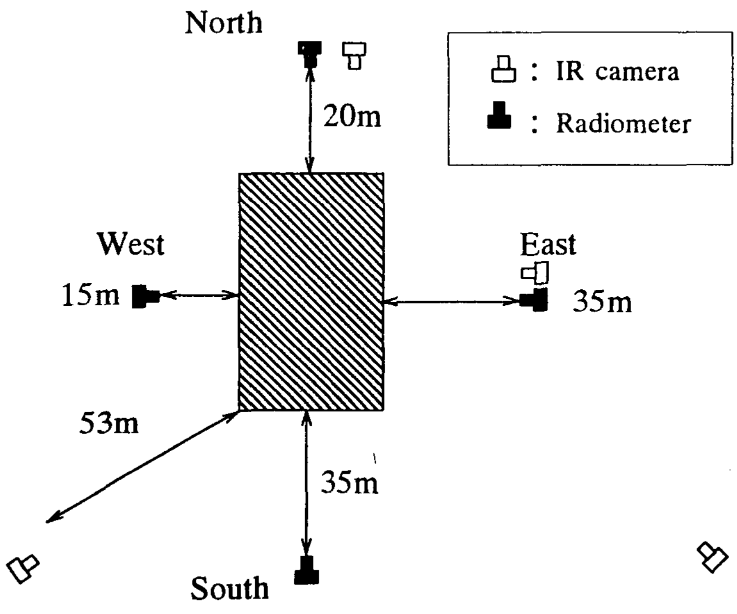
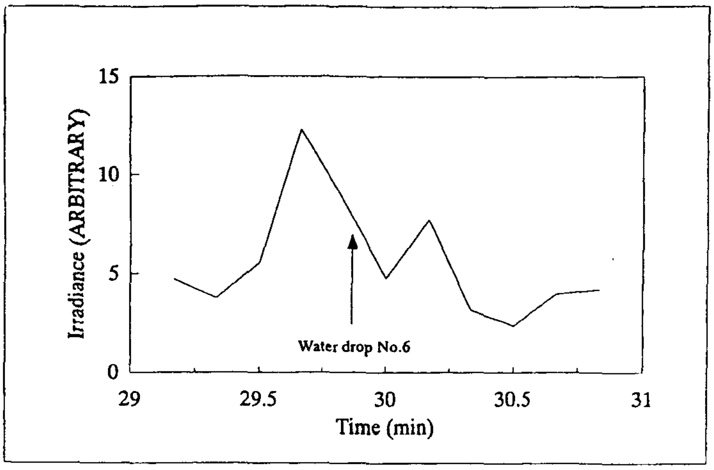
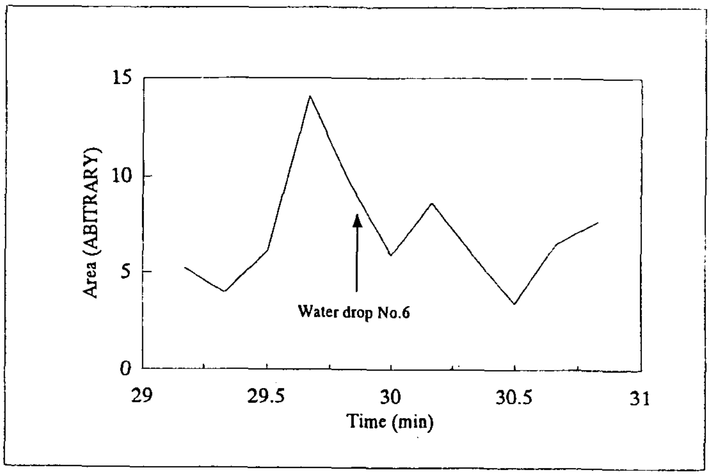


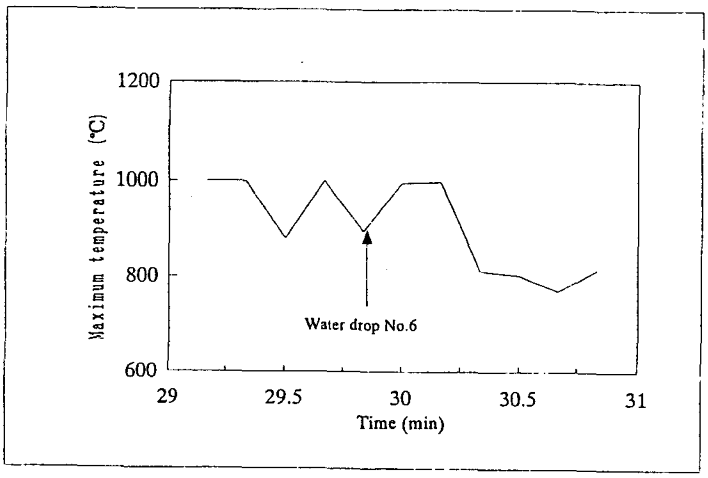
Fig.2 Positions of IR cameras and radiometers.



(a) Irradiance.



(b) Flame Area.



(c) Maximum temperature.

Fig.4 Change of irradiance, flame area and maximum temperature before and after water drop No.6.

RESULTS AND DISCUSSION

Because kerosene was used as igniter, fire expanded fast. Fire started to expand to the surrounding houses about three minutes after ignition. The about eighty percentage of the houses were burnt were in ten minutes after ignition. Aerial fire fighting by helicopters started thirteen minutes after ignition. Fire reached the maximum of the fire scale twenty minutes after ignition, then fire gradually went down. Details was reported by the Japan Association for Fire Science and Engineering [3].

1. Measurement by radiometer

Irradiance was measured by four radiometers around the burning area every ten seconds. Because the distance between the burning area and each radiometer differed, the measured values of irradiance were normalized into the values at the position which was thirty meters away from the center of the burning area. The time history of the normalized irradiances is shown in Fig. 3. The zero point of horizontal axis means the beginning of the ignition. The position of arrow shows the time when helicopter begins to drop water. The length of the arrow shows the relative amount of water. The longer the arrow, the larger the amount of water. The number above the arrow shows the order of water drop. Radiation was the maximum on south, east and west sides at five minutes after ignition. Compared with others, irradiance was small on north side. This reason was that the bank prevented irradiance from the burning area. The peak at five minutes was not seen on north side. It was considered as reason that the ignited houses of 1 line and 3 line were relatively far from the radiometer. Moreover, there might be influence of wind. The velocity of the wind was about 2 ~ 4 m/s. Wind was came from north during the experiment. Therefore irradiance in the south was the highest among four points. The peak at about eleven and twenty-one minutes seemed to mean that the fire expand to 4-3 and 4-4 house, respectively.

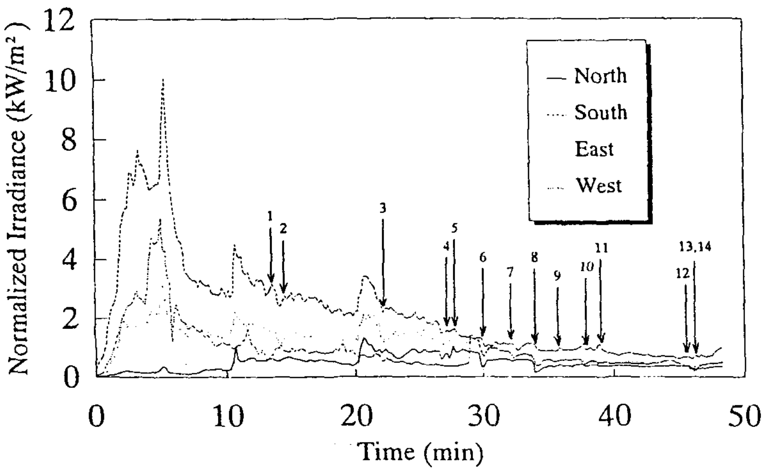


Fig.3 Time history of normalized irradiance.
All measured irradiances were converted into values at 30 m from the center of burning area.

2. Characteristics of flame measured by IR camera

The characteristics of flame in the narrow range was examined by the IR camera. The IR camera had the range of about 13 m times 17 m of view field in this experiment condition. The IR images were took by the IR camera before and after water drop was conducted. Here temperature was given from IR image, when emissivity of flame was assumed to be 1. The changes of irradiance, area of the flame and maximum temperature before and after water drop No. 6 are shown in Fig. 4. The change of irradiance by the radiometers was comparatively large in water drop No. 6. The zero point of horizontal axis means the beginning of ignition. When a part of the IR image was more than 425°C, it was regarded as flame which could give the radiant heat. The area of flame was found on the basis of the part which was more than 425°C on the IR image. The area is an arbitrary unit in the IR image. Flame occupies about 1/2 ~ 1/3 part in the view field. The area of flame was relative values because the IR images were not took from the horizontal or the vertical direction. In water drop No.6, No.7 and No.8, irradiance and the area of flame decreased. However, irradiance and the area of flame restored to near to its previous level in one or two minutes in most cases. Though the highest temperature of flame did not change, the average flame temperature showed a tendency to decrease as a whole.

3. Change rate of irradiance

In order to know the influence of aerial fire fighting, the change rate λ was defined to examine the change of irradiance by water drop as follows.

$$\lambda = (q_{av})_{after} / (q_{av})_{before} \times 100 \quad (\%) \qquad (1)$$

Where $(q_{av})_{after}$ was the average value of irradiance of one minute after water drop, and $(q_{av})_{before}$ was the average value of irradiance of one minute before water drop.

Fig. 5 shows λ in each water drop. The horizontal axis shows the order of water drop and the vertical axis shows the change rate, λ. It is thought that the extinguishing effect by water drop is exerted if λ decreases.

In water drop No.4, the decrease of irradiance was eight percentage on the average in all directions. It was thought as reason of small influence that water did not hit the flame missing to the north side. In water drop No.6, the decrease of irradiance was twenty-four percentage on the average in all directions. Compared with other water drops, this value was large. The height of the flame became lower after water drop. White smoke rose and the force of the fire became weak temporarily. In water drop No.8, the decrease of irradiance was twenty-six percentage on the average in all directions. This value was the largest in all water drops. White smoke rose from the burning area that water hit. However, the force of the fire was observed to restore during about thirty seconds. No.12, 13 and 14 the drop water were consecutive. Therefore they were regarded as a group of water drop No.12. The decrease of irradiance was measured on the east side and the west side. The decrease of irradiance was not observed on the north side and the south in a group of water drop No.12. The force of the fire was observed to restore even water drop hit the fire and white smoke went up.

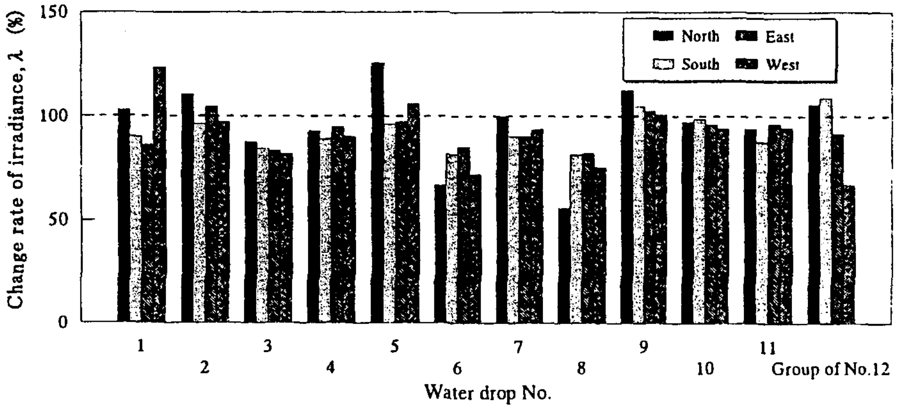


Fig.5 Change rate of irradiance in each water drop.

There might be a possibility that the amount of water affected the change of irradiance. The relationship between the amount of water and λ was examined. Fig. 6 shows the relationship between w l and λ. Compared with the other water drops, the value of λ of No.10 was large. It was thought as the reason that water did not hit the fire and the force of the fire already became weak. The value of λ did not comparatively decrease so much in spite of the large amount of water of a group of NO.12. Because the experiment of the consecutive water drop was conducted only once, a clear conclusion was not obtained. However, the value of λ tended to be larger when the amount of water drop was larger.

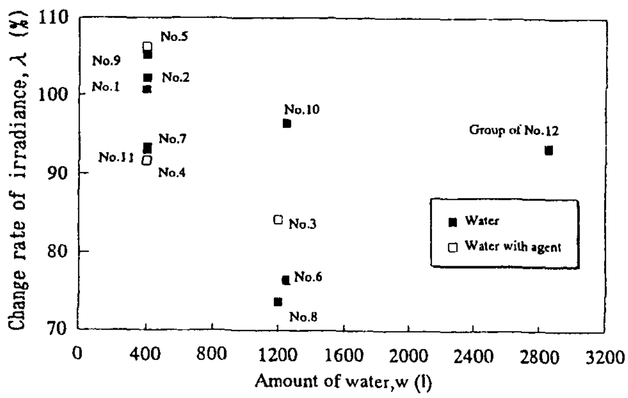


Fig.6 Relationship between amount of water and change rate of irradiance.

4. Value of λ per unit volume of water

. The value of λ was converted into the value per unit volume of water χ, as following equation.

$$\chi=(\lambda-100)/w \quad (\%/l) \qquad (2)$$

The value of χ expressed λ per unit volume of water. The Fig. 7 shows the relationship between χ and w. Because the data varied, the average value of χ of 400 l drop and the average value of χ of 1200 l and 1250 l drops are shown in Fig. 7. The decrease of χ tended to become comparatively large when the large amount of water was dropped by helicopter. The average value of χ of 1200 l and 1250 l drops were about five times larger than that of 400 l drop. The reason was that the water-dropped area became large when the large amount of water was dropped. Therefore the probability that the water hit the burning area became large.

The water drops including the extinguishing agent (the aqueous foam extinguishing agent, 0.3 %) is shown in Fig. 6 and Fig. 7. The amount of water gave the decrease of λ and χ the greater influence than the presence of the extinguishing agent. However, a clear influence of the agent on λ and χ was not found out in this experiment. This reason may be for the short of the trial times.

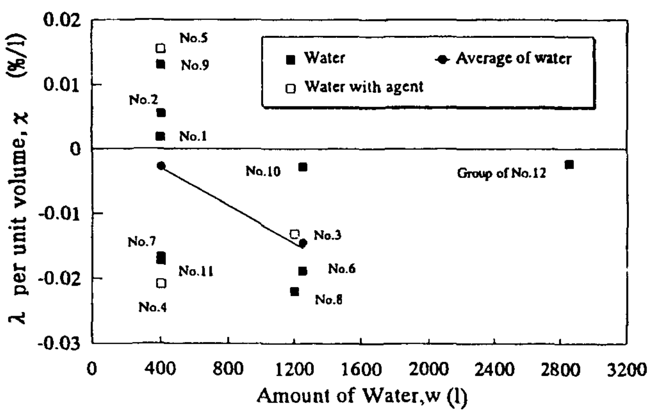


Fig.7 Relationship between amount of water and change rate of irradiance per unit volume.

CONCLUSION

An experiment concerning aerial fire fighting for large scale fire was conducted. Irradiance and the IR images were measured during the experiment. The change of the measured values before and after water drop were examined. With regard to large water drops, the area of water drop became large and water hit the burning area. The temporary decrease of irradiance and shrink of flame area were observed. However, they restored in a few minutes in many cases. We need more experiment to clarify the influence of water drop.

REFFERENCES

1.Fire Research Institute, Study on Expanded Fire in Large Earthquake, FRI Technical Report No. 5, October, 1973(in Japanese)

2.Fire Research Institute, Study on Expanded Fire in Major , FRI Technical Report No. 6, July, 1975(in Japanese)

3.Research Committee concerning Aerial Fire Fighting, Study on Aerial Fire Fighting against Urban Fire, Japan Association for Fire Science and Engineering Report, February, 1997(in Japanese)

ACKNOWLEDGEMENTS

This research was conducted under "Research Committee concerning Aerial Fire Fighting" in the Japan Association for Fire Science and Engineering. The authors thank committee chairman Youichi Uehara, and the Tokyo Fire Department.