Experimental Investigation on Liquid Fuel Droplet Combustion in Electro-Magnetic Environments at the Regime of Far Infrared Ray

USUI, Kiyoto / 臼井, 清人

(発行年 / Year)
2008-03-24

(学位授与年月日 / Date of Granted)
2008-03-24

(学位名 / Degree Name)
修士(工学)

(学位授与機関 / Degree Grantor)
法政大学 (Hosei University)

2007 年度修士論文

Experimental Investigation on Liquid Fuel Droplet Combustion in Electro-Magnetic Environments at the Regime of Far Infrared Ray

遠赤外線領域のある波長領域における電磁波雰囲気での燃料液滴燃焼に関する研究

指導教授　岡島　敏

川上　忠重

法政大学大学院工学研究科機械工学専攻修士課程

06R1104

ウスイ　キヨト

臼井　清人

Usui Kiyoto

Contents

Experimental Investigation on Liquid Fuel Droplet Combustion in Electro-Magnetic Environments at the Regime of Far Infrared Ray

Kiyoto Usui

Abstract

Recently, the exhaustion of fossil fuels and global warming caused by CO2 emission bring us a lot of serious problems. The development of energy saving technology is very important to reduce CO2 emission and to prevent air pollution. Thus, the present study has been carried out to examine how the fuel spray combustion is influenced by resonance frequency of electro-magnetic wave to chemical species of combustion. This electro-magnetic wave belongs to the regime of far infrared ray. Particularly, the study has been conducted to focus on the combustion of single fuel droplets which is the most important component of splay combustion.

Electro-magnetic wave employed in the study is 1200cm^{-1} of wave number and more than 0.90 of spectral emissivity. This wave number corresponds to the absorption region of methane molecules. The chemical species including methane molecule produced by thermal decomposition

during the combustion process have an ability to absorb such electro-magnetic wave. These rays may lead to more accelerate the spin and vibration modes of methane molecule and its reaction precursor, that is, chemical species,

and then to enhance the collision energy and frequency between molecules of fuel and oxygen. Consequently the flame temperature gives rise to increase due to the acceleration of combustion reaction rate.

The experiments have been carried out to verify the combustion promotion by means of the utilization of electro-magnetic wave. The experimental methods are as follows that first is fuel droplet combustion in quiescent air, and second is fuel droplet combustion in uniform flow of air.

The main results obtained for the study are as follows that

(1)The reduction percentage of combustion lifetime of fuel droplets burning in electro-magnetic field may be about 4.56 % for n-heptane droplets, 3.53% for kerosene droplets, 1.76 % for methanol droplets, 0.8% for bunker oil A droplets and 0.79 % for benzene droplets.

(2) The flame temperature rise of fuel droplets burning in electro-magnetic field may be approximately 100℃ for n-heptane droplets, 60℃ for kerosene droplets.

(3)The increase on surface temperature of electro-magnetic radiant materials leads to increase the reduction of combustion lifetime and the flame temperature of n-heptane droplets and these values are about 5.62% for combustion lifetime and 150℃ for flame temperature rise when the surface temperature of electro-magnetic radiant material is 65℃.

(4)Reduction percentage of combustion lifetime of n-heptane is approximately 4 % at any air velocity. This means that the electro-magnetic effect to combustion did not be influenced by the electro-magnetic wave.

(5)From these results it may be predicted that such electro-magnetic wave may be very effective to accelerate the burning rate of spray combustion accompanying with resonance frequency to methane molecule produced by thermal decomposition during combustion process.

1. Introduction

1-1. Background

Recently, the exhaustion of fossil fuels and global warming caused by CO_2 emission bring us a lot of serious problems. The development of energy saving technology is very important to reduce CO_2 emission and to prevent air pollution. ICPP(Intergovernmental Panel on Climate Change) predicts the average temperature will rise by about 4℃ between 2071 and 2100. According to the Kyoto Protocol resolved in 1997, Japan must cut down its annual emission of greenhouse gases by 6% by 2012 from 1990 levels. Therefore, it is investigated many research laboratories.

For reduction of CO2 emission the three kinds of technique may be suggested, that is

(1)Development of high efficiency combustion technique

(2)Development and promotion of nuclear power

(3)Reclamation possibility

In these methods we are focused on the (1)high efficiency combustion technique by introducing the new combustion concept based on the electro-magnetic wave method.

Figure 1 shows carbon cycle system on the globe. From this figure, the half of greenhouse effect gases emitted from the fossil fuel combustion may be accumulated in air. Therefore, the high efficiency combustion as the one of the reduction methods of CO2 emission has to be established, immediately, by accompanying with striking originality method.

Under these circumstances, we have developed the new combustion concept by utilization of electro-magnetic wave. The gas phase reaction of liquid fuel combustion includes a number of elementary reactions. So, we have focused on the effect of electro-magnetic wave on intermediate products, especially methane and its reaction precursor generated by thermal decomposition in combustion process of hydrocarbon fuels. Methane and its reaction precursor are able to absorb significant electro-magnetic energy around wave number of $1200cm^{-1}$.

This present investigation has been carried out to examine how the fuel spray combustion is influenced by electro-magnetic wave at the regime of far infrared ray. Particularly, the study has been conducted to focus on the combustion of single fuel droplets which is the most important component of splay combustion.

1-2. Wave characteristics of electro-magnetic radiant material

Figure 2 shows the Wave Characteristics of electro-magnetic radiant material developed for the study. This radiant material is compounded several kinds of ore that is can discharge the electro-magnetic wave. In this figure, the vertical red line shows the wave number of the absorption band of methane molecule and the horizontal red line shows the spectral emissivity of 0.9.

This material can discharge the electro-magnetic wave with wave numbers in the range of 800 to 2000 cm^{-1} and more than 0.90 of spectral emissivity, which belongs to the regime of infrared ray. This wave number corresponds to the absorption band of methane molecule(Figure 3). This wave number is also very safety for human body and the instruments. Because the intensity of radioactivity is about 0.04 μ Sv/h.

1-3. Combustion promotion method by means of electro-magnetic wave

Figure 4 shows the combustion promotion method by means of electro-magnetic wave. These rays may lead to more accelerate the spin and vibration modes of methane molecule and its reaction precursor, and then to enhance the collision energy and frequency between molecules of fuel and oxygen accompanying with the resonance frequency. Consequently the flame temperature gives rise to increase due to the acceleration of combustion reaction rate. [1,2,3]

2. Experimental apparatus and procedure

2-1. Experimental condition

The experimental condition is shown in table 1. The experiments have been carried out in room temperature and atmospheric pressure. The initial droplet diameter used for the study is approximately 1.80 mm. The fuels used for the study are n-heptane, kerosene, methanol, benzene and bunker oil A.

2-2. Experiment (1):Fuel droplet combustion in quiescent air

2-2-1. Test assembly

Figure 5 shows the experimental set-up of test assembly employed in the study and it consists of a combustion chamber (size is 170mm×180mm×180mm), a D.C power supply, an ignition coil, a mercury switch, a voltage regulators, a thermometer, an 8-mm video camera and a high-speed digital camera. The silica fibre (size is 0.4mm in diameter and 60 mm in length) for suspending fuel droplet is located in the center position of combustion chamber and ignition is done by fine needle electrodes beneath the liquid fuel droplet.

2-2-2. Details of fuel droplet and electro-magnetic radiant material

Figure 6 shows the arrangement of fuel droplet and electro-magnetic radiant material. The configuration of electro-magnetic radiant material is a cylindrical shape of 80 mm in diameter and 100 mm in length. The fuel droplet is located in the central position of cylinder. As the strength of radiant energy from energy sheet can be controlled by changing the surface temperature of radiant material, the surface temperature of radiant material is adopted in the range from 25 ℃ to 65 ℃ by the voltage regulators connected with the electric heater attached the outside of radiant material.

2-2-3. Experimental procedure

The experimental procedure is shown as follows,

(1) In the experiment on the temperature change of the electro-magnetic radiant material, the temperature of radiant material is controlled by electric heater to a given temperature.

(2)Fuel droplet is suspended on the silica fibre by the micro-syringe.

(3)Ignition is done by fine needle electrodes. After the ignition, fine needle electrodes are quickly shifted to downward from fuel droplet.

(For kerosene and bunker oil A, it is very difficult to ignite by spark electrodes only. Ignition is done by small pilot flame)

(4) The combustion is observed by taking the direct photographs with 8-mm digital video camera or high-speed digital camera.

(The combustion lifetime is examined by observation with 8-mm digital video camera through the observation window. The average flame temperature is measured by taking the direct photographs with high-speed digital camera equipped with two-color pyrometer.)

2-3. Experiment (2):Fuel droplet combustion in uniform flow of air

2-3-1. Test assembly

Figure 7 shows the experimental set-up of test assembly employed in the study and it consists of a Wind tunnel (80 mm in diameter and 1200 mm in length), a Fan, an Anemometer, a D.C power supply, an ignition coil, a mercury switch, a voltage regulators, a thermometer, an 8-mm video camera and a high-speed digital camera. The silica fibre (0.4mm in diameter and 60 mm in length) for suspending fuel droplet is located in the center of combustion chamber and ignition is done by fine needle electrodes beneath the liquid fuel droplet.

2-3-.2 Details of fuel droplet and electro-magnetic radiant materials

In figure 8 is shown the layout between the electro-magnetic radiant material and liquid fuel droplet. The radiant material is cylindrical shape of 90 mm in diameter and 100 mm in length. The fuel droplet is located in the central position of radiant material and air velocity is controlled by voltage regulators attached the fan.

2-3-3. Experimental procedure

The experiment procedure is shown as follows,

(1) Air velocity is controlled by voltage regulators attached the fan.

(2)Fuel droplet is suspended on the silica fibre by the micro-syringe

(3)Ignition is done by fine needle electrodes. After the ignition, fine needle electrodes is quickly shifted to downward from fuel droplet.

(4) The combustion lifetime is examined by taking the direct photographs with 8-mm digital video camera through the observation of the glass window.

3. Experimental results and discussion

3-1.Experiment (1):Fuel droplet combustion in quiescent air

3-1-1. Combustion lifetime of liquid fuel droplets

Figures 9, 10, 11, 12, and 13 show the typical distribution of combustion lifetime of five kinds of fuel droplets, that is, n-heptane, kerosene, methanol, bunker oil A and benzene, respectively. The combustion lifetime is determined by 50 more droplet combustion tests.

In Table 2 is shown the combustion lifetime and reduction percentage on fuel droplets burning in the electro-magnetic field or not. The reduction rate *R* of combustion lifetime is defined as follows:

$$R = \frac{Tw - Two}{Two} \times 100 \qquad (1)$$

Tw is combustion life time of presence of radiant material, ***Two*** is combustion lifetime of absence of radiant material. From these figures, one can recognize that the reduction percentage of combustion lifetime on fuel droplets of n-heptane, kerosene, methanol, bunker oil A and benzene are 4.25%, 3.53%, 1.96%, 0.80% and 0.69% respectively. The discrepancies of the combustion lifetime of these fuels depend on the amount of methane of the chemical species generation by thermal decomposition of combustion process.

3-1-2. Flame temperature of liquid fuel droplets

Figures 14, 15, 16 and 17 show the time-variation ratios of flame temperature rise of four kinds of fuel droplets, that is, n-heptane, kerosene bunker oil A and benzene burning in electro-magnetic field or not, respectively. From these figures it can be seen that, for n-heptane and kerosene droplets, their flame temperatures of presence of radiant materials during combustion are always higher than that it absence of radiant material. The flame temperature rise of the fuel droplets of n-heptane and kerosene is approximately from 50 to 100℃ and 30 to 60℃, respectively. For the fuel droplets of bunker oil A, there is almost no flame temperature rise during combustion.

In Table 3 is shown the ratio of flame temperature rise on the fuel droplets of n-heptane, kerosene and bunker oil A burning in electro-magnetic field or not. These data are those obtained from two-color pyrometer analysis by the high-speed digital camera at 200 frames per second. The ratio of flame temperature rise (α) is defined as follows:

$$\alpha = \frac{T_{fw}}{T_{fo}} \qquad (2)$$

T_{fw} is the flame temperature of presence of radiant material and T_{fo} is the flame temperature of absence of radiant material. As seen from Table 3, the ratio of flame temperature rise of n-heptane droplets is larger than those on the fuel droplets of kerosene and bunker oil A corresponding to the results of Figures 14, 15, 16 and 17.

For these experimental results, it would be summarized that there is significant effect on the burning rate of n-heptane and kerosene droplets by the utilization of electro-magnetic wave, but not observed in bunker oil A. This phenomenon may cause by the amount of methane of the chemical specises and its precursor generated by thermal decomposition during combustion process of hydrocarbon fuel droplets.

3-1-3. The effect of radiant energy from electro-magnetic wave on the combustion properties of liquid fuel droplets

From the viewpoint of practical use of electro-magnetic wave, it is very significant to examine the effect of radiant energy from the electro-magnetic wave on the burning properties of liquid fuel droplets.

Figure 18 shows the typical distribution of combustion lifetime of n-heptane fuel droplets as a parameter of surface temperature of radiant material and Fig. 19 also shows the reduction percentage of combustion lifetime of n-heptane droplets against the surface temperature of radiant material. Table 4 also shows the combustion lifetime and reduction percentage of n-heptane droplet based on Figs.18 and 19. The reduction percentage R of combustion lifetime is obtained from Eq. (1).

From table 4 and Figs.18 and 19, it is found that the reduction percentage of combustion lifetime on various surface temperature of radiant material at 25℃, 45℃ and 65℃ are 4.25%, 4.62%, and 5.62%, respectively and these reduction of combustion lifetime increases with increasing surface temperature of radiant material .

Figure 20 shows the time-variation ratio of flame temperature rise of n-heptane droplets and Table 5 shows the ratio of flame temperature rise of n-heptane droplet burning in electro-magnetic field or not. The ratio of flame temperature rise is obtained from Eq.(2). As above-mentioned, the surface temperature of radiant material can be changed from 25℃ to 65℃

by voltage regulators connected with electric heater. These data are obtained from two-color pyrometer analysis by the high-speed digital camera at 200 frames per second. From Table 5 and Fig. 20, it is found that the ratio of flame temperature rise increases with increasing surface temperature of radiant material. The increase of the flame temperature of n-heptane droplets is about 150℃ at 65℃ of surface temperature of radiant material .

The expression of Stefan-Boltzmann law of radiation is shown as follows：

$$q = \varepsilon \sigma T^4 \qquad (3)$$

$\boldsymbol{q}$ is radiant energy , $\boldsymbol{\varepsilon}$ is spectral emissivity of radiant material, $\boldsymbol{\sigma}$ is Stefan-Boltzmann constant number(5.6697×10^{-12}[w/cm^2・K]) and $\boldsymbol{T}$ is temperature of radiant material. From this expression, electro- magnetic energy is proportional to the forth power of the temperature of radiant material. Consequently, this fact may result from the increase of radiant energy due to the increase of the surface temperature of radiant mataerial.[4]

3-1-4.The effect of electro-magnetic energy on total flame height and width of fuel droplets combustion

Figure 21 shows the flame height ***H*** and flame width ***W*** of n-heptane droplets burning in electro-magnetic field or not. From this figure, it is recognized that the flame height and width of n-heptane droplets burning in electro-magnetic environments are larger than that without electro-magnetic environments. This is due to the promotion of vaporization from the fuel droplets caused by the flame temperature rise.

3-2. Experiment (2):Fuel droplet combustion in uniform flow of air

Figure 22 shows the direct photograph of combustion behavior of n-heptane droplets at various air velocities. From this figure, the flame becomes to be long as flow velocity increases. Table 6 shows the combustion lifetime and reduction percentage of n-heptane droplet as a parameter of air velocity.

The reduction ***R*** of combustion lifetime is obtained from Eq. (1).

From this table, it is found that the reduction percentage of combustion lifetime on various air velocities at0m/s, 0.15m/s, 0.25m/s, 0,35m/s and 0.45m/s are 4.25%, 4,04%, 3,90%, 3,96%and 4.31%, respectively. Figure 23 shows the combustion lifetime of n-heptane droplets as a parameter of air velocity. The combustion time becomes to be shortened accompanying with increasing of air flow velocity. Reduction percentage of combustion lifetime of n-heptane is approximately 4 % at uniform flow of air velocity. It is confirmed that air flow did not influence the effect of the electro-magnetic wave.

4. Conclusion

Experiments have been conducted to examine the effect of electro-magnetic wave on the burning rate of fuel droplet combustion. The main results obtained for the study are as follows:

(1)The reduction percentage of combustion lifetime of fuel droplets burning in electro-magnetic field may be about 4.56 % for n-heptane droplets, 3.53% for kerosene droplets, 1.76 % for methanol droplets, 0.8% for bunker oil A droplets and 0.79 % for benzene droplets.

(2) The flame temperature rise of fuel droplets burning in electro-magnetic field may be approximately 100℃ for n-heptane droplets, 60℃ for kerosene droplets.

(3)The increase on surface temperature of electro-magnetic radiant materials leads to increase the reduction percentage of combustion lifetime and the flame temperature of n-heptane droplets and these values are about 5.62% for combustion lifetime and 150℃ for flame temperature rise when the surface temperature of electro-magnetic radiant material is 65℃.

(4)Reduction percentage of combustion lifetime of n-heptane is approximately 4 % at any air velocity. This means that the electro-magnetic effect to combustion did not be influenced by the electro-magnetic wave.

(5)From these results it may be predicted that such electro-magnetic wave may be very effective to accelerate the burning rate of spray combustion accompanying with resonance frequency to methane molecule produced by thermal decomposition during combustion process.

Acknowledgements

The author would like to acknowledge the continuing guidance and encouragement of Prof. Satosi Okajima and Prof. Tadashige Kawakami. I am also thankful of the staffs of Workshop Center of Hosei University. Thanks are due to my member `s of laboratory with whom I have discussed this problem.

References

1. Weinberg, F. J., The combustion Temperature, The Future, Nature, 233(1971), pp.239-241.

2. T. Takada, Y. Egawa and H. Sasaki, Practice of Far Infrared Ray, Human and Hidstroy Ltd., 1999.

3. S. Okajima, S. Takahashi, O. Zushi, M. Koyama, M. Ito, Combustion Society of Japan 43^{st} Symposium on Combustion, pp512-513(2005).

4. K. Katayama, et al, JSME Date Book: Heat Transfer 4th Edition, JSME, 1986

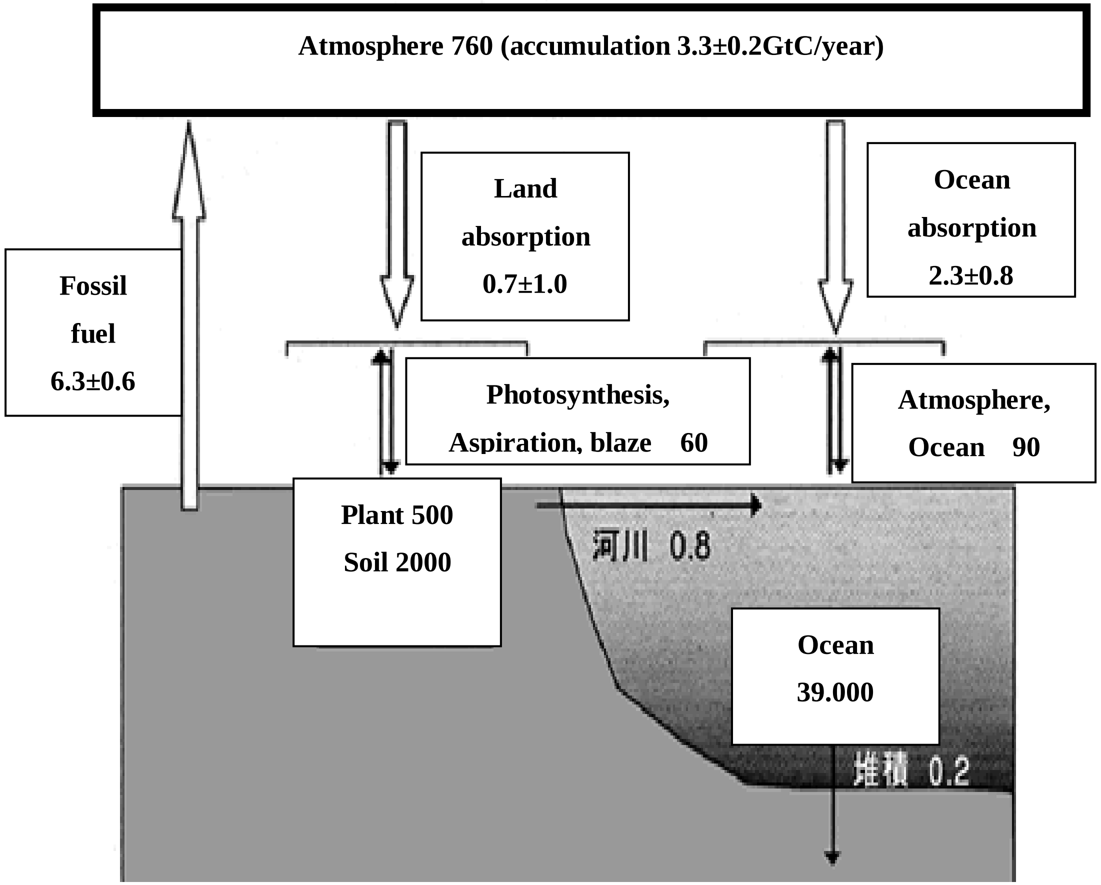


Fig.1. Carbon cycle system

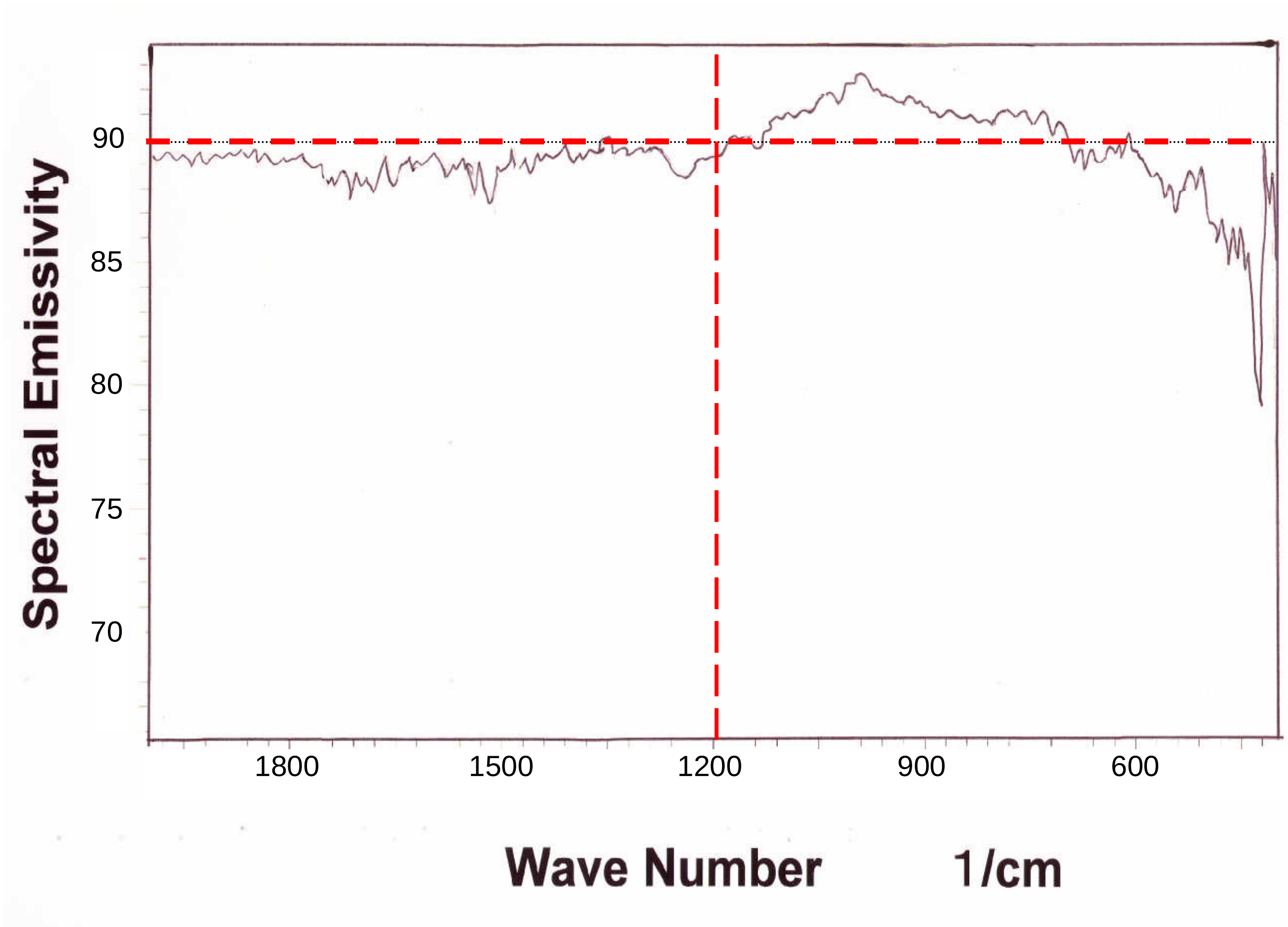


Fig.2. Spectral emissivity of electric-magnetic radiant material

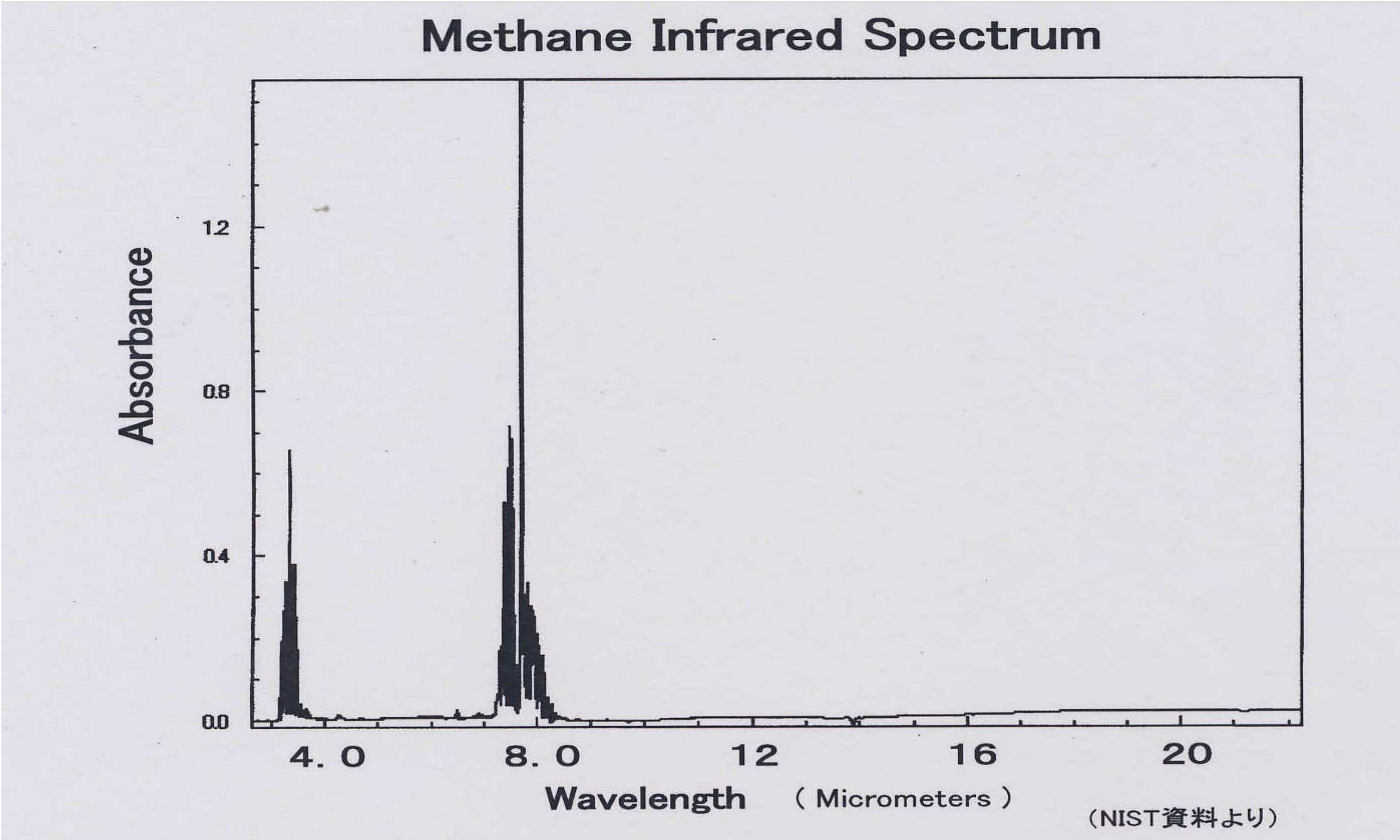


Fig.3. Methane Infrared Spectrum。

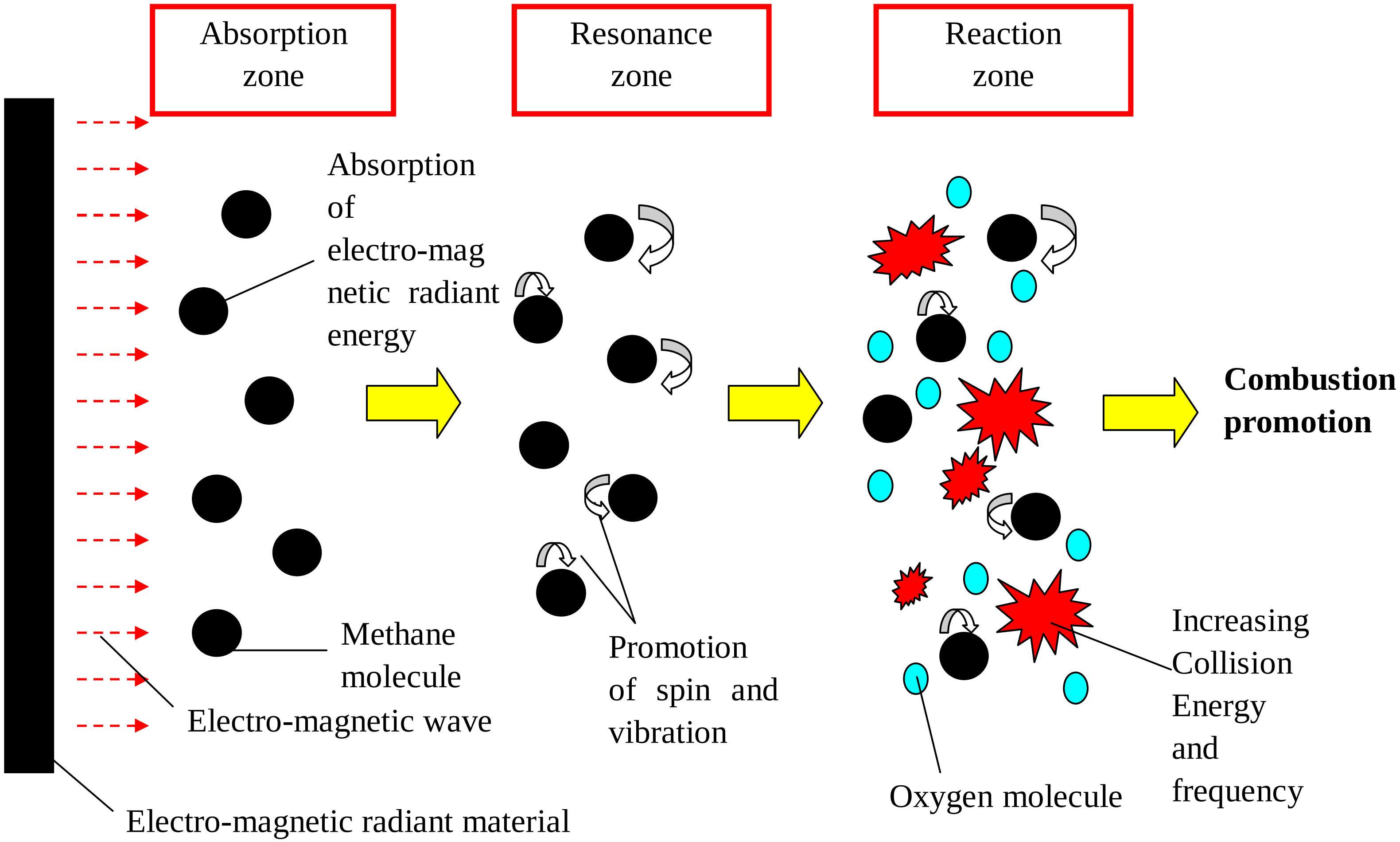


Fig.4. Combustion promotion principal by means of Electro-magnetic Wave

Table.1. Experimental condition

Test fuels	n-Heptane Kerosene Methanol Bunker oil A Benzene
Ambient temperature	Room temperature
Ambient pressure	Atmospheric pressure
Initial droplet diameter	1.80mm

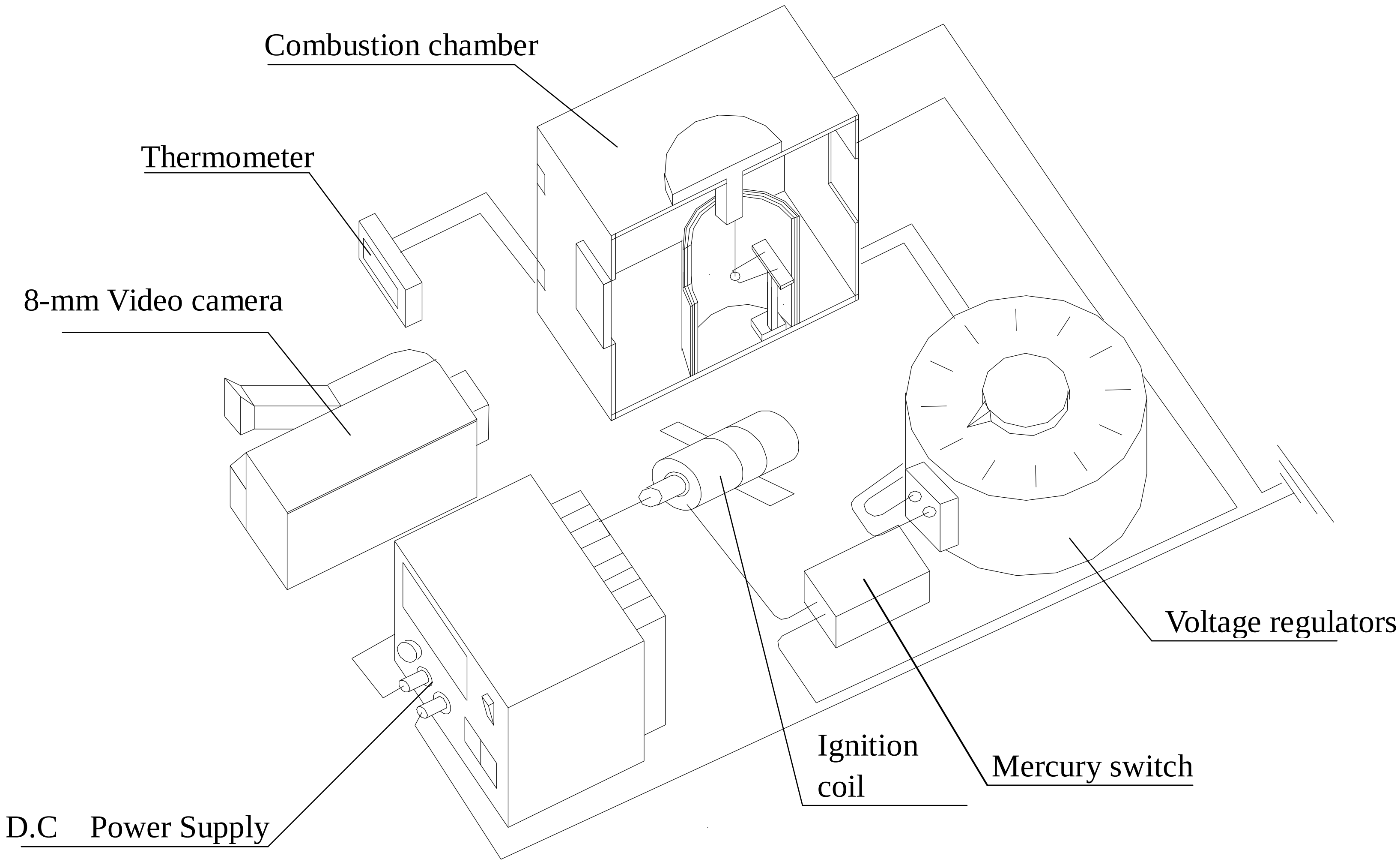


Fig.5. Test assembly (1):Fuel droplet combustion in quiescent air

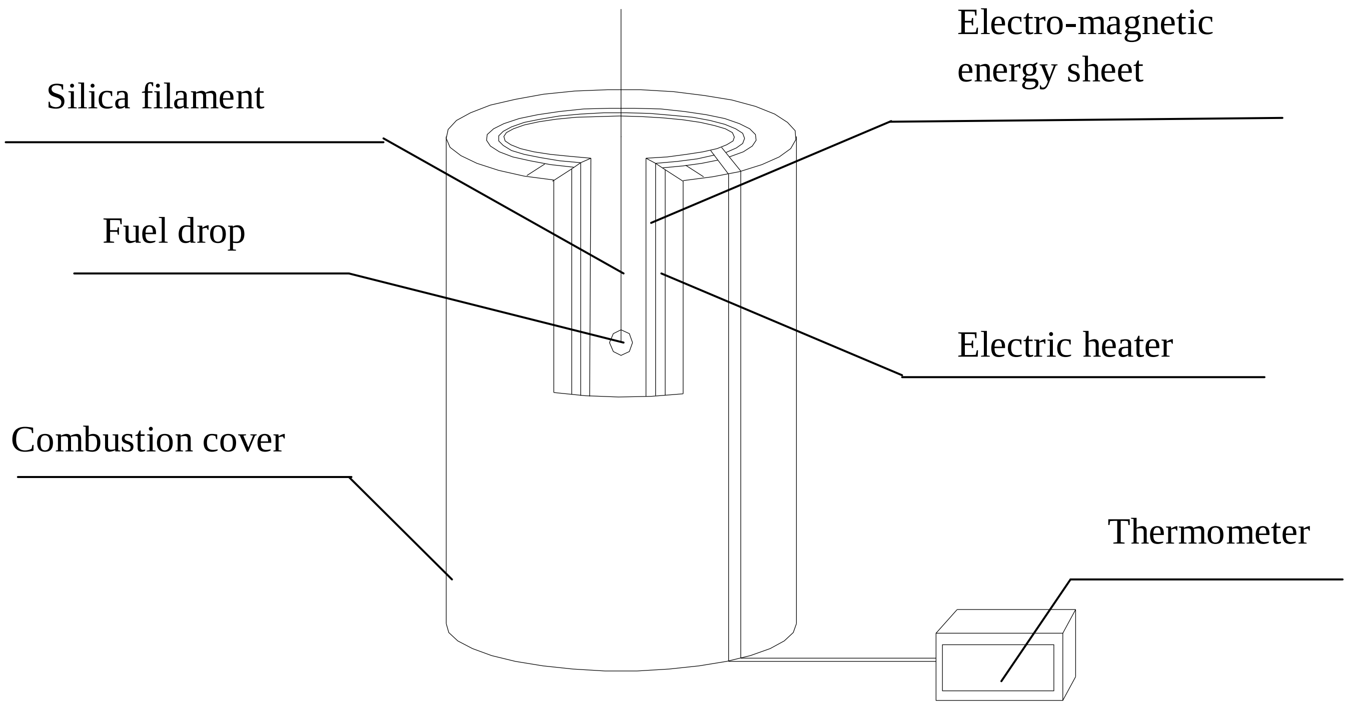


Fig.6. Layout between fuel droplet and electro-magnetic energy sheet.

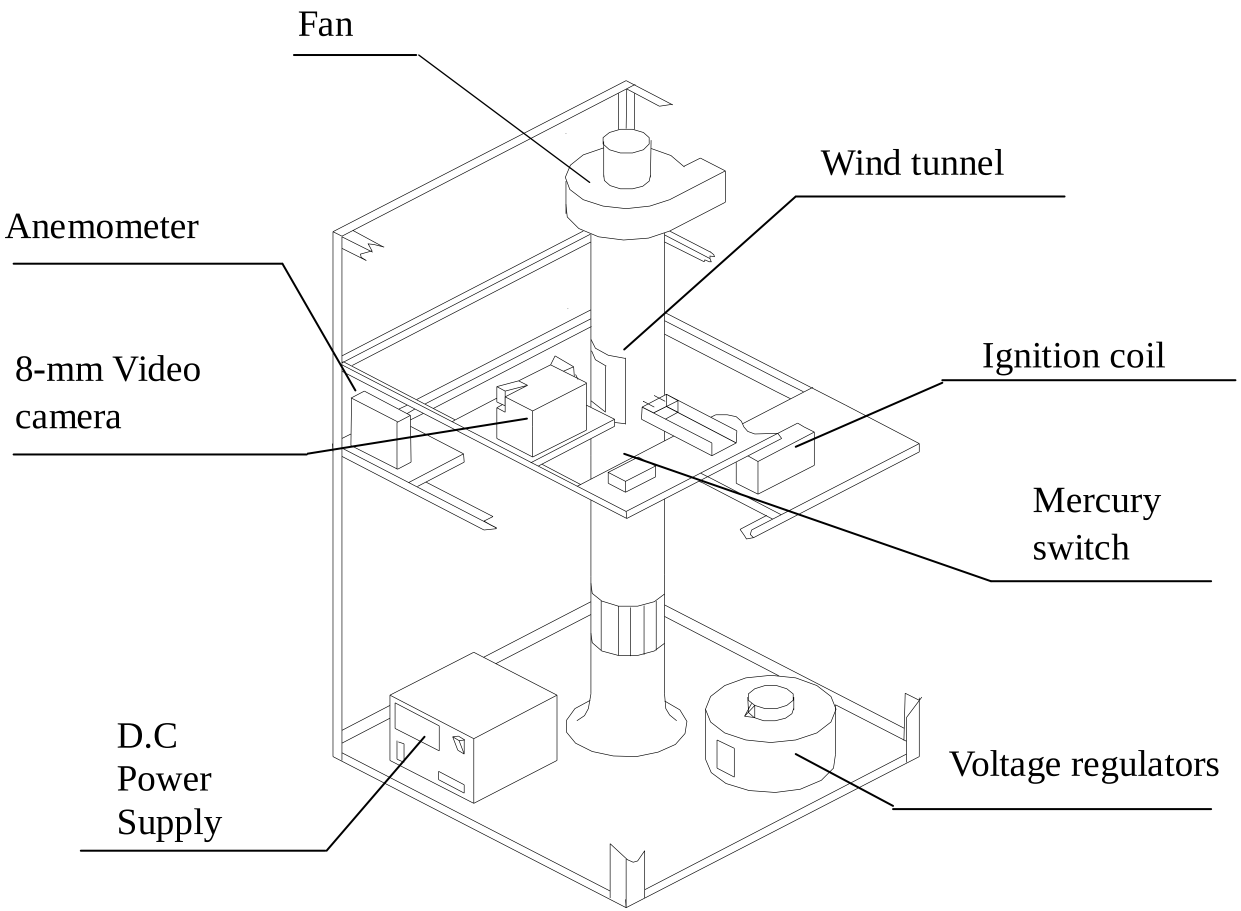


Fig.7. Test assembly (2):Fuel droplet combustion in uniform flow of air

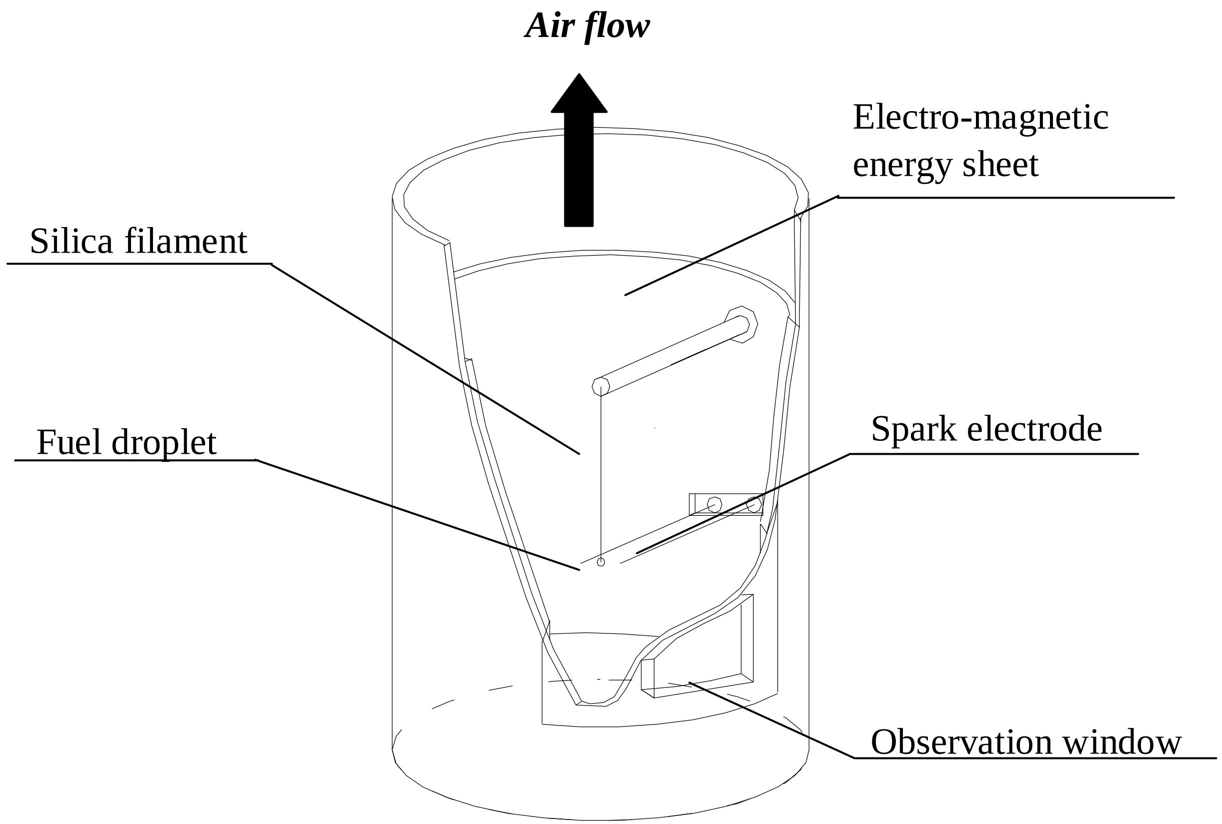


Fig.8. Layout between fuel droplet and electro-magnetic energy sheet.

Table 2. Combustion lifetime and reduction percentage of n-heptane, kerosene, methanol, benzene and bunker oil A droplets.

	n-Heptane	Kerosene	Methanol	Bunker oil A	Benzene
Combustion lifetime Tw s (Presence of radiant material)	2.54	2.73	3.06	3.09	2.78
Combustion lifetime Two s (Absence of radiant material)	2.65	2.83	3.12	3.12	2.80
Reduction percentage of combustion lifetime Rt %	4.25	3.53	1.96	0.8	0.69

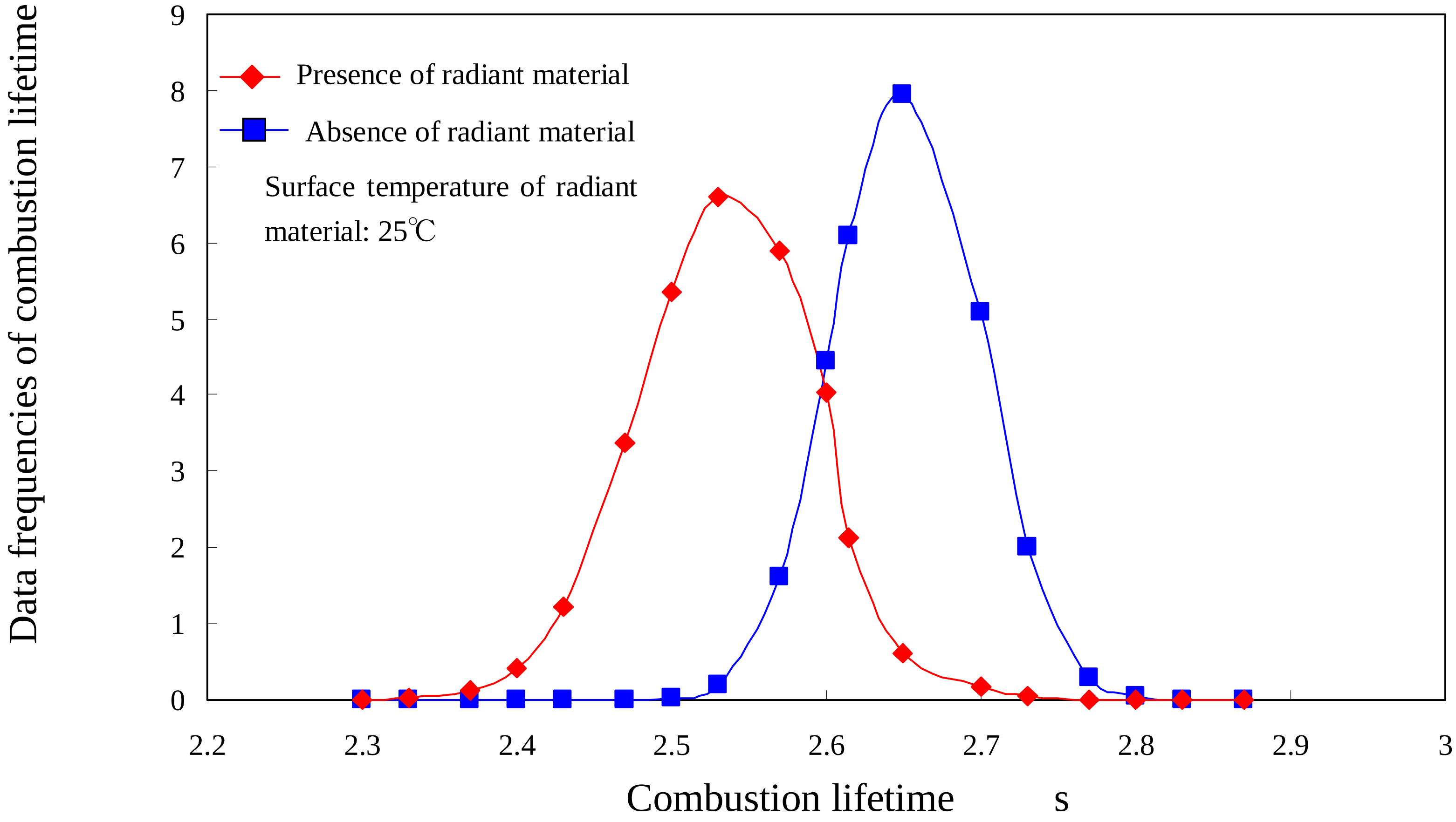


Fig.9. Typical distribution of combustion lifetime of n-heptane droplets.

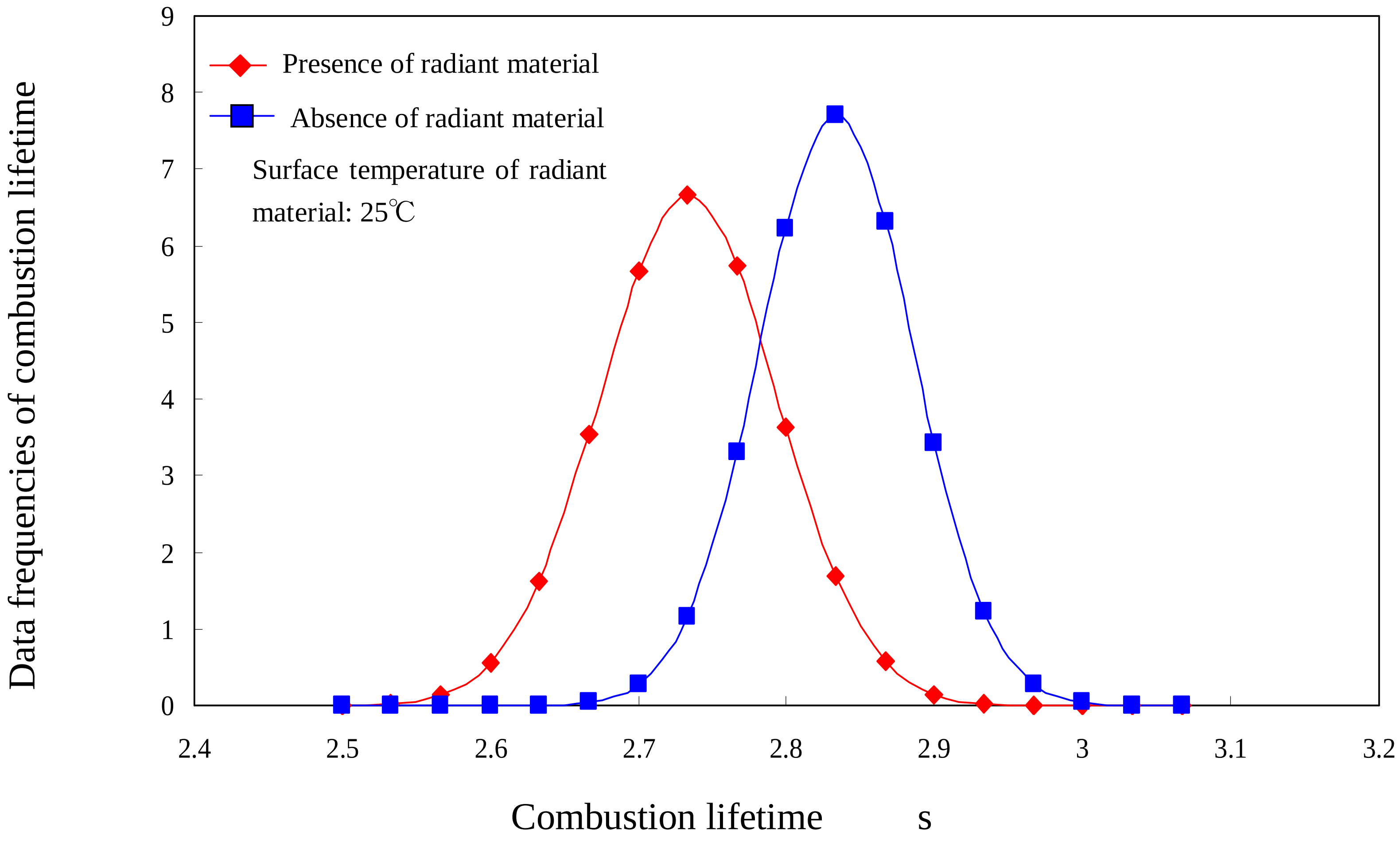


Fig.10. Typical distribution of combustion lifetime of kerosene droplets.

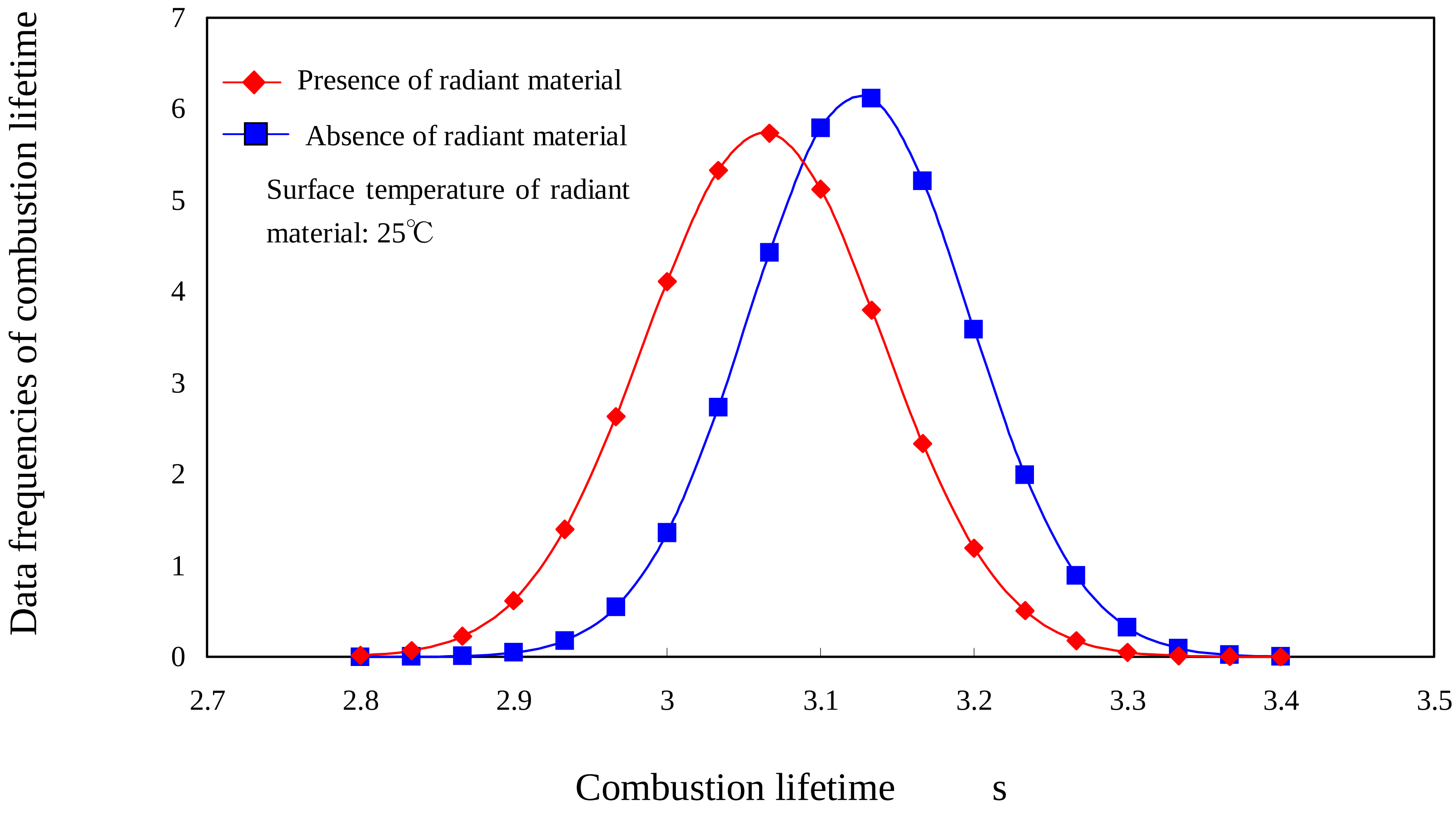


Fig.11. Typical distribution of combustion lifetime of methanol droplets.

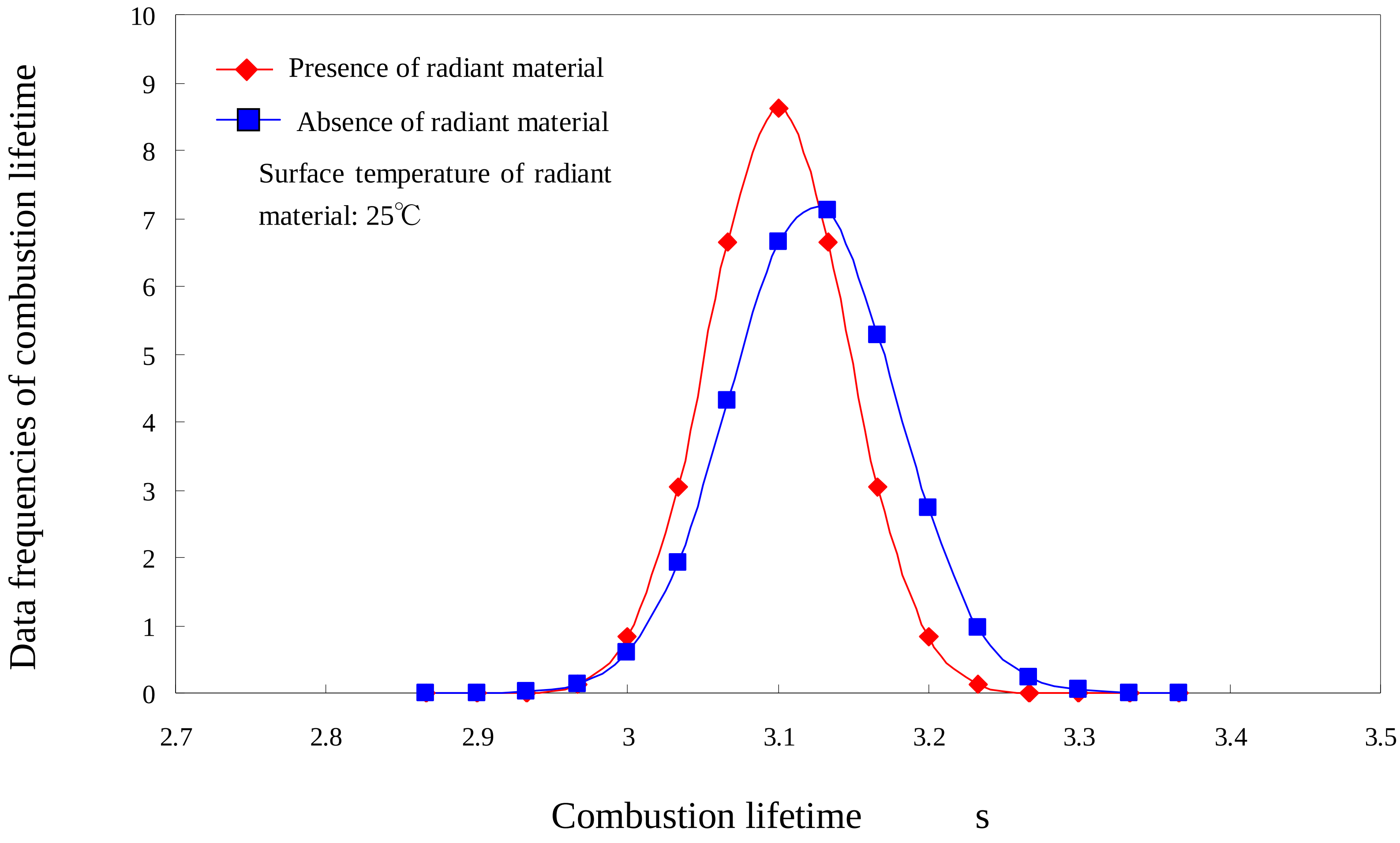


Fig.12. Typical distribution of combustion lifetime of fuel droplets of bunker oil A.

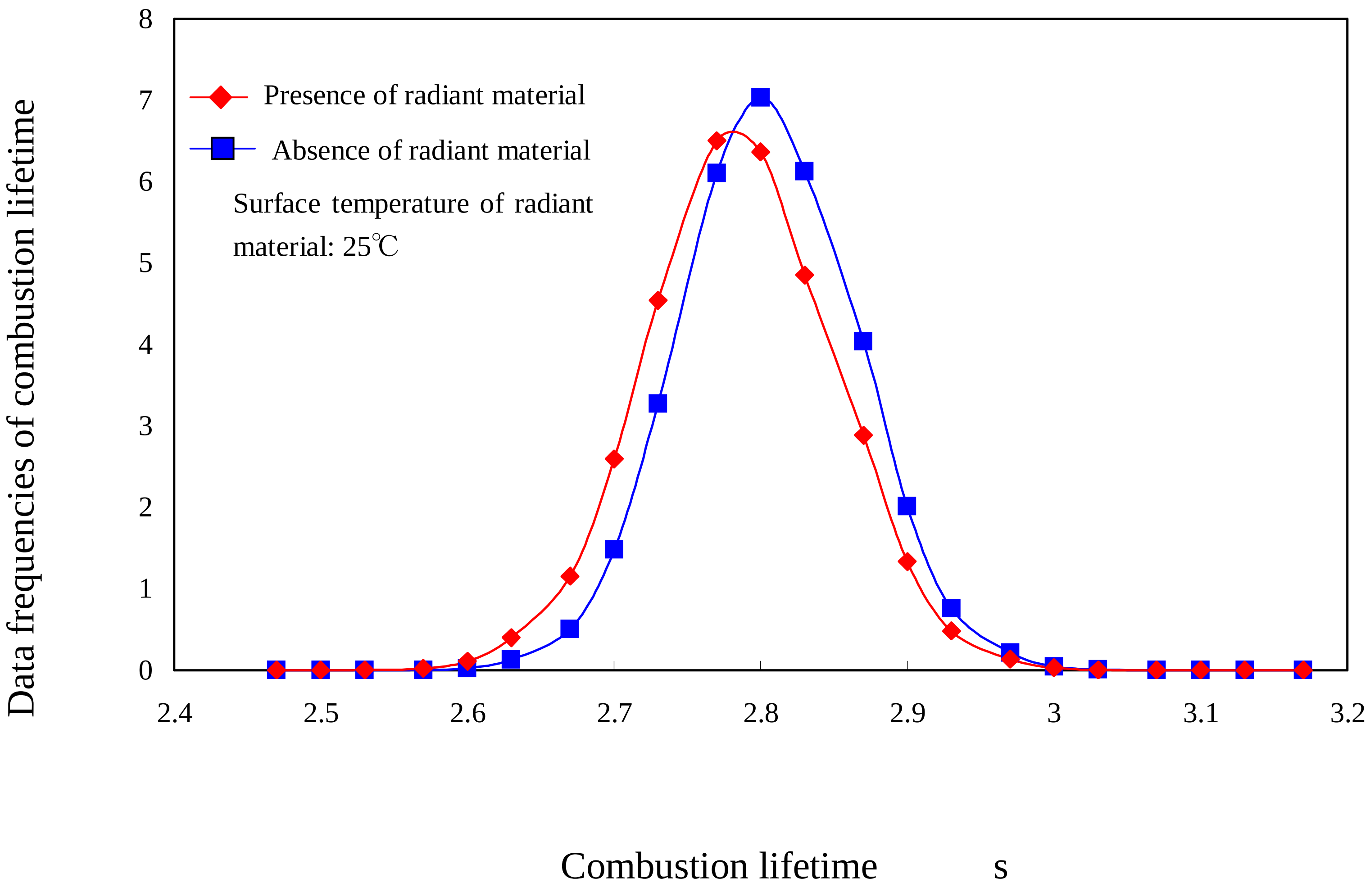


Fig.13.Typical distribution of combustion lifetime of fuel droplets of benzene.

Table 3. Ratio of flame temperature rise of n-heptane, kerosene, bunker oil A and benzene droplets.

	n-Heptane	Kerosene	Bunker oil A	Benzene
Ratio of flame temperature rise	1.033	1.023	1.008	0.998

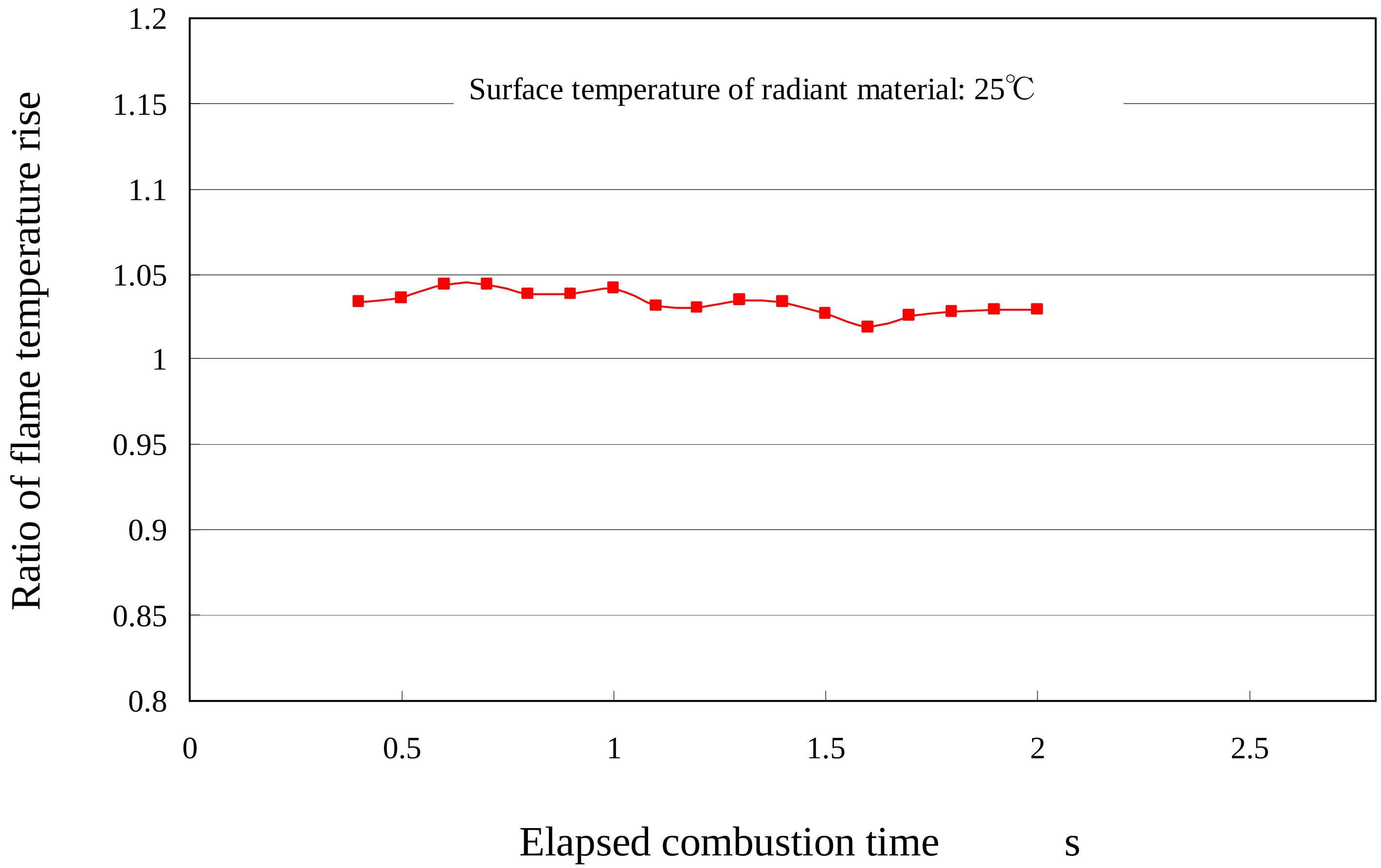


Fig.14. Time-variation ratio of flame temperature rise of n-heptane droplets.

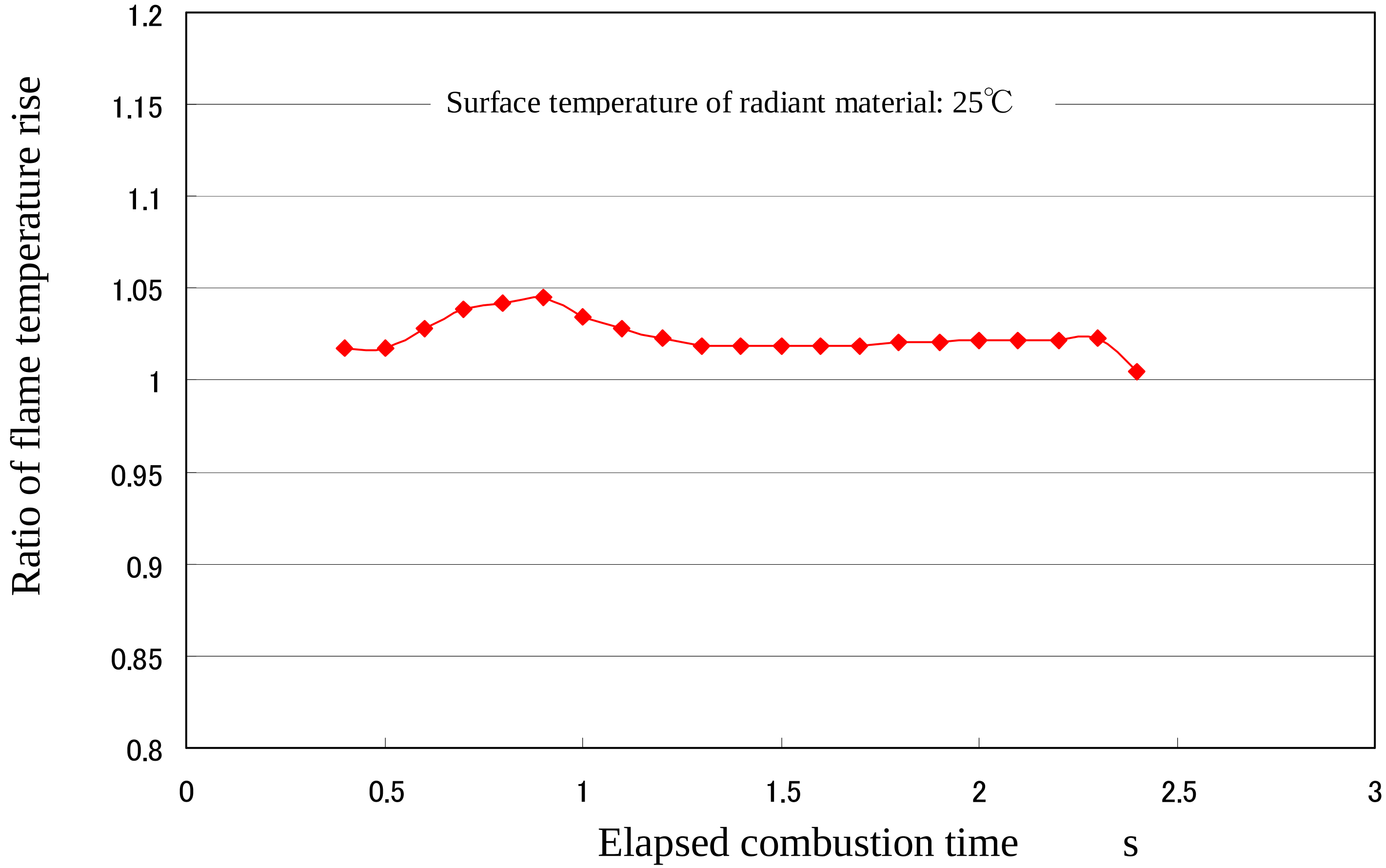


Fig.15 Time-variation ratio of flame temperature rise of kerosene droplets.

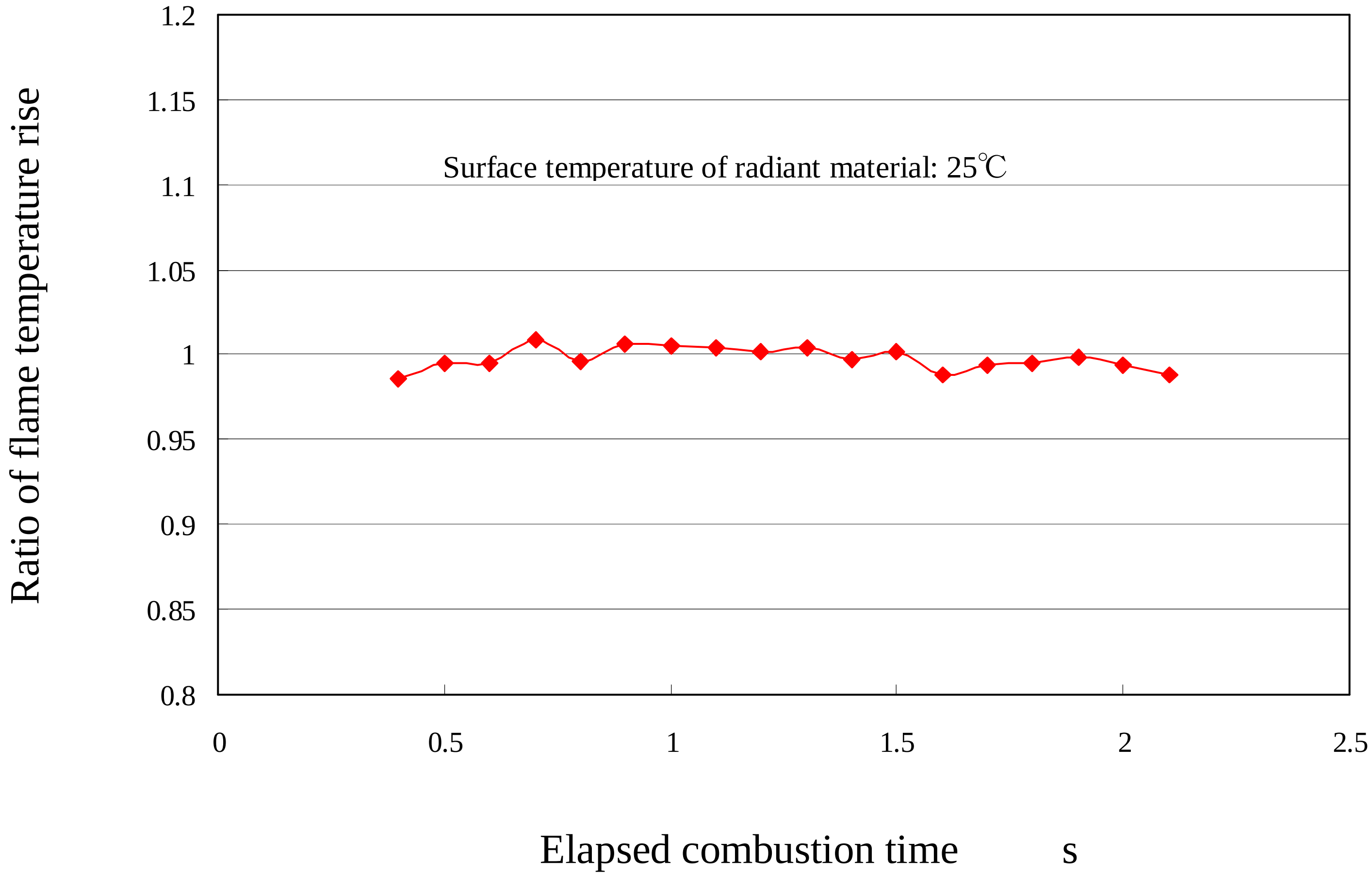


Fig.16 Time-variation ratio of flame temperature rise of benzene droplets.

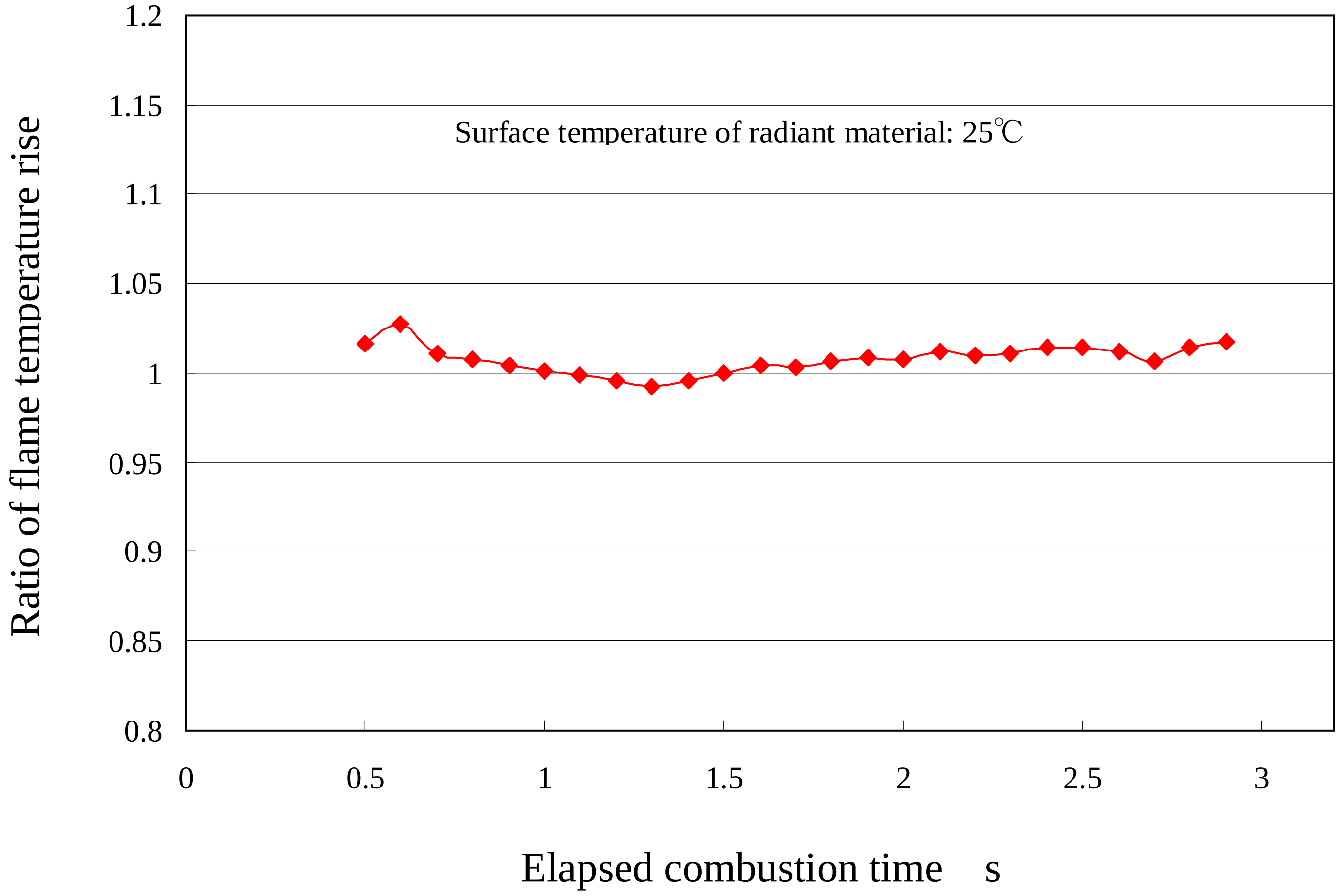


Fig.17. Time-variation ratio of flame temperature rise of fuel droplets of bunker oil A.

Table 4. Combustion lifetime and its reduction percentage of n-heptane

Surface temperature of radiant material ℃	25	35	45	55	65
Combustion lifetime Tw s (Presence of radiant material)	2.54	2.53	2.52	2.51	2.49
Combustion lifetime Two s (Absence of radiant material)	2.65	2.65	2.65	2.65	2.65
Reduction percentage of combustion lifetime Rt %	4.25	4.48	4.62	5.02	5.62

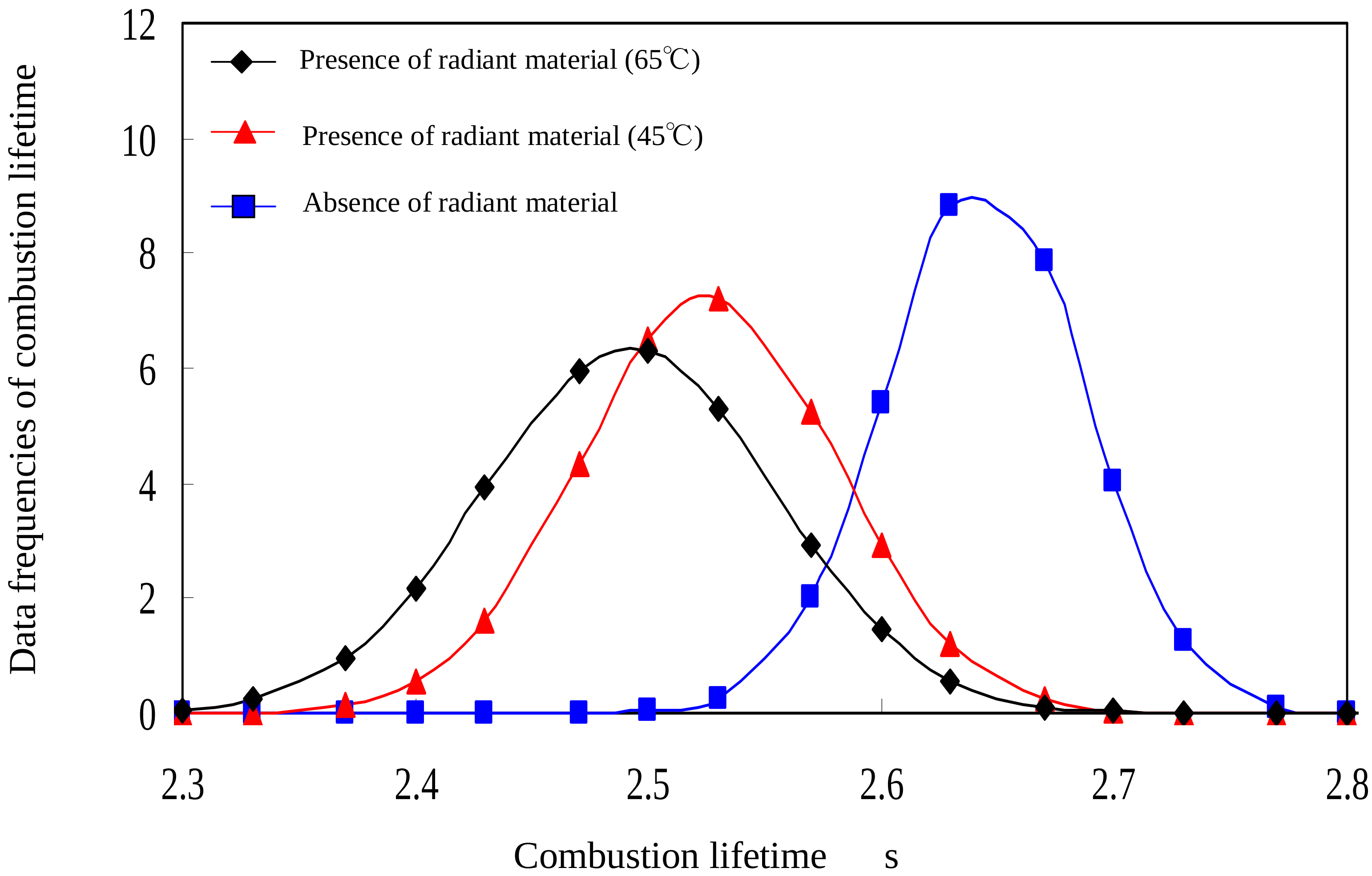


Fig. 18. Typical distribution of combustion lifetime of n-heptane droplets.

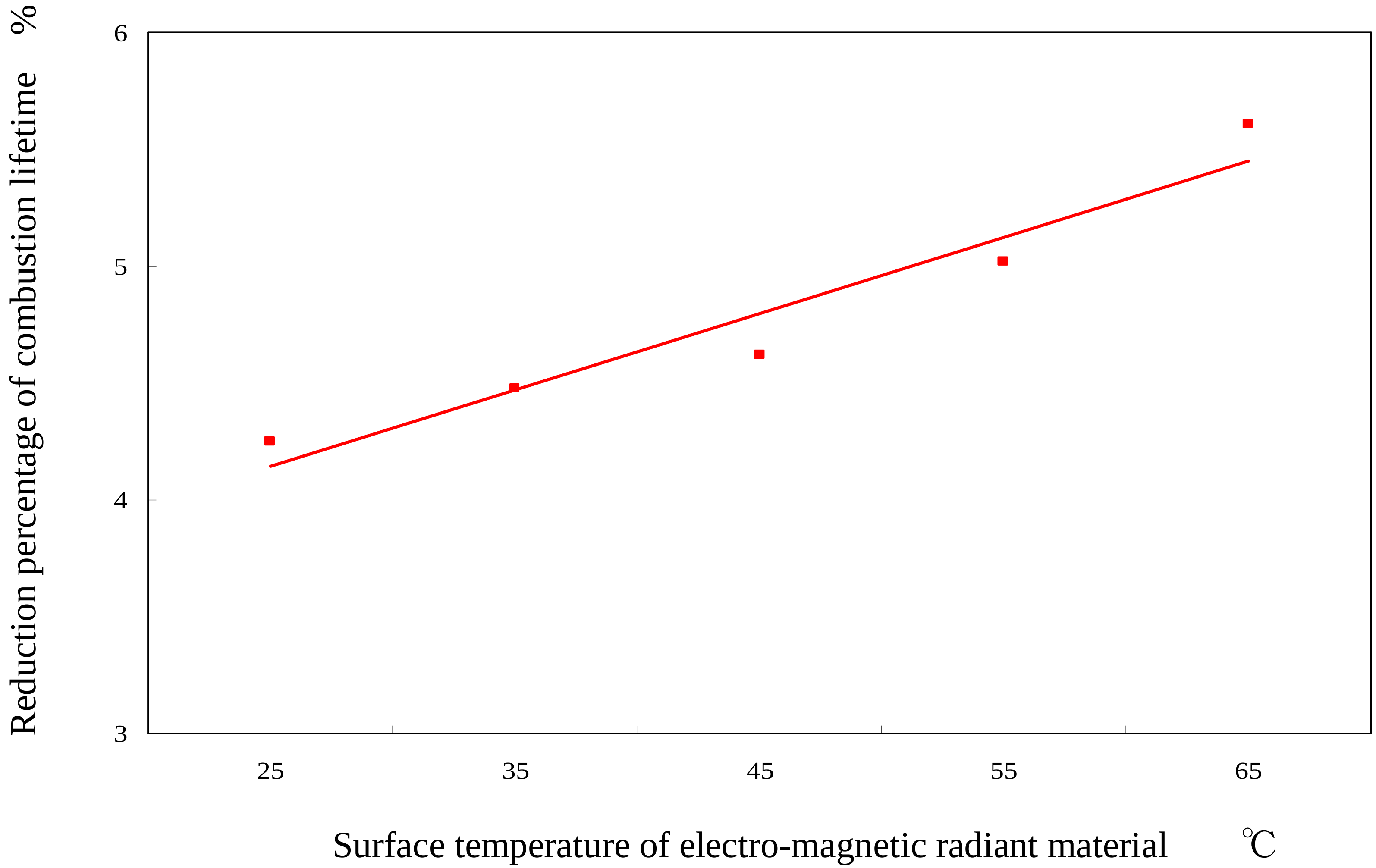


Fig.19. Reduction percentage of n-heptane droplet burning in electro-magnetic field.

Table 5. Ratio of temperature rise of n-heptane droplet burning in erector-magnetic field or not, respectively and energy sheet surface temperature is changed from 25℃ to 65℃

	Ratio of flame temperature rise
Absence of radiant material	1
Presence of radiant material(35℃)	1.033
Presence of radiant material (45℃)	1.038
Presence of radiant material (55℃)	1.042
Presence of radiant material (65℃)	1.069

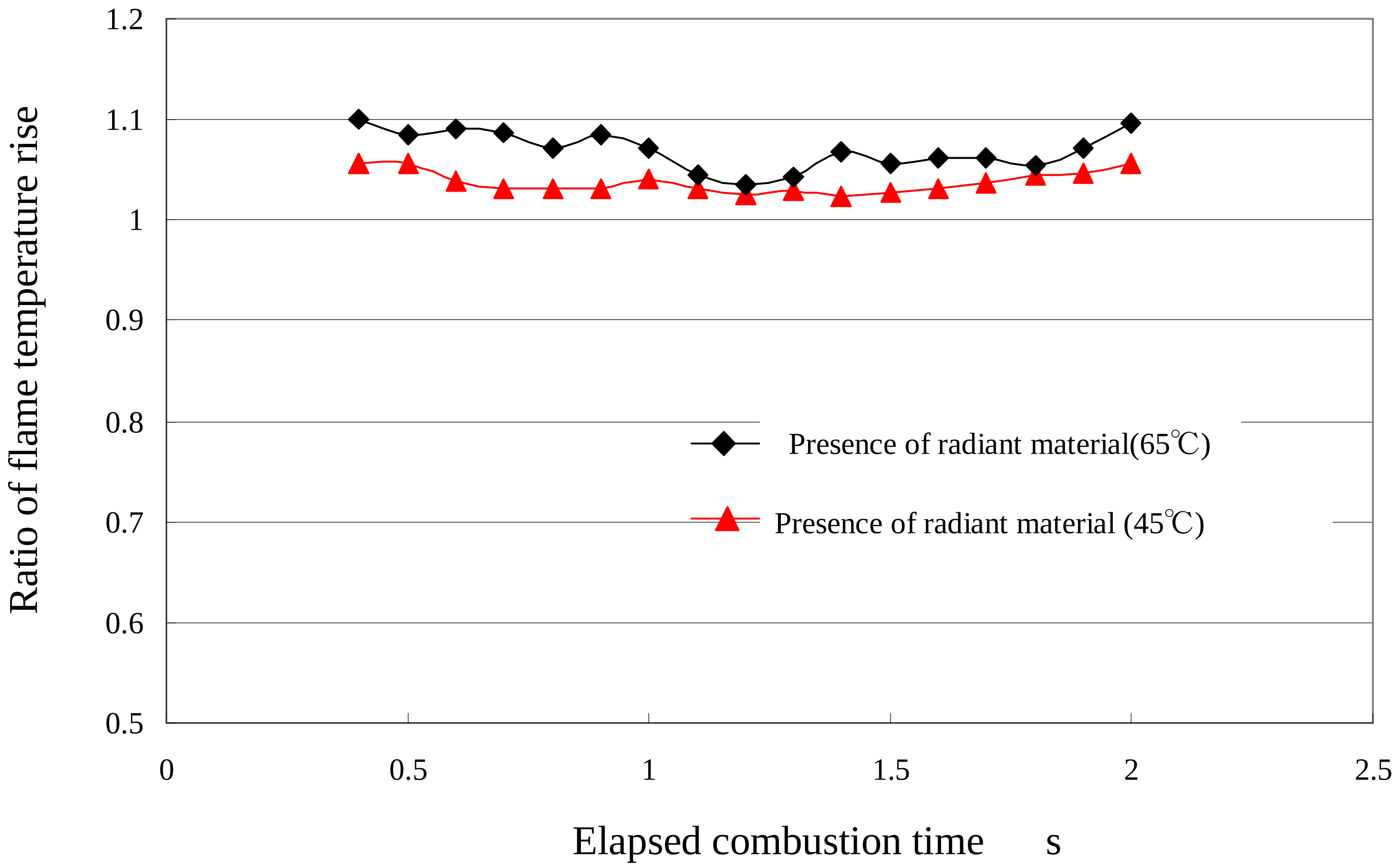


Fig.20. Time-variation ratio of flame temperature rise of n-heptane droplets.

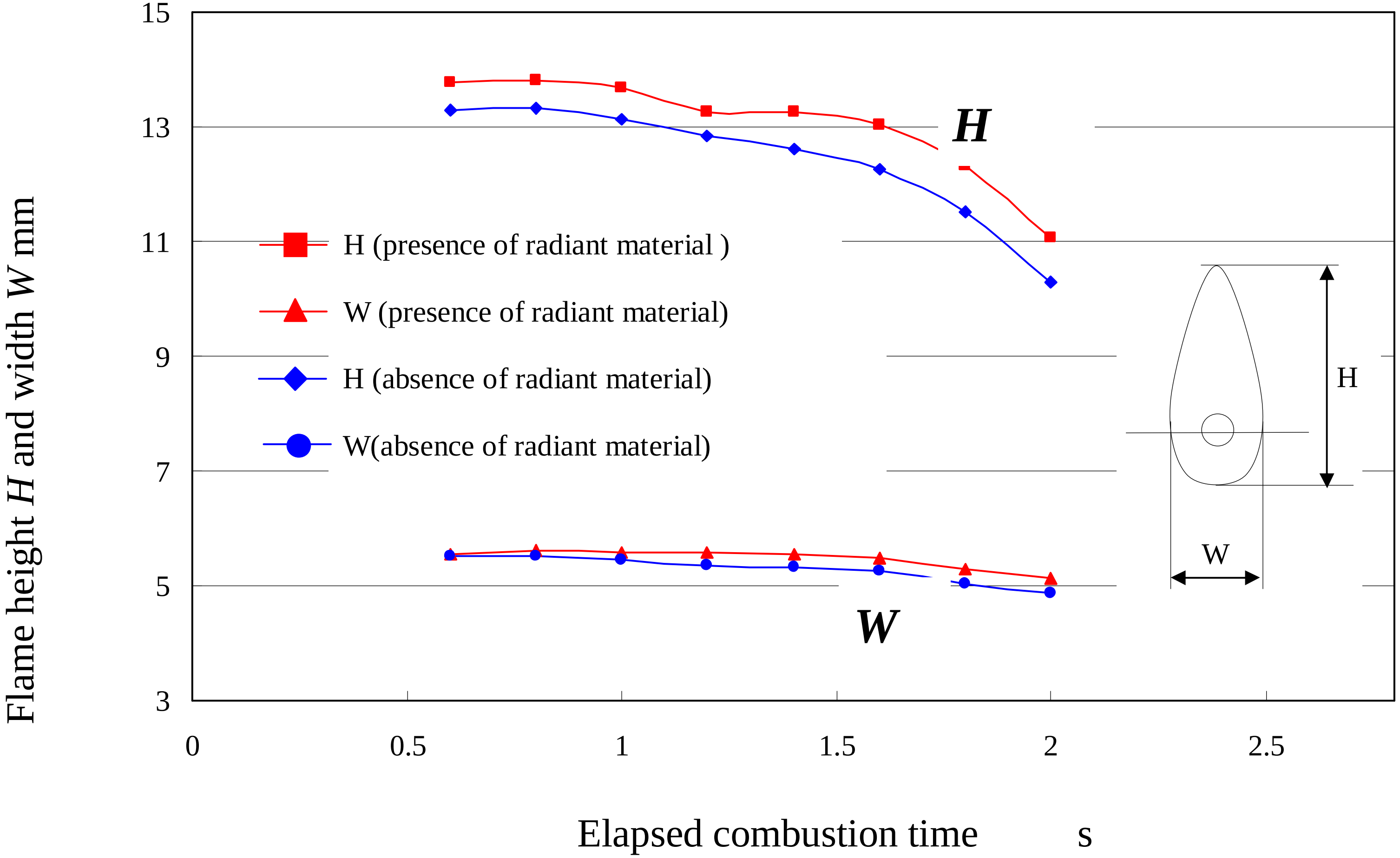
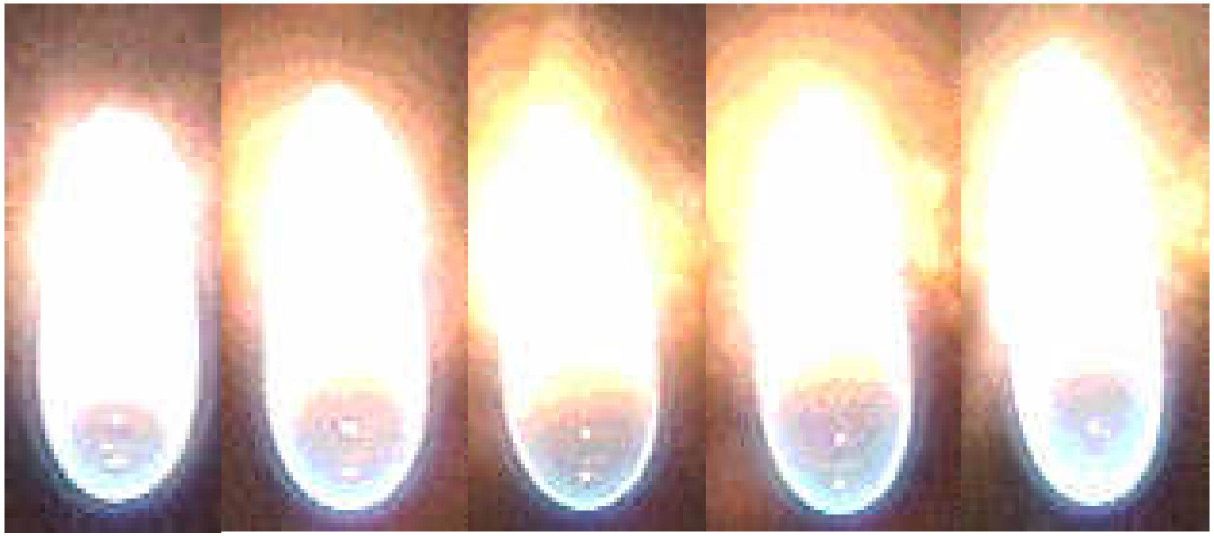


Fig. 21. The flame height H and flame width W of n-heptane droplets.



0m/s 0.15m/s 0.25m/s 0.35m/s 0.45m/s

Fig.22 Combustion behavior of single fuel droplets at various air velocities（n-heptane）

Table 6. Reduction percentage of combustion lifetime of single fuel droplets of n-heptane at various air velocities

Uniform air velocity cm/s	0	0.15	0.25	0.35	0.45
Combustion lifetime Tw s (Presence of radiant material)	2.54	2.49	2.37	2.23	2.16
Combustion lifetime Two s (Absence of radiant material)	2.65	2.59	2.46	2.39	2.26
Reduction of combustion lifetime Rt %	4.25	4.04	3.90	3.96	4.31

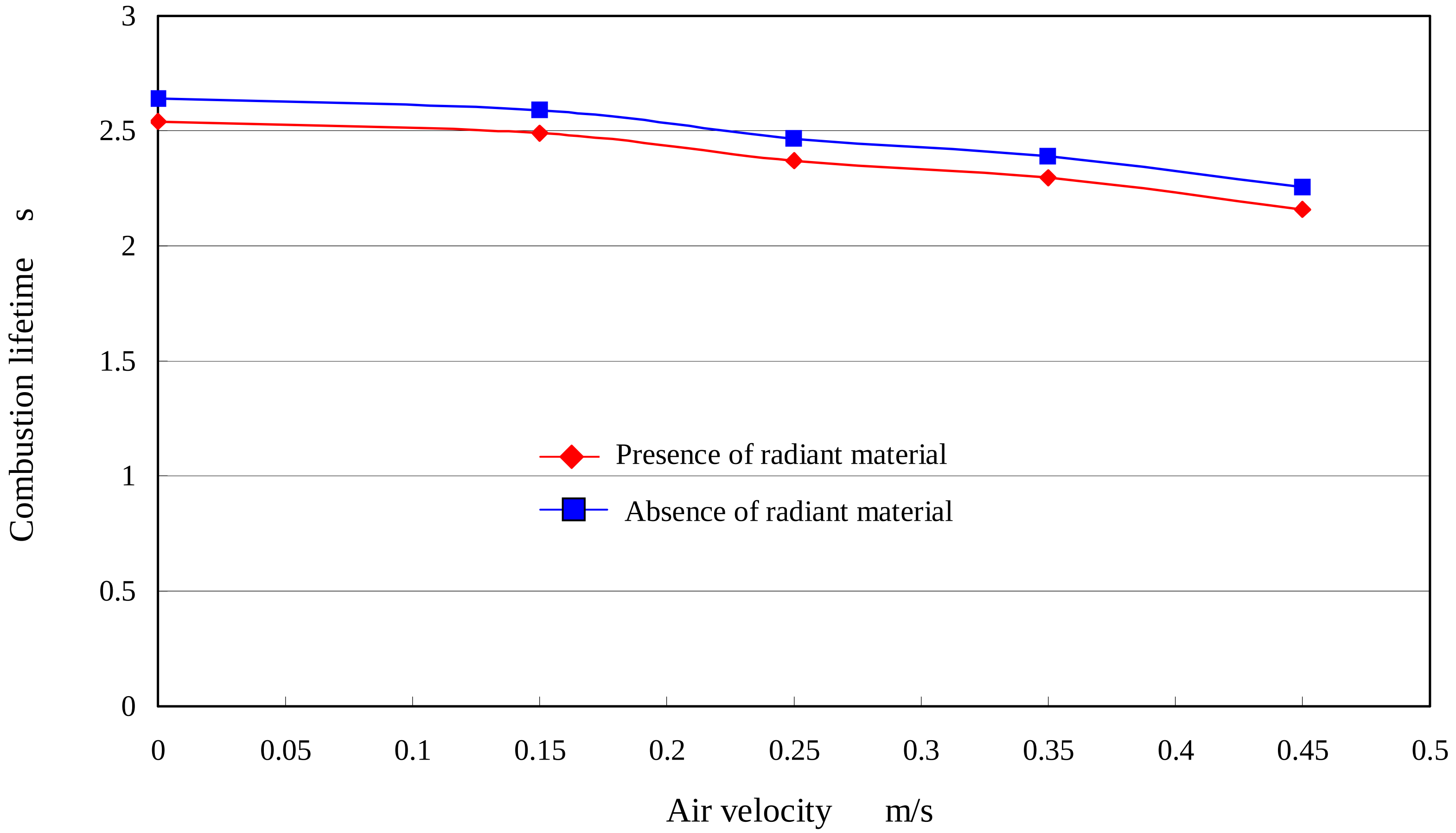


Fig.23 Combustion lifetime of single fuel droplets of n-heptane at various air velocities

Publication paper

（１）
論文題名
和文：特定波長領域電磁波放射エネルギーによる単一燃料液滴の燃焼促進について
英文：Combustion Promotion of Single Fuel Droplets by Electro-Magnetic Wave
発表者：臼井　清人・岡島　敏・高橋　清太郎・図子　修・小山　勝
論文発表年月：2006 年 3 月
論文発表誌名：北陸信越支部 第４３期総会・講演会 講演論文集

（２）
論文題名
和文：電磁波雰囲気中での単一燃料液滴の燃焼に関する研究
英文：Combustion of Single Fuel Droplets in Electro-Magnetic Fields
発表者：臼井清人､岡島敏
論文発表年月：2006 年 9 月
論文発表誌名：日本機械学会 2006 年度年次大会 講演論文集

（３）
論文題名
和文：ある特定波長電磁波雰囲気中での燃料液滴の燃焼挙動について
英文：Combustion Effect of Liquid Fuel Droplets in Electro-Magnetic Energy Field
発表者：臼井清人､岡島敏、高橋　清太郎
論文発表年月：2006 年 12 月
論文発表誌名：第 44 回燃焼シンポジウム 講演論文集

（4）

論文題名

和文：遠赤外線領域のある特定波長の液体燃料液滴への照射による燃焼促進効果について

英文：Combustion Promotion of Liquid Fuel Droplets by Discharge of Electric-Magnetic Energyin Far Infrared Ray

発表者：臼井清人､岡島敏、高橋　清太郎

論文発表年月：200７年９月

論文発表誌名：日本機械学会 2007 年度年次大会 講演論文集

（5）

論文題名

和文：流れ場におけるある特定波長電磁波環境での燃料液滴燃焼挙動の観察について

英文：Experimental Observation on Combustion Behavior of Liquid Fuel Droplets Burning in Electro-Magnetic Fields Under the Force Convection

発表者：臼井清人､岡島敏、高橋　清太郎

論文発表年月：2007 年 12 月

論文発表誌名：第 45 回燃焼シンポジウム 講演論文集

(6)

論文題名：Experimental Observation on Combustion Behavior of Liquid Fuel Droplets Burning in Electro-Magnetic Fields at the Regime of Far Infrared Ray

発表者：臼井清人､岡島敏、Amit Lal、岡島　明子

論文発表年月：2007 年 12 月

論文発表誌名：HIGH ENERGY MATERIALS CONFERENCE & EXHIBIT-2007