(6) Burning Characteristics of Kerosene

Kerosene was burned as a reference material. Kerosene has a higher HRR_{avg} (632 kW/m^2), MRL (0.11 g/s), $\dot{q}_f''$ (1.30 kW/m^2), and k (2.58 1/m) than any of the crude oils. However, the smoke yield (0.064) is lower. This can be explained by the fact that the MRL of kerosene approximately two times higher than those of experimented crude oils, while the difference in k values is much smaller. The correlations between different combustion characteristics and density established on the basis of the crude oil data can be extended to kerosene.

4. CONCLUSIONS

Small-scale free-burning pool fire experiments were conducted to obtain the combustion characteristics of various crude oils. The main results are as follows.

(1) Heat release rate, radiant heat flux from the flame, and smoke yield are a function of the type of crude oil and appear to correlate well with crude oil density. The effective heat of combustion is almost constant for the range of crude oils experimented.

(2) Tendency of boilover is dependent with distillation property of crude oil.

Additional intermediate or large scale experiments are needed to extend the validity of these correlations to real size fires, so that they can be used to develop improved methods for fire protection of crude oil storage facilities and suppression of crude oil tank fires.

REFERENCES

1. Environment Canada, A Catalogue of Crude Oil and Oil Product Properties (1992 Edition), 1993
2. Petty, S. E., "Combustion of Crude Oil on Water," *Fire Safety Journal*, 5, p.123, 1983
3. Mulholland, G., V. Henzel, and V. Babrauskas, "The Effect of Scale on Smoke Emission," *Fire Safety Science*, 2, p.347, 1989
4. Huggett, C., "Estimation of Rate of Heat Release by Means of Oxygen Consumption Measurements," *Fire and Materials*, 4, p. 61, 1980
5. Natsume, Y., H. Koseki, T. Hirano, and T. Takahashi, "Large Scale Crude Oil Fire Experiments - Outline and Procedure of the Experiments," *14th UJNR Panel Meeting on Fire Research and Safety*, Tsukuba and Tokyo, June 1998
6. Burgess, D. S., A. Strasser, and J. Grumer, "Diffusive Burning of Liquids in Open Trays," *Fire Research Abstracts and Review*, 3, p.177, 1961
7. Modak, A.S., "The Burning of Large Pool Fires," *Fire Safety Journal*, 3, p.177, 1981
8. McCaffrey, B.J., "Combustion Efficiency, Radiation, CO and Soot Yield from a Variety of Gaseous, Liquid, and Solid Fueled Buoyant Diffusion Flames," *22nd Symposium (International) on Combustion*, the Combustion Institute, Pittsburgh, PA, p.1251, 1988
9. Technical note of Idemistu Oil Co., Crude Oils and Their Distillation Data, 1996

A Study of Full-scale Flammability Test of Flame Retardant and Non-Flame Retardant Curtains

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ABSTRACT

Fabric products such as curtains and bedclothes play an important role for fire propagation in an early stage of fire. However the flame retardant standard test currently used in Japan for such fabric material pays more attention to ignitability than flammability and any other characteristics of combustion. In this study, the full-scale burning test of curtains was conducted by using a room calorimeter to obtain basic information for future flammable test development associated with fabric products. Prior to the experiment, a set of ignition heat source model is introduced from wastebasket fire tests, i.e. 50kW for 5 min and 30kW for 10 min. The heat release rate of various kinds of curtains are examined under different ignition heat source conditions. Some discrepancies of test results between the full-scale and the present standard flame retardants test are found. These are caused by thermal characteristics of fabric material such as melting and shrinking. To develop new evaluation test methods, these characteristics should be taken into account.

KEYWORDS: flammability, fire, fabric material, full-scale test, curtain, combustion, flame retardant

INTRODUCTION

In the beginning of building fires especially for residential fires, fabric products such as curtains and bedcloths play an important role for fire propagation because of latent risk of ignitability, flammability and its large surface area which causes fire propagation widely. Some of those fabric material are processed with various flame retardant (FR) treatments, and adoption of these FR material in certain locations such as in high-rise buildings is enforced by the Japanese Fire Service Law

However the present flame retardant standard tests in Japan for such fabrics mainly evaluate ignitability by using a small pilot flame like a tobacco but hardly evaluate flammability, fire propagation, heat release rate and combustion products etc. From the viewpoint of fire safety, performance of FR fabrics is expected to be evaluated in more detailed items as expressed above. For this decade, conecalorimeter test has been getting popular for evaluating risk of various material in fire and now it is expected to be the international standardized test. We utilized the conecalorimeter test for FR retardant fabrics, and some discrepancies were found between the test results obtained by the conecalorimeter and the existing Japanese standard test as reported in the past [1]

Our final goal of this study is to develop rational bench scale tests for FR fabric material by using the conecalorimeter. Before accomplishing this object, the relation between the results obtained by full-scale, the bench scale and the present standard tests should be examined. In this study, full-scale burning tests for FR curtains are conducted. The reason why we select the curtain as one of the typical fabric products is that curtain fires are often observed in residential fires and those allow fire propagation rapidly to a ceiling and cause flash over. Prior to the burning test of curtains, a small wastebasket fire scenario is examined, and a set of model is proposed.

FIRE SCENARIO AND IGNITION HEAT SOURCE MODEL

Fire scenario for full-scale fire tests of curtain

The reasonable fire scenario based on an ordinary daily life situation is very important for full-scale fire tests to evaluate fire risk of flammable material. It is because the flammability performance is relatively sensitive to shape, layout positions, i.e. horizontal and vertical, and external thermal radiation conditions. Also fire propagation of such fabrics highly depends on its thermal decomposition characteristics such as shrinking, melting and dripping. Some of fire scenarios are examined prior to the full scale test from fire statistics, and a typical and simple fire scenario for curtains is adopted, such as " the tested curtain is suspended just adjacent to a wall surface, and fire starts from a wastebasket just below the curtain and fire spreads up from the bottom edge".

Based on fire statistics in Japan [2], the most frequent ignited material is cooking oil for *tempura* (3,419 fires in 17,536 residential fires: almost 20%), and the second one is bedclothes (1,750 fires in 17536 residential fires: almost 10%). Also both of dust and wasted papers are major ignited items summed up to 15% (2,496 fires). Almost all cooking oil fires occur in kitchens, however fire spreading to fabric material seldom happens, because the fire risk in kitchens is well recognized and such items like curtains are not used near cooking ranges. On the other hand, the fire scenario from bedclothes' fire to a curtain can be anticipated. However, in this case the intensity of fire of bedclothes is equal to or more than that of curtain fire and latent risk of curtain fire itself is relatively small. Finally we adopted a wastebasket fire as one of realistic ignition heat sources to the curtain.

Some of the heat release rate data of wastebaskets fire were reported in the past. Those values depend on quality and quantity of the wastebaskets themselves, and inside contents as well. In general, the peak heat release is reported to be in the range between 20 kW to 50 kW [3][4]. Recently plastic wastebaskets having high heat release is getting popular in many residents, however the available data of those plastic wastebaskets fire are very limited. For this reason, we conducted a series of wastebasket experiments prior to full-scale curtain fire tests to model the ignition heat source.

TABLE 1. List of wastebaskets tested to model ignition heat source for full scale curtain burning test

No.	Diameter × height [mm]	Volume [little]	Weight [g]	Materials (Heat per unit weight [kJ/g])		Total Heat Release [MJ]
1	ϕ235×H291	6.6	333.1	Polyethylene	(43.28)	14.4
2	ϕ247×H315	9.8	386.3	Polypropylene	(43.31)	16.7
3	ϕ195×H265	6.5	528.6	Regenerated Polystyrene	(39.85)	21.1
4	ϕ273×H345	11.8		Galvanize Steel		

Contents : A. Paper tissues (desiccated during over 24 hours) :Almost 1/2 of paper tissue box.
100 sheets : 113g : about 1.8MJ (estimated as cellulose)
B. Foamed polystyrene trays
size : 195×94×h18mm, 30sheets : 88.6g : 3.5MJ

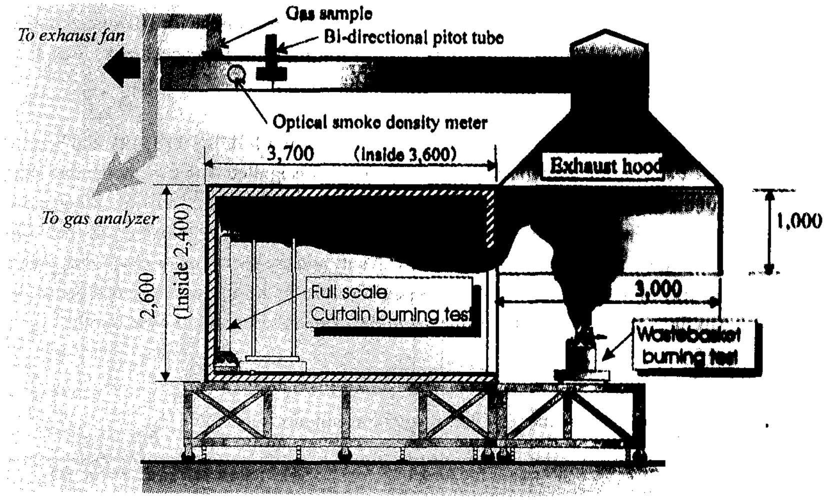


FIGURE 1 Schematic of experiment by using room calorimeter

Wastebasket test samples and experimental set up

Total four kinds of wastebaskets (three of which are made of different kinds of plastic and one is made of steel) filled with two different contents are selected from prevailed products as shown in TABLE 1. One of the contents is 30 sheets of food trays made of polystyrene foam, and the other is 100 sheets of tissue papers The wastebaskets are burnet under the exhaust hood equipped for the room-calorimeter based on ISO9705 [5] standard as shown in FIGURE 1. Expected magnitude of heat release rate is less than 1/10 of heat release rate obtained by standard room fire test, so exhaust volume rate is reduced to 3,000 m^3/h (about 1/4 of the standard exhaust rate). The heat release rate of wastebasket fire is estimated by two ways. One is oxygen consumption method, and the other is estimated by weight loss rate measured by using a high resolution electric balance meter (resolution is 0.05 g). Prior to each test run, the oxygen consumption measurement was calibrated by using a 30cm diameter methanol pool fire of almost 30 kW. Weight loss data is sampled every two seconds and 10 sec. time averaged data is used for estimating heat release rate by multiplying heat release per unit weight.

Results and Fire Model

FIGURES 2 and 3 show time curves of the heat release rate for each wastebasket burning test. Major heat release rate data including peak heat release rate are indicated in TABLE 2. As for the oxygen consumption method, the out put data have time delay compared with weight loss data due to gas sampling. In these figures, such a time rag is offset. In general, estimations of heat release rate by oxygen consumption method and weight loss method agree except in the case of regenerated polystyrene one, of which accurate heat release value is not available. The discussions on heat release rate below are based on the data obtained by the oxygen consumption method.

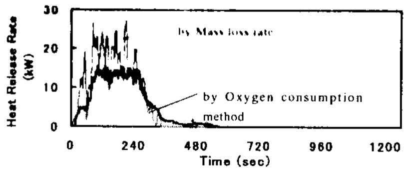
FIGURE 2(a) and 3(a) show the heat release rate of contents inside a steel wastebasket. The heat release rate in this case becomes lower and burning duration becomes longer than the counterparts in a case of open fire due to the air inflow limitation. Both of the burning continue for 10 minutes and the average heat release rate is 7 kW for tissue papers, 13 kW for plastic trays respectively, which are proportional to total heat release of the contents.

Heat release rate of each plastic wastebasket itself is expressed in FIGURE 2 (b)-(d) and 3(b)-(d) with fine dash line. Each plastic wastebasket without contents was ignited with a methenamine tablet set at the bottom of the side wall. In almost all cases, plastic wastebaskets burn well after the side wall melts which makes airflow inlet. Only the regenerated polystyrene wastebasket tends to be self-extinguished after the ignition, because of its large heat capacity and less thermoplasticity. Once plastics melted into a base tray of 30 cm square, it burnt as pool fire and the heat release rate reached to 35 - 50 kW, which was three to four times higher than tat in the case inside contents were burnt.

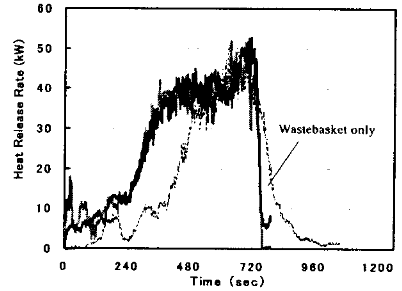
TABLE 2 Results of heat release rate (by the oxygen consumption method)

Run No.	Contents	Material of waste-basket (*1)	T - square fire model: A [$\times 10^{-4}$ kW/sec^2]	t_b [sec]	*(time period for obtaining least square regression [sec])*	Heat release rate in developed fire: Averaged heat release rate [kW] *(time period: during Δt_p [min:sec] from t_{p0} [sec])*	Peak heat release rate [kW] (time [sec])
1	None	PP	2.7	16	*(248-514)*	40.4 *(3:14' from 564)*	50.3 *(656)*
2		PE	4.7	93	*(330-468)*	37.1 *(1:20' from 590)*	43.9 *(636)*
3		PS	1.0	4	*(36-340)*	30.9 *(3:40' from 442)*	36.2 *(560)*
4	Polystyrene Foam tray	ST	19.3	9	*(234-369)*	13.3 *(2:42' from 88)*	15.5 *(98)*
5		PP	4.3	66	*(430-736)*	41.9 *(5:06' from 430)*	52.9 *(714)*
6		PE	1.5	15	*(458-698)*	44.4 *(4:00' from 458)*	55.3 *(674)*
7		PS	1.4	380	*(424-754)*	36.3 *(5:30' from 874)*	43.2 *(1042)*
8	Paper Tissue	ST	N.A	N.A	N.A	6.6 *(3:58' from 30)*	8.2 *(234)*
9		PP	2.7	101	*(228-290)*	35.8 *(2:40' from 698)*	41.8 *(820)*
10		PE	2.8	358	*(408-664)*	28.7 *(6:34' from 672)*	34.0 *(1028)*
11		PS	N.A	N.A	N.A	21.8 *(6:40' from 692)*	26.1 *(992)*

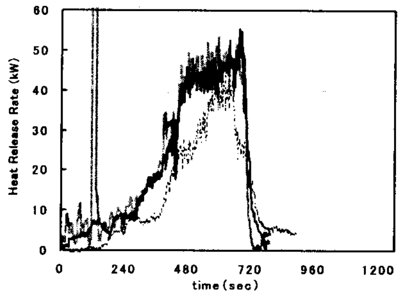
**1: ST: Steel, PP : polypropylene, PE : Polyethylene, PS : regenerated Polystyrene*



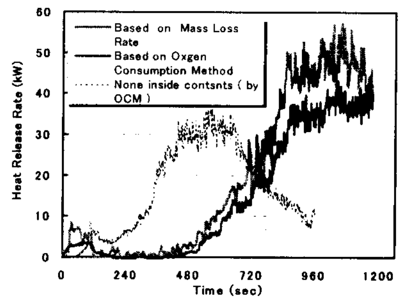
(a) Steel with foamed PS trays



(b) Polyplopylene with foamed PS trays

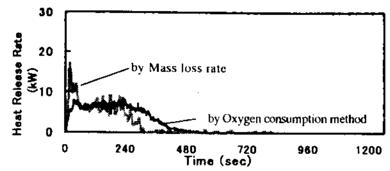


(c) Polyethylene with foamed PS trays

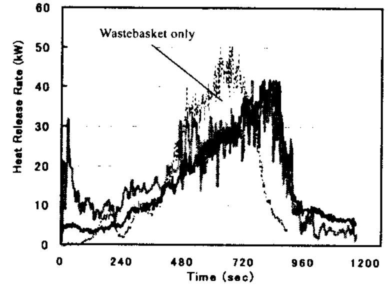


(d) Polystylen with foamed PS trays

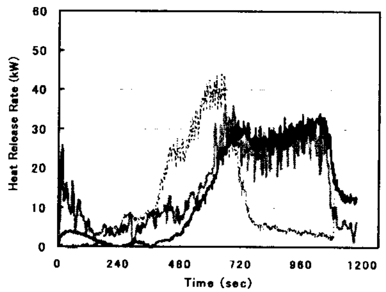
FIGURE 2 Heat release rate of wastebasket fire
(Contents : Foam polystyrene trays : 30 sheets)



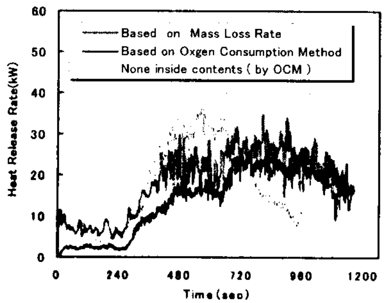
(a) Steel with tissue papers



(b) Polyplopylene with tissue papers



(c) Polyethylene with tissue papers



(d) Polystylen with tissue papers

FIGURE 3 Heat release rate of wastebasket fire
(Content: Tissue papers : 100 sheets)

FIGURE 2 (b)-(d) show the heat release rate of each plastic wastebasket with polystyrene foam food trays. The average peak heat release rate increases by about 4% in polypropylene, 13% in polystyrene, 17% in regenerated polystyrene wastebaskets compared with the heat release rate of wastebasket fire without contents. This indicates that the inside content burning does not accelerate wastebasket burning, and total heat release rate can be expressed by simple algebraic additions of wastebasket's and content's heat release rate.

Whereas the heat release rate with tissue papers decreases by about 20%, 25%, 35% respectively and burning duration becomes longer as shown in FIGURE 3(b)-(d). In spite of the increase of total heat release with tissue papers, the heat release rate is mitigated due to thermal insulation effect and obstruction of thermal radiation feedback from flame by charred residual of papers.

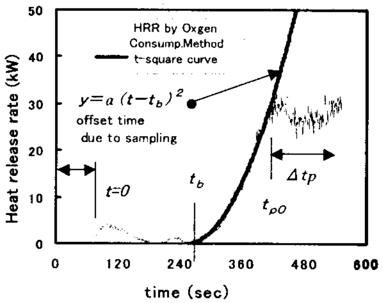
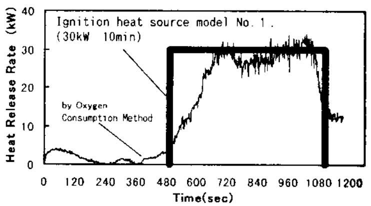


FIGURE 4 T-square fire model

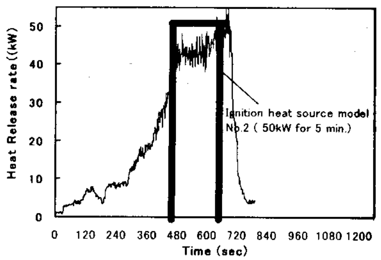
Ignition heat source model

Time - square fire model expressed by $Q_f = a\,(t-t_b)^2$ (where Q_f is heat release rate [kW], t is time [sec] t_b is offset time [sec] and a is experimental coefficient [kW/sec^2]) is proposed as fire growth models in early stage as shown in FIGURE 4. The test results indicate that this t-square fire model can be applicable except paper tissue contents fire as shown in TABLE 2.

The value of the coefficient a is almost 1/10 of the value of existing model used for automatic fire detection prescribed in NFPA72E[6], i.e. $a = 2.9 \times 10^{-3}$ in the case of slow fire growth. And the offset time varies between each test and no remarkable correlations are found. This t-square fire seems to be convenient for mathematical predictions but not practical as full-scale ignition heat source model for curtain combustion.



(a) 30 kW model



(b) 50 kW model

FIGURE 5. Ignition heat source model proposed

Finally we specified two following simple models as ignition heat source as indicated in FIGURE 5., i.e.

" No.1: 30kW during 10 min. as lower heat source,
No.2: 50kW during 5 min as higher heat source"

The fire area is supposed to be 30cm square or 17 cm square. The latter 50 kW fire model does not include t-square patr, because we consider that the higher peak region is significant as ignition and also simple model is needed.

FULL SCALE FIRE TEST FOR CURTAIN

Present standard tests for the FR fabric material in Japan mainly are [illegible] mentioned above. Further synthetic test methods will be needed for [illegible] effective fire safety evaluation system. Before developing such a system, the [illegible] full-scale and bench scale test data should be examined. Some of the [illegible] reported [7], however more data of various material by using both full-[illegible] are still needed. In this study, we conducted full-scale fire tests of FR and non-[illegible] the model ignition heat source as introduced above, and the useful information [illegible] as follows.

Curtain test samples and experimental set up

Total eight kinds of curtain samples are selected, i.e. sets of FR and non-FR rayon, cotton (*kanpachi* velveteen) and polyester, acrylic and modacrylic curtains. TABLE 3 shows the characteristics of each test sample and the flammable ratings by the present 45 degree flame retardant test according to the Fire Service Law. Test sample size is of 2m (length) x 0.9-1.2m (the width depends on the curtain cloths) cut from a roll of curtain cloth (width 0.9-1.2m, length 40m). Prior to each test run, these samples are dried in 50 deg.C electric dryer for 24 hours and cooled in the desiccator for more than 2 hours.

A fire room for the ISO9705 [5] is used for this full scale experiment. The test curtain is hung at the center, about 10 cm apart from the back wall surface, just opposite to the entrance opening. A sand burner of propane fuel is set at 5 cm below the bottom end of the curtain as shown in FIGURE 1 and 6. Two sizes of

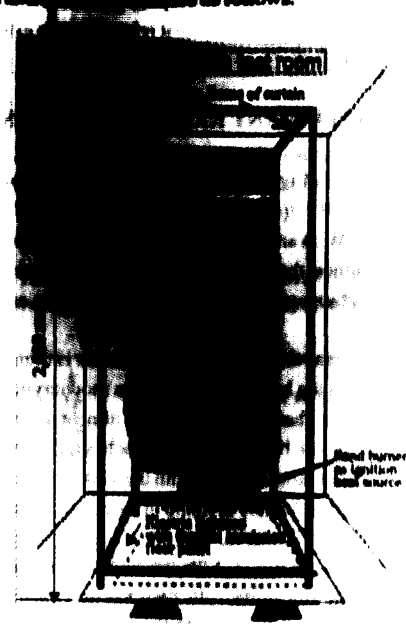


FIGURE 6 Schema of curtain fire test : location in the fire room is indicated in FIGURE 1

TABLE 3 List of test samples of curtain

Test No.	Material of textile	Woven pattern	Weight (g/m²)	Rating by flame retardancy test	Test No	Materials	Woven pattern	Weight (g/m²)	Rating by flame retardancy test
1	Cotton (flammable)	Dobby cloth	217	Fail	5	Acrylic	Jacquard cloth	241	Fail
2	Cotton (non-flammable)		260	Pass	6	Modacrylic (*1)		[illegible]	Pass
3	Rayon (flammable)	Jacquard cloth	351	Fail	7	Polyester (flammable)	Jacquard cloth	[illegible]	Fail
4	Rayon (non-flammable)		337	Pass	8	Polyester (non-flammable)		[illegible]	Pass

*cf (*1) Acrylic synthetic fibers are polymers primarily composed of the acrylonitrile monomer more than 50 wt%, whereas polymers composed of the monomer between 40 to 50wt% is expressed as "Modacrylic" in this paper, which corresponds to non-flammable Acrylic fibers.*

square burner, i.e. 17cm and 30cm are used as
external ignition heat source. Two kinds of ignition heat source models introduced from plastic waste-basket fire test and an additional lower heat level fire are adopted, i.e. 30 kW for 10 minutes, 50kW for 5 min. and 10kW for 10 min.

The major measurement item is heat release rate by the oxygen consumption method, carbon monoxide yield, optical smoke density, ceiling temperature and weight loss etc., and these data are recorded by a data recorder every two seconds. Prior to each test, the heat release rate measurement is calibrated with the propane gas burner. The heat release rate of the external ignition heat source is subtracted from total heat release rate to estimate the heat release rate of curtain burning.

EXPERIMENT RESULTS AND CONSIDERATIONS

Effect of ignition heat source area on heat release rate

FIGURE 7(a) shows the heat release rate of a rayon curtain under different size ignition heat source of 30 kW as an example. This indicates that once the curtain is ignited, the time curve of heat release rate is almost the same under different ignition heat source area conditions. The same burning behavior can be observed in the cases of cotton, rayon and polyester curtain made of both FR and non-FR fabrics.

Whereas the remarkable difference is found between acrylic and modacrylic curtain. FIGURE 7(b) shows the heat release rate of a modacrylic (FR rating) curtain burning with the 30kW ignition heat source. The heat release rate is almost none with 30 cm square burner, while it reaches to 50 kW in 90 seconds after ignition with the 17cm square burner. Similar tendency is found in the acrylic curtain with 10 kW heat source. This result seemed to be caused by thermal shrinkability of the fabric material. The acrylic and modacrylic fiber has the characteristics to be shrunk by heat. Therefore additional special tests so-called "45 degree angled loose test", in which characteristic of shrinking is taken into account, is applied for such fabric material by Fire Service Law.

In this experiment, flame length of the 17cm square burner is longer than that of the 30cm burner under the same heat release rate condition. Once the curtain shrunk with heat, shorter flame of the 30cm square burner does not reach the curtain to continue burning.

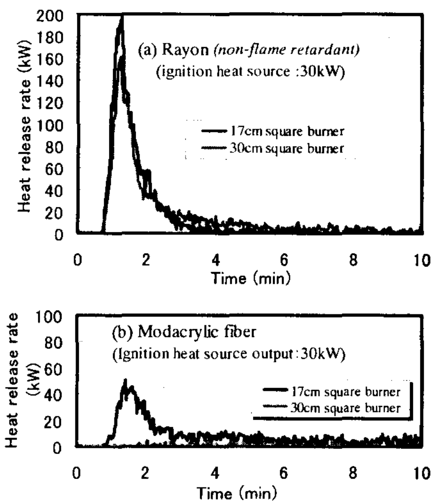


FIGURE 7 Heat release rate of non-FR and FR curtains under different heat source area

As for polyester, the thermal characteristic is similar to that of acrylic and modacrylic fiber, i.e. melt by flame. Especially polyester is easy to melt and to drip, when it is exposed to flame. In the experiment, it melted and dripped during a very short period just after ignition, however main part of the curtain did not continue to burn. Therefore the effect of fire area is not confirmed.

Effect of ignition heat source intensity on curtain combustion

FIGURE 8 shows the heat release rate of the non-FR cotton curtain under different ignition heat source intensity of 10 kW, 30 kW and 50 kW with the 30 cm square burner. It indicates that the peak heat release rate of curtain fire is proportional to the external ignition heat output. This tendency is recognized in cases of FR and non-FR of rayon, cotton, and also this can be often observed in the conecalorimeter tests for ordinary combustible material.

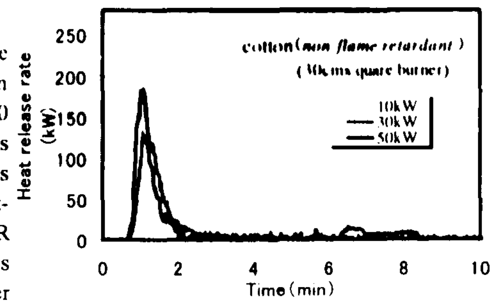


FIGURE 8 Heat release rate of non-flame retardant Cotton under different heat source output conditions

Usually external heat to combustion material promotes decomposition, and then it enhances heat release rate, however some of the FR curtains such as modacrylic fabric seems to more depend on area contacting to flame than the preheat decomposition effect. Because those material need higher heat input to continue burning. Further research is needed for understanding this effect. Both of FR and non-FR polyester curtains do not continue to burn under 10 kW to 50 kW ignition heat source like wastebasket fire due to melting and dripping phenomena.

FIGURE 9 shows the heat release rate of acrylic and modacrylic curtains under different heat sources. It indicates that the threshold for fire spread is in the range between 10kW and 30 kW for acrylic, and 30kW and 50 kW for modacrylic.

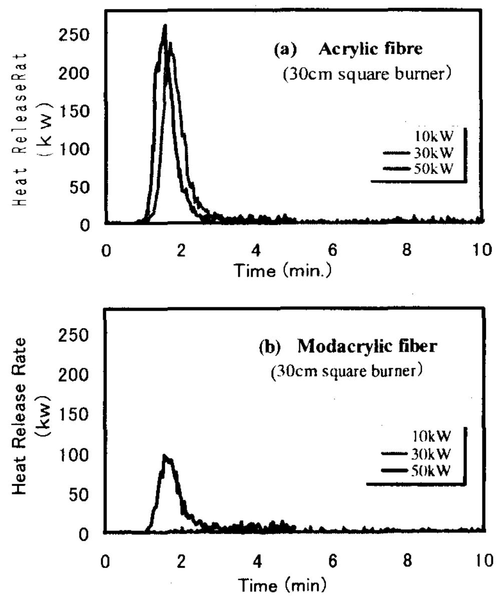


FIGURE 9 Heat release rate of acrylic and modacrylic curtain under different heat source output conditions

Heat release rate of different fabric material

The peak heat release rates of different fabric material under different external ignition heat source are shown in FIGURE 10. In general, the peak heat release rate of FR curtain burning is less than 1/10 of that of non-FR curtains. This indicates that FR curtains have quite less risk in the early stage of fire. However polyester curtain of non-FR treated, which is very popular fabric material, tends to melt and drip by the ignition sources adopted in this experiment, and does not cause fire propagation. The rating test currently used does not evaluate such a phenomenon.

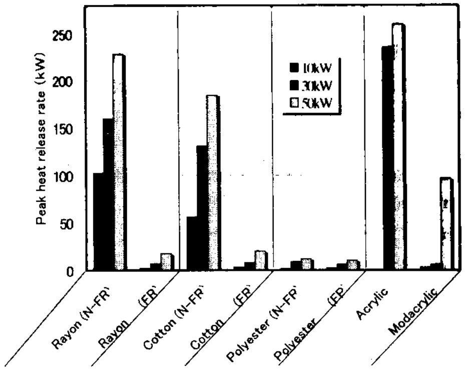


FIGURE 10 Peak heat release rates of curtain made of different material.

The order of the peak heat release rate of each material changes under different ignition heat output as follows.

10kW fire : " rayon (non-FR) = cotton (non- FR)>others"
Only nonflammable rayon and cotton curtains burn with 10kW fire
30kW fire : " acrylic> rayon (non-FR) = cotton (non-FR)>others"
Acrylic curtain burns well, once it is ignited with 30kW fire.
50kW fire: "acrylic>rayon(non-FR)=cotton (non-FR)>modacrylic >others"
Modacrylic curtain begins to burn with 50 kW ignition heat source.

The effect of the ignition heat source area on the peak heat release rate is distinguished on an acrylic curtain which is shrunk with heat as explained above, however such effect is not recognized in any other material.

CONCLUSIONS

The full scale experiment of curtain fire was conducted with a small ignition heat source by using a room-calorimeter to obtain basic information for future flammable test development of fabric material. Prior to the experiment, the ignition heat source modes are introduced by wastebasket fire tests, i.e. 50kW for 5 min and 30kW for 10 min. The relations between heat release rates of different material and the fire source conditions is examined. The followings are major knowledge obtained.

1. The areas of ignition heat source adopted in this study do not have big effects on heat release rate of curtain burning except acrylic and modacrylic which has thermal shrinkability. A 17cm square burner currently used in ISO9705 test is preferable for tests, because it gives higher heat release rate exposure for the shrinkable material.

2. In general, heat release rate of curtains increases as external heat source output increases. However this is not always applicable to flame retardant curtains. Further research will be needed.

3. A non-FR rating polyester curtain do not continue to burn, while modacrylic ones (corresponds to FR rating) continues to burn with small ignition heat source. The discrepancy between this full-scale test and present standard flame retardant test results is caused by thermal characteristics of fabric material such as melting and shrinking. For developing new evaluation test methods, these factors should be taken into account.

REFERENCES

[1] Suzuki T., YANAI E. and YAMADA T. "A Study on the Flammability of Non-Flame retardant and Flame-Retardant Materials by using Cone Calorimeter", Proceeding of International Symposium on Fire Science and Technology(ISFST'97) Nov.12 Seoul,Korea pp.85-92 1997

[2] Fire and Disaster Management Agency, "About Realities of Residential Fires", Report by the conference for promoting residential fire protection, 1997

[3] Mizuno T. "Burning Behavior of Furniture and Fitting", Japanese Assoc. of Fire Science & Eng., Handbook of Fire, the 3rd edition,p.864, 1997

[4] Babrauskas V.,"Burning Rates", The SFPE Handbook of Fire Protection Engineering, the ,Pst Edition.p.p2-1 - p.p2-15, 1988

[5] ISO, "Fire Tests – Full scale room tests for surface products", ISO-9705(1993(E))

[6] Evans D.,"Ceiling Jet Flows", The SFPE Handbook of Fire Protection Engineering, the ,Pst Edition.p.p1-138 - 1-145, 1988

[7] Moore L.D.,"Full scale Burning Behavior of Curtains and Drapes", NBSIR 78-1448, National Bureau of Standards, Washington (1978)