Evaluation of Garment Flammability using Thermal Mannequins

Y. UEHARA and M. UMEZAWA
Department of Safety Engineering
Division of Materials Science and Chemical Engineering
Faculty of Engineering
Yokohama National University
156 Tokiwadai, Hodogaya-ku, Yokohama 240, Japan

ABSTRACT

The flammability of garments was studied using thermal mannequins with sensors which were dressed in 73 sets of clothes commonly available in Japan. The results showed that all of them, except for 18 sets, were highly flammable and indicated a possibility of serious fire injuries within a short time. The maximum temperature and the maximum heat flux obtained on the body surface were 437°C and 335 kJ/m2 s, respectively. To evaluate the hazards, method of evaluation based on the burning rate, size and degree of fire injury plus a combination of these factors were proposed to be useful.

INTRODUCTION

Clothing, together with food and housing, is the most basic factor in our daily life and indispensable in maintaining protection of the body against cold weather and outer hazards. However, some garments are so flammable that a large number of casualties are the result of garment fires every year. Being aware of the hazards, several countries in the world have already established standards of flame proof garment which are centered on children's nightclothes, or restrictions have been placed on garments.

This paper intends to explain garment fires in Japan and to report on the classification of garment flammability based on tests using thermal mannequins dressed in everyday clothes.

GARMENT FIRES IN JAPAN

Of the 1,332 total deaths, except for suicidal arson, 130(9.8%) were caused by garment fires in 1978, according to the "Process to Death" in the White Paper on Fire Service (1). The death toll by garment fires accounts for 180(13.8%) of 1,301 deaths in 1979 and 141(11.4%) of 1,238 in 1980 (143(13.0%) of 1,096 in 1982 and 153(13.3%) of 1,152 in 1983). Of the 491 total deaths, except for suicidal arson, 50 are considered to have been caused by garment fires within the jurisdiction of the Tokyo Fire Department Agency during the five years from 1975 through 1979. This rate is almost equal to that in the White Paper on Fire Service (2). The rates consist of only the cases where clothes caught fire directly from a flame. If those cases of fires transferred by intermediaries are included, such as where a cigarette smoked in bed ignited bedding which then transferred to night clothes, or where leaked oil caught fire and spread to garments when an oil stove was accidentally overturned, the

death toll by garment fires amounts to 128 out of 491 deaths.

Of those total deaths, people over 61 and children under 10 account for 50.6% and 12.6%, respectively. Girls under 5 account for a remarkably high percentage among children.

EXPERIMENTS

Experimental Apparatus (Thermal Mannequins)

The mannequins employed in this study were those on the market and manufactured by FRP. Their surface was covered with an asbestos and cement mixture with a thickness of 5 to 10 mm to provide them with heat resistance. Heat conductivity of asbestos-cement is 1.67kJ/m h deg at 90°C, and is close to 1.80 to 2.72kJ/m h deg, which is the heat conductivity of human skin obtained at 23 to 25°C. Three types of thermal mannequins were designed: one with a height of 175cm for a male, one with a height of 166cm for a female and another with a height of 113cm for a child. To measure heat flux, a 0.3 mm chromel-alumel thermocouple was welded onto the center of 15 mm diameter and 1 mm thick copper-plates. The surface of these sensors was coated with black heat resistant paint to increase heat absorption. Eight such thermoplates were installed on the mannequin and their positions are shown in Fig.1. These thermoplates were calibrated using a black body radiation surface. Conducting wires of the thermoplates were taken out from the wrists and heels of the mannequins.

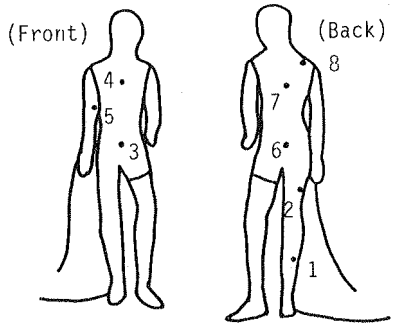

Fig. 1 A Thermal Mannequin (Male) and Position of Sensors

Samples

Generally, in burning tests the results are not always consistent even though the same samples are employed. Thus, tests are usually performed several times under the same conditions. However, since there are many types of garments, it is not possible to test all of them. This explain why relatively simple styled garments, such as nightclothes and A-line, one piece dresses, had mostly been used in past thermal mannequin tests (3-6,15). In the present tests, samples which cover as many types of garments as possible, ranging from nightclothes to suits including underwear, were selected and examined under the same conditions used every day. Detailed descriptions of the samples are omitted here due to the limitation of papers. However, care was taken to ensure that main fabrics, such as cotton, polyester, nylon, silk, wool and

acrylic fiber, were covered. The samples were brand-new and no special pretreatment was carried out.

Test Method and Items

The tests were carried out in a laboratory room with a floor space of $55m^2$ and 7.85m high. Air flow was generated by ventilating fans at a velocity of 0.2 to 0.3m/s at a position 1m above the floor from the left front to the right of a mannequin during the tests. Ignition was made on contact with a diffused flame for 10 seconds using a Bunsen burner charged town gas (46,000kJ/m3) at a velocity of 325ml/min. Ignition place were in principle: in trousers, the front bottom of the leg on which a sensor was installed; in skirts and kimonos, the front hem. The burnings were recorded by VTR and photographed. Outputs of the thermoplates were also continuously recorded during the tests. The following were obtained from the temperature curve based on the output of the thermoplates:(1) the time required from contact with a flame to the beginning of combustion;(2) the time required from the beginning of combustion to the peak;(3) the peak temperature;(4) the maximum heat flux;(5) the time required from contact with a flame to causing a second degree burn.

Here, a second degree burn means a burn which injured depth is 100 micrometers or which has blisters and some broken skin. Henrique, Stoll, Greene, Chienta and others have the relation between a second degree burn and heat flux (7-11). The time required for a second degree burn was determined by measuring heat flux at various times. The maximum heat flux was obtained from the output of the thermoplates that provided the sharpest slope during the time from the beginning of combustion to its peak.

RESULTS

Comparison of Flammability

Tests were conducted on 73 sets of general everyday garments, of which men's, ladies', boys' and girls' were numbered 18, 27, 14 and 14, respectively. Of all the samples, 18 sets of garments were not ignited by a 10-second contact with a flame of a bunsen burner or the fire self-extinguished after a small part was burnt. The remaining 55 sets were readily ignited and blaze up.

Flammability of Various Garments

Yukata dresses (cotton kimonos for summer wear). Nightclothes generally showed high flammability and yukata dresses in particular were highly combustible. In a test using a female mannequin dressed in a pure cotton yukata and nylon underwear, flames reached near the face in 8 seconds after ignition, then flared up to 50cm over the head. The yukata itself was almost totally consumed in a minute and 10 seconds. At the back waist, the maximum temperature and the maximum heat flux were 300°C and 138kJ/m2 s, respectively; it took 21 seconds to produce a second degree burn. At the jaw, the maximum temperature was 108°C and the maximum heat flux 25.1kJ/m2 s. The time required for a second degree burn was 43 seconds.

Pajamas. A test of male mannequin wearing a cotton, short-sleeved pajama jacket and trousers, a cotton short-sleeved undershirt with a U shaped neck, and cotton briefs with a 15% polyester blend, demonstrated that flames exten-

ded to the face 20 seconds after ignition on contact with a gas flame. The garment almost burnt up in one minute and 40 seconds. Figure 2 shows the relationship between the time and the temperature and heat flux at measuring points. The maximum temperature of 149 °C and the maximum heat flux of 110kJ/m2 s were obtained at the waist and hips, respectively. In the latter, it took 18 seconds to produce a second degree burn.

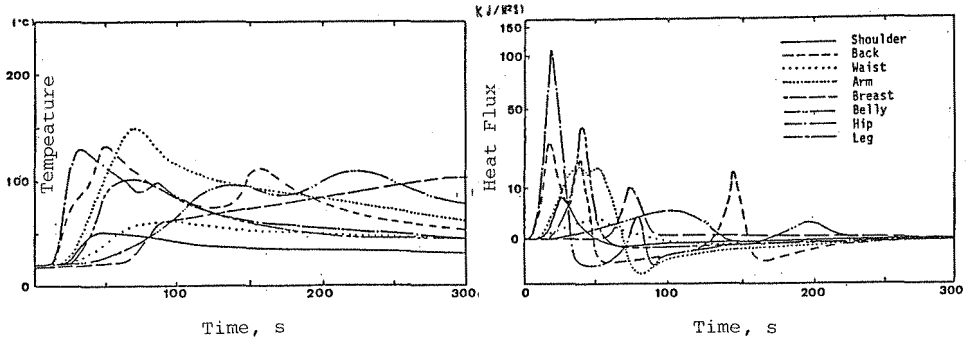

Fig. 2 Time Dependence of Temperature and Heat Flux (M1)

Negligees. A test was conducted using a female mannequin with a cotton short-sleeved negligee, a nylon of a polyurethane mix and cotton panties. Flames reached the face 12 seconds after contact with a gas flame and the garment was consumed within one minute and 30 seconds. The maximum heat flux at the waist and that at the left arm were 139.7kJ/m2 s and 58.6kJ/m2 s, respectively.

Suits. In a test of woolen suits, a small flame was raised by a 10-second contact with a gas flame on the bottom of the right leg. However, it extinguished immediately when the gas flame was removed. Then a 25-second contact with a flame was made on the back bottom of the jacket. The lininig (55% cuprammonium rayon and 45% nylon) caught fire and spread to the shirt and the combustion reached its peak one minute and 20 seconds later. Eight minutes were required until the suits were completely consumed. A similar situation occurred with polyester suits with 45% wool. They were ignited when touched with a flame on the front bottom of the jacket for 15 seconds. A fire extended to the face in one minute and 20 seconds afterward, and the combustion reached its peak 5 minutes and 30 seconds later. It took 16 minutes until most of the suites were consumed.

These two types of suits were relatively flame proof. They began burning only when the lining was ignited. However, cotton corduroy suits exhibited a rapid combustion owing to the fluffy surface. Flames reached the face in one minute and 30 seconds and it took 2 minutes until the burning reached its peak. The maximum temperature and the maximum heat flux were 208 C and 46.0kJ/m2 s, respectively, at the foot. It took 27 seconds to produce a second degree burn.

Jeans. Cotton jeans were ignited after being touched with a flame for 10 seconds. Since they fit the body tightly, their burning rate is low; it took 5 minutes before the flame reached the femur. In two types of jeans, the fire self-extinguished at the femur. Although modes of combustion were similar, big flames occurred in the other type and a fire transferred to a polo shirt

in one minute and 30 seconds,or an acrylic sweater in 2 minutes.

Combination of sweaters and skirts or trousers(including pantaloons). It is difficult to generalize the flammability of these combinations because their modes of combustion are greatly affected by combination. For example, the bottom portion may be dressed in flammable skirt or trousers, and if the upper portion may be dressed in a sweater with high wool content it will not catch fire easily. On the contrary, the more acrylic fiber contained in the garment, the more flammable it becomes. An example is given by a female mannequin wearing an acrylic sweater and an acrylic skirt with 25% polyester and 5% wool. In this test, flames reached the jaw 30 seconds after ignition, where the maximum temperature of 344°C and the maximum heat flux of 334.7kJ/m2 s were obtained. It is considered that these high values were obtained because flames attacked the sensor directly.

Combination of shirts (blouses) and skirts or trousers. In a test of a female mannequin with a T-shirt and a skirt, the latter exhibited fierce combustion. The face was covered in flames 30 seconds later and the skirt was burnt out in one minute and 30 seconds to 3 minutes. On the contrary, the T-shirt was not severely damaged. In a combination of a blouse and a polyester skirt, the latter was not ignited but melted in drops. However, fierce combustion was observed in the case where underwear caught fire which spread to the blouse.

Tests of boys' T-shirts and short pants presented low burning rates with small damage to the T-shirts, regardless of the pants being cotton or polyester.A comparison between a combination of a T-shirt with a skirt and that of a T-shirt with short pants proved that the former was greatly hazardous.

One-Piece dresses. Most of the one-piece dresses were readily ignited. Flames covered the face 20 to 30 seconds after a gas flame touched the dress and the garment burnt up about 2 minutes and 30 seconds later. An example is given by a test of a sleeveless, polyester, one-piece dress with a 35% cotton mix. The maximum temperature and the maximum heat flux at the abdomen were 172°C and 68.5kJ/m2 s, respectively.

Kimono dresses. A woolen men's kimono ensemble (a kimono dress and a short coat) with 15% silk and 5% nylon blended, was ignited after a 10-seconds contact with a gas flame. However, the fire extinguished 40 seconds later. Contact with a gas flame was again made on the bottom of the right sleeve for 20 seconds. The polyester lininig caught fire and flames leapt up to the face one minute and 30 seconds later. Two minutes and 30 seconds were required until the combustion reached its peak and 9 minutes were required until most of the clothes burnt out. A maximum temperature of 212°C and a maximum heat flux of 20.1kJ/m2 s were obtained at the waist and the back, respectively.

A silk ladies' kimono was not ignited, although a flame was in contact for 10 seconds. The fire extinguished burning a small part of the lining only. Then, contact with a flame was made on the bottom of the sleeve for 20 seconds; however, the kimono did not ignite and only the ignition place was carbonized. Lastly, an obi (a sash belt, the outer side of which is polyester and the lininig rayon) was ignited after a 10-second contact with a flame and exhibited an extremely dull combustion. A maximum temperature of 437°C was measured at the arm approximately 5 minutes 50 seconds later. The maximum heat flux of 25.1kJ/m2 s was observed at the abdomen.

Working clothes. A polyester working garment with a 20% cotton blend was ignited after being touched with a flame for 10 seconds. Although the combus-

tion was slow, flames spread over the clothes. The maximum temperature was obtained at the back 7 minutes later and the maximum heat flux indicated 3.3kJ/m2 s. Another one, made of aromatic polyamide, did not exhibit a flame at all and only the part which was directly touched with a gas flame was carbonized although it was exposed to a gas flame for a long period.

Sports wear. Polyester sports wear was tested and when ignited, they melted fiercely, falling down in drops. The part which were burnt peeled off. Therefore, they exhibited a low apparent flame propagating rate and the temperature of the body did not increase. Therefore, good results were obtained from the tests. However, in one of them, a sudden rise in temperature was observed at the abdomen 3 minutes later and it exceeded 250°C 4 minutes and 30 seconds later.

Coats. Three types of coats, a polyester one blended with 40% wool, a polyester one with 35% cotton and a 100% cotton one, were tested. In all tests, flames spread to the face one minute to one minute and 20 seconds after coming into contact with a gas flame. The combustion reached its peak one minute and 30 second later. However, in the case of coats, clothes put on under a coat, such as suits, greatly affected the combustion; the heat flux on the body surface became small because of the suits. Thus, a higher safety mark was given to the coats than one would assume from the appearance of combustion.

Comparison with past tests

In the present tests, the heat flux of 4 to 84kJ/m2 s is frequently obtained. A heat flux of 335kJ/m2 s, the maximum of all measured, is obtained once. On the other hand, the maximum temperature generally does not exceed 300 C, although the temperature of 437°C is observed once.

Finley and others (3-5) recorded the maximum heat flux of 11kJ/m2 s and the maximum temperature of 204°C in a test of a cotton A-shaped one-piece dress, in which the time taken to reach the peak of combustion was 37 seconds.

In the tests of flammability of yukata dresses designed by the Ministry of International Trade and Industry of Japan, the maximum heat flux was 4.2 to 13.4kJ/m2 s and it took about 35 to 55 seconds to obtain the highest value(12).

The temperature and time given by these two tests nearly coincide with those of the present tests. However, the heat flux seems to be a little lower in their tests.

On the contrary, in Ohya's experiments (13), the heat flux of 250kJ/m2 s was frequently observed, and that of 355kJ/m2 s was also reported. The time to the peak of combustion is 30 to 50 seconds which is a little longer than the value measured in the present tests. Hence, it can be said that the values shown in the present tests were proved to be appropriate.

Summary of Garment Flammability Tests

Flammable garments. The results of fire tests are summarized as follows:

(1) Clothes made of flammable materials are hazardous enough to make flames reach the face in 10 to 90 seconds. Heat flux was generally 4 to 84 kJ/m2 s but 335kJ/m2 s was observed as the maximum flux once.

(2) It is difficult to make a conclusion owing to various factors; however,

cotton, acrylic clothes, those of a mixture of cotton and polyester and those of a mixture of cotton and acryl are relatively flammable. Silk, woolen, nylon and aromatic polyamide clothes are relatively flame proof.
(3) In cotton clothes, thick textures, such as jeans, exhibit a very low burning rate. On the contrary, a mixture of cotton and polyester and that of cotton and acryl are relatively flammable regardless of their thickness.
(4) In clothes which are made of cotton and polyester and fit the body relatively well, the fibers contract and the clothes shrink to the surface of a mannequin when heated. A fire self-extinguished because of the shortage of air in most cases. It is difficult to classify this type of case because it appears to be flame proof. On the other hand, the heat contraction of fibers is small in clothes of a mixture of cotton and acryl, therefore, fire spreads.
(5) Generally, girls' wear is flammable in both materials and forms. More attention should be paid to this.

Nonflammable garments. As was mentioned above, 18 sets of all the garments were not ignited by the first contact with a gas flame for 10 seconds. The reasons of self-extinguishment of almost the garments are due to melt, drip or shrink of tex-tiles, or the fitness of clothes. After all, only the garments made of wool, silk, mixture of wool and nylon and aromatic polyamide were found to be substantially flame proof.

PROPOSAL OF A NEW TEST METHOD FOR THE CLASSIFICATION OF GARMENT FLAMMABILITY USING THERMAL MANNEQUINS

Classification Method

To classify garment flammability using thermal mannequins, three measurements, such as burning rate, size of degree of fire injuries were introduced.

Burning rate. After fire tests were performed, the mean times required to cause a second degree burn at various parts were calculated. These values were classified into four classifications as shown in the following. The percentages are also listed for each group for the 73 sets of garments.

Classification	Type	Rate(%)
A	180 seconds or more	34
B	from 120 to 179 seconds	25
C	from 60 to 119 seconds	25
D	59 seconds or less	16

Size of fire injuries. Classification was made by the total number of second degree burns as follows:

Classification	Type	Rate(%)
A	1 - 2 places	12
B	3 - 4 places	18
C	5 - 6 places	44
D	7 - 8 places	26

Degree of fire injuries. The mean maximum heat flux was calculated for

portions where the maximum heat flux was larger than 2.9kJ/m2 s, designed as the degree of fire injury and classified as follows:

Classification	Type	Rate(%)
A	10kJ/m2 s or less	12
B	10 - 20 kJ/m2 s	44
C	21 - 30 kJ/m2 s	22
D	30kJ/m2 s or more	22

General classification. Using the above three evaluation standards, measurements, A, B, C and D were given 4, 3, 2 and 1 point, respectively, and the general classification of garment flammability was evaluated by counting the points. The results are follows:

Classification	Type	Rate(%)
A	11 - 12 points	11
B	8 - 10 points	34
C	5 - 7 points	41
D	3 - 4 points	14

Discussion on the General Classification

Classification results are shown in Table 1. Judging from the general classification, working cloth made of fire resistant fiber provided good results without doubt. Classified into class A are a combination of a woolen sweater and trousers, that of a woolen jumper and trousers with a nylon blend, polyester sports wear, woolen suits, suits of wool and nylon, a combination of a cotton T-shirt and trousers blended with polyester. These clothes are flame proof in material and fit the body relatively well. Good results were obtained in polyester sports wear because they melted fiercely and fell in drops when ignited. However, they should be re-examined.

Clothes which come under class B in the general classification are a combination of a T-shirt and trousers, that of a T-shirt and jeans, kimono dresses and a combination of a shirt and trousers, arranged according to superiority in other classifications. They are relatively difficult to burn except for kimono dresses. Therefore, good results were yielded although many of them were cotton. Kimono dresses made of wool or silk were difficult to burn. Listed in a lower rank of class B are two-piece dresses, a combination of a polo shirt and pantaloons, that of a sweater and a skirt and cotton suits. Their materials are flammable and many of them are ladies' wear.

Coupled within a high rank of class C are a combination of a shirt and trousers, pajamas and one-piece dresses. Those listed in a lower rank are a combination of a T-shirt and a skirt, one-piece dresses, negligees and so on. Most of them are ladies' wear and some girls' wear is included.

Those classified into class D, the lowest group, are all kinds of nightclothes such as yukata dresses and pajamas, sports wear and a combination of a T-shirt and skirt. This classification evidently shows how flammable nightclothes are.

The results of the general classification obtained after those three evaluation standards are completely identical with experimental results. Besides, points are given according to the level of safety, and it is clear that the proposed method allows a useful and quantitative evaluations of the safety of garments from fire.

Table 1 Classification of Garments According to the Proposed Method

No *1	Garment	Composition *2	Weight (g)	Burning rate	Size of burn	Degree of burn *3		General	No. of contact with a flame
B 1	T-shirt & trousers	CT70,PE30/CT100	148	A	B 4	A 6		A	
B 2	T-shirt & trousers	CT100/CT95,PU5	173	B	A 2	A 3		A	
B 3	T-shirt & trousers	PE65,CT35/PE50CT50	226	B	C 1	B 7		B	
B 4	T-shirt & trousers	CT100/PE80,CT20	216	A	C 5	B 5		B	
B 5	T-shirt & trousers	PE65,CT35/PE100	154	A	B 4	B 4		B	
B 6	Yukata dress	CT100	186	C	D 8	B 8		C	
B 7	Yukata dress	CT100	298	D	D 7	D 7		D	
B 8	Pajama(half sleeve)	CT100	143	B	D 7	B 8		C	
B 9	Pajama(half sleeve)	CT100	143	B	D 8	B 8		C	
B 1 0	Yukata dress	CT100	204	D	D 7	D 8		D	
B 1 1	Pajama(half sleeve)	CT100	167	B	D 8	B 8		C	
B 1 2	Training wear	PE100	461	B	A 1	B 1		B	2
B 1 3	Sweater & jeans	AN80,WL20/CT80PE15	235	A	C 6	B 7		B	
B 1 4	Sweater & trousers	WL100/CT100	162	A	A 1	A 2		A	
G 1	T-shirt & skirt	CT100/PE65,CT35	138	D	B 4	B 7		C	
G 2	T-shirt & skirt	CT100/PE65,CT35	224	C	D 8	C 8		C	
G 3	T-shirt & skirt	CT50,PE50/CT100	135	D	C 6	C 6		C	
G 4	T-shirt & skirt	CT50,PE50/CT100	146	C	D 7	D 7		D	
G 5	Yukata dress	CT100	286	D	C 6	D 7		D	
G 6	Pajama(half sleeve)	CT100	133	D	D 8	D 8		D	
G 7	Pajama(half sleeve)	CT75,PE25	179	C	D 8	C 8		C	
G 8	One-piece dress	CT80,PE20	130	C	C 5	B 6		C	
G 9	One-piece dress	CT100	148	C	C 6	B 6		C	
G 1 0	Pajama(half sleeve)	CT50,PE50	70	C	A 1	D 1		C	
G 1 1	One-piece dress	PE100	150	C	C 5	B 5		C	Drip
G 1 2	Sweater & skirt	AN70,WL30/PE65RY35	161	C	B 3	C 2		C	
G 1 3	Sweater & skirt	AN80,PE20/CT100	175	B	C 6	B 7		B	
G 1 4	Sweater & skirt	AN100/AN75PE20WL5	100	C	C 6	D 6		C	2
L 1	One-piece dress	PE100	185	A	C 5	B 6		B	Drip
L 2	Negligee	CT100	140	D	C 5	D 7		D	
L 3	Pajama	CT100	170	C	D 7	C 8		C	
L 4	Negligee,half sleeve	CT80,PE20	171	C	C 6	C 7		C	
L 5	Blouse & skirt	PE65,CT35/PE100	216	A	C 6	C 6		B	2 Drip
L 6	One-piece dress	CT100	253	D	C 5	B 5		C	
L 7	One-piece dress	PE65,CT35	274	C	C 6	C 6		C	
L 8	Blouse & skirt	PE100/PE100	377	B	B 3	D 3		B	3 Drip
L 9	Polo & Pantaloon	CT50,PE50/CT50PE50	402	A	C 5	B 6		B	
L 1 0	Blouse & skirt	CT80,RY20/PE100	419	A	C 6	B 6		B	
L 1 1	Pajama(half sleeve)	CT70,PE30	217	B	C 6	C 6		C	2
L 1 2	Cardigan & pantaloon	WL100/CT50,PE50	256	B	B 4	C 5		B	
L 1 3	Polo & pantaloon	PE52,CT48/CT50PE50	528	B	C 6	B 7		B	
L 1 4	T-shirt & jeans	CT50,PE50/CT100	539	A	A 1	D 1		B	2
L 1 5	Yukata dress	CT100	325	C	C 5	B 7		C	
L 1 6	T-shirts & jeans	CT100/CT100	577	A	B 3	B 4		B	
L 1 7	Yukata dress	PE65,CT35	495	C	D 7	C 7		C	
L 1 8	Polo & jeans	PE65,CT35/CT100	600	A	C 5	C 6		B	2
L 1 9	Negligee,half sleeve	WL100	175	D	A 1	D 2		C	2
L 2 0	Training wear	PE100	681	A	A 2	B 5		A	2
L 2 1	Pajama(half sleeve)	CT70,PE30	217	B	C 5	C 6		C	
L 2 2	One-piece dress	AN94,WL6	712	B	D 7	B 7		C	
L 2 3	Two-piece dress	WL90,NL10	838	C	B 3	B 4		B	4
L 2 4	Sweater & skirt	AN90,WL10/WL70AN20	446	B	C 6	C 6		C	
L 2 5	Coat	PE65,CT35	340	A	C 5	B 5		B	
L 2 6	Coat	CT100	745	A	C 5	B 5		B	3
L 2 7	Kimono dress	SILK100	727	A	B 4	B 5		B	
M 1	Pajama(half sleeve)	CT100	316	D	C 6	C 8		D	
M 2	Pajama	CT70,PE30	475	B	D 7	B 7		C	
M 3	Pajama	CT70,AN30	453	C	D 7	A 8		C	
M 4	Training wear	CT100/PE65,CT35	785	B	D 8	D 8		D	
M 5	T-shirt & trousers	PE65,CT35/CT100	700	A	C 5	D 6		C	
M 6	Bath robe	CT100	330	D	D 7	C 7		D	
M 7	Yukata dress	CT100	390	D	C 6	D 6		D	
M 8	Yukata dress	PE65,CT35	480	D	D 7	D 7		D	
M 9	Jumper & trousers	WL100/PE95,CT5	600	A	D 7	B 7		B	3
M 1 0	Suits	WL100	1200	A	B 3	A 7		A	3
M 1 1	Jumper & trousers	AN90,PE10/PE65RY35	993	A	B 4	D 4		B	2
M 1 2	Suits	PE55,WL45	737	A	B 4	A 4		A	3
M 1 3	Working cloth	PE65,CT35	826	A	C 6	A 7		B	
M 1 4	Kimono dress	WL100	1400	A	B 3	B 5		B	2 Drip
M 1 5	Suits	CT100	1400	B	C 6	B 7		B	
M 1 6	Jumper & trousers	NL100/WL100	924	A	A 2	B 2		A	3
M 1 7	Coat	PE60,WL40	740	A	C 5	A 4		B	
M 1 8	Working cloth	AA80,NL20	900	A	A 0	A 0		A	

Note:

*1 B:Boy, G:Girl, L:Lady and M:Man

*2 CT:Cotton, WL:Wool, PE:Polyester, AN:Polyacrylonitrile, NL:Nylon PU:Polyuretane, RY:Rayon, AA:Aromatic polyamide

*3 Numerical value indicates the number of thermoplates counted.

CONCLUSION

The fire tests using thermal mannequins dressed in 73 sets of everyday garments showed that all of them, except for 18 sets, exhibited fierce combustion for 10-second contact with a gas flame and also indicated a possibility of causing serious fire injuries to the body within a short time. On the other hand, some clothes were proved to be fire proofed and these were classified into three groups: one group is that the material itself is fire resistant, such as aromatic polyamide, wool and silk; another is that the fiber melts and falls in drops, such as polyester and nylon; and the third group is that the material is thick or fits the body like jeans, though the material itself is flammable, such as cotton. Standards of classification, such as burning rate, size and degree of fire injuries and a combination of these factors were proposed to be viable.

ACKNOWLEDGEMENT

We are deeply grateful to Mr. Hideo Terasaki, Chief of the Research Division of the Japan Fire Retardant Association for a great amount of information for this study. We also extend our thanks to Mr. Akira Kubota, a student of this department, for his assistance in our tests, Messrs. Kazuhiko Tamura and Hiroshi Morijiri, research students, Mr. Gouichiro Kuwaki and Miss Kaoru Shimogawara, students of this department, for helping with data processing.

REFERENCES

1. Fire Defence Agency of Japan, Annual White Paper on Fire Service
2. Data from the Tokyo Fire Department Agency (1980)
3. Finley, E.L.: "Ignition System used as a Testing Technique for Studying Garment Flammability," J. Fire and Flammability, 1: 166-174 (1970)
4. Finley, E. L. and Carter, W. H.: "Temperature and Heat-Flux Measurements on Life-Size Garments ignited by Flame Contact," ibid., 2: 298-320 (1971)
5. Finley, E. L. and Butts, C. T.: "Garment Conformation on a Mannequin changes Flammable Characteristics," ibid., 4: 145-155 (1973)
6. Chouinard, M. P., Knodel, D. C. and Arnold, H. W.: "Heat Transfer from Flammable Fabrics," Textile Research Journal, 431: March 1973
7. Seaman, R. E.: Bull. N.Y. Acad. Med., 43: 8, 649 (1967)
8. Henriques, F. C., Jr.: Archives of Pathology, 43: 489-502 (1947)
9. Stoll, A. M. and Greene, L. C.: J. Applied Physiology, 14: 373-382 (1959)
10. Stoll, A. M. and Chianta, M. A.: "Burn Production and Prevention in Convective and Radiant Heat Transfer," Aerospace Med., 39: 1097-1100 (1968)
11. Moritz, A. R. and Henriques, F. C.,Jr.: American Journal of Pathology, 23: 695 (1947)
12. Ministry of International Trade and Industry: "On the Results of Tests of Flammability of Children's Yukata Dresses" (1980)
13. Ohya, H.: Garment Flammability and Heat Injury, 60, Maruzen, Tokyo (1983)
14. Braun, E., Cobble, V. B., Helzer, S., Krasny, J. F., Peacock, R. D. and Stratton, A. K.: "Back-Up Report for the Proposed Standard for the Flammability of General Wearing Apparel," NBSIR 76-1072, National Bureau of Standards, Washington, D. C. (1976)
15. Cooperative Industry Program on General Apparel Flammability (1977)