Q&As Concerning Fire of Flexible Polyurethane Foams: Hazards and Prevention

«For Houses and Buildings»

March　2010

Final Report

Translation into English by JUII
Technology and Safety Committee
Fire Safety Working Group

Introduction

These Q&As have been made as part of our ongoing efforts for risk management in fire safety.
A variety of polyurethane foams are used in the building and housing sector in many applications depending on their characteristic properties. Flexible polyurethane foams are not presently used as building materials regulated by the Building Standard Law or similar regulations, but are widely used in houses and other buildings in various applications.
Occurrences of fire continue in spite of many measures taken, including efforts of providing improved fire proof materials. The Japan Urethane Industry Institute (JUII) has been conducting activities for advancement of fire safety.

Fire prevention activities thus far carried forward by the Fire Safety Committee includes publication of Q&As on rigid polyurethane foams.
The following Q&As on flexible polyurethane foams are intended to call attention to the hazards of fire, in terms of secondary ignition in particular, of flexible polyurethanes used widely as interior goods and products in the house.

The members of the Committee have read carefully, and construed as fairly and properly as possible, publicly known information, including JUII's official booklets and information on its home page,, and have made use of such information in editing these Q&As as model answers .
Please bear in mind that these Q&As have been edited from the viewpoint of risk management and do not reflect the official positions of JUII.

It is our strong desire that these Q&A would help win understanding of people who handle or use flexible polyurethane foams about the hazards and prevention of fire.

16th May 2010
Japan Urethane Industry Institute (JUII)
Technical and Safety Committee
Fire Safety Working Group

Content

Q1. In what applications are flexible polyurethane foams used in the construction sector?

A: Flexible polyurethane foams are rarely used in the construction sector. An example of specialty applications is sound insulation of acoustic chambers such as studios.

Q2. I'd like to know some instances of fire of flexible polyurethane foams that occurred in Japan.

A: Fire accidents that occurred in the past include combustion of sofa cushions of flexible polyurethane materials resulting in burning down of a building and combustion of polyurethane mats on the floor that caused burning down of a gymnasium.

Table2 the recent typical fire incidents in Japan

Month Year	**Occurrence location**	**Cause**	**Situation of the occurrence**
3.1995	**Gunma prefecture**	**Spark in the polishing**	**When the blade of the cutter is ground with the grinder, the flying spark ignited to the polyurethane rubbish scattered on a surrounding floor at the polyurethane foam processing factory.** **NO personal damage**
11.2001	**Okayama prefecture**	**Short of wiring**	**The power wiring such as cutters is short-circuited at the polyurethane foam manufacturing factory, the electric wire tube is melted, it sets sparks flying, and the polyurethane foam is ignited.** **NO personal damage**
10.2001	**Physical exercises gym in Tokyo**	**Playing with fire**	**It broke out in university gym 3F only for physical exercise, the polyurethane foam mat burnt, and the spreading expansion was done rapidly.** **NO personal damage**
10.2002	**Mie prefecture**	**Spark in the polishing**	**At the polyurethane foam processing factory, the spark of the grinder that grinds the blade of cutter ignites the polyurethane foam in the vicinity.** **NO personal damage**
10.2008	**Private video shop in Osaka**	**Arson**	**The sofa made of polyurethane foam etc. burn by arson in the private video shop at midnight, and it spreaded in a short time.** **15 persons failed to escape killed** **10 persons injured**

Q3. What are typical causes of fire accidents of flexible polyurethane foams? And will you give some instances that occurred in overseas countries?

A: The Fire Service White Paper for Fiscal 2007 lists, as causes of housing fire, arson, stove, and cigarette in the order of most occurrences. Fires of houses have occurred from careless handling of small fire sources such as cigarettes leading to burning of sofas, mattresses, pillows, sheets or other personal belongings. Many buildings other than houses, public buildings in particular, contain upholstery and acoustic materials of flexible foams (See Q1). During interior work, fire may break out of welding or cutting sparks sticking to such materials.

Overseas instances include fire disasters caused by sparks of toy fireworks sticking to upholstery flexible foams. Flexible polyurethane foams should be kept away from any fire sources. The table below shows instances of overseas fire accidents.

Table3 Fire incident (oversea)

Month/ Year	Location	Outline of fire	Damage situation Death toll
Jan. 2009	Bangkok in Thailand	The fire of fireworks emitted in the new year celebration ignites the interior material in the night club.	60persons killed 212persons injured
Jan. 2009	Fujian、 in China	The fire of fireworks where the guest originates ignites the polyurethane foam for the decoration of the ceiling in a Latin system bar.	17persos killed 22persons injured
Sept.2008	Shenzhen In China	The fire of fireworks has spread to the building though fireworks show "Night of the indoor fireworks" was seen at the Shenzhen night club.	43 persons killed 88persons injured

Q4. What is the amount of combustible matter placed in an average house? Will you describe the burning behaviors of such combustibles?

A: The wooden house combustibles consist of live fire load, that is, furniture, bedding, interior cloth and other combustible matter placed in a house, and the building structures such as pillars and beams. Reportedly, an average wooden house has live fire load of 30-50kgs per square meter in terms of timber and about 80kgs of building structures. A house contains many combustible substances. According to the Fire Service White Paper, by far the greatest number of ignition instances occur with a ‘futon’ and the things attached to it, which amounts to double the number of instances of clothing that rank second. This indicates that fire tends to spread to things nearby. Most of the things in the room that may catch fire are furniture and other live load items rather than interior finishing. If many pieces of furniture cover the walls, it must be said that a situation would arise in which the incombustible interior finishing would turn to combustible.

The fire safety verification method prescribed in the Building Standard Law is based on the premise of standard fire spread behavior. However, things in a house are various and their burning behaviors vary accordingly. Combustible furniture, fixtures, interior goods and products can be made incombustible or flame retardant so that the time to ignition may be retarded. The retarded time to ignition will retard gas evolution and reduce the quantity of gases evolved. Fig. 4 shows heat releases of typical combustibles.

Houses seldom undergo evacuation safety verification, but the Enforcement Ordinance of the Building Standard Law stipulates the limit of heat release from live fire load in a houseroom in the provisions of its Article 108-3, Paragraph 2, Item 1. It is 720MJ/m^2 and is the second highest, following the figure for the salesroom of the department store of 960MJ/m^2. Such stipulated limits of heat release will be the basis for the respective evacuation safety verifications.

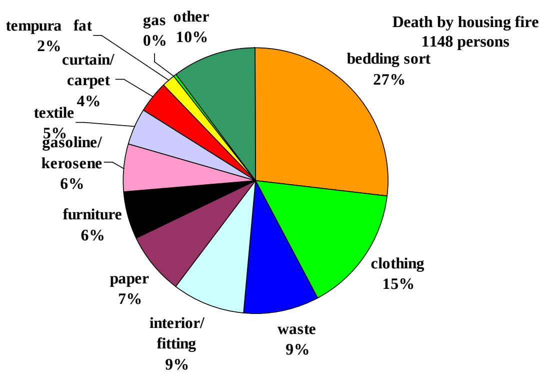
Table **4 Test result of heat release rate and total caloric value of the typical storage combustible material**

Storage combustible material		Initial weight (g)	Max. heat release rate (kw)	Total caloric value (MJ)
BEDDING	Pillow 1	1550. 0	No- burning	No- burning
	Pillow 2	1360. 0	No- burning	No- burning
	Blanket made of toweling (thick)	1825. 0	306.3	35.1
	Blanket made of toweling (thick)	761.0	213.0	14.1
	Fur	1287.0	103.7	20.2
	Sheet	490.0	360.0	10.0
	Futon 1	3790.0	15.0	14.2
	Futon 2	2200. 0	120.0	15.0
	Futon 3	4240.0	54.0	18.0
	Mattress 1	1850.0	178.1	44.9
	Mattress 2	1830.0	121.2	37.7
	Mattress 3	1690.0	298.4	39.5
	Mattress 4	1840.0	91.7	44.0
	Mattress 5	1590.0	112.8	35.1

Source: Combustibility of storage combustibles as a design fire

Source for fire safety design , BRI – H18 course text

Fig4 Death toll of housing fire by Ignition material in 2007 (except arson/suicide)



Source: fire white paper in 2008

Q5. What is the phenomenon of flashover ?

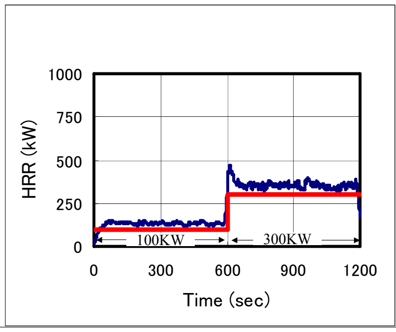
Will it occur when flexible polyurethane foam is burning?

A: Heat of fire accumulated within a room that is on fire will raise the temperature of the combustible materials such as ceilings, walls and furniture up to a point of ignition and cause sudden combustion of the entire room followed by quick spread of fire. This is called a flashover. (See Fig.1 of Q8)

If the furniture and other things in the room are flammable, the fire tends to spread quickly up to a flashover. Thus the burning behavior of the walls, ceilings, interior materials and other combustibles in the building will greatly affect the flashover.

Polyurethane foams as well as other combustibles will, if a fire is spreading, contribute to the occurrence of a flashover. The photo below shows a full size experiment of burning. When a flashover (FO) occurs, the rate of heat generation will rise sharply. From the occurrence of the flashover on, the concentration of CO_2 will rapidly increase and the CO concentration will also increase. Another phenomenon that will occur is an increase of smoke emission.

Fig5. Phenomenon of Flashover in room corner test (ISO 9705)



The gas burner of the room corner (generation of heat speed 100KW for 0-10 minutes and then 300KW for another 10 minutes) is ignited and the combustion expansion along the surface of the interior is measured.

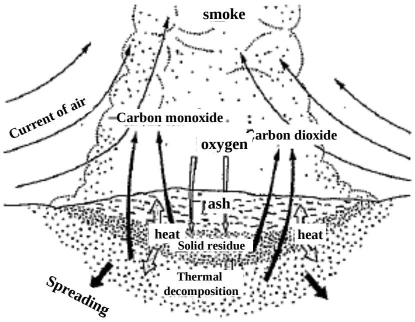
Q6. What phenomenon do you call smoldering?

A: Smoldering means flameless combustion accompanied by smoke emission. An example is a burning cigarette or incense stick. Another is a 'futon' burning without emitting flame for a while after a lit cigarette is dropped on it.

If combustible gases evolved by thermal decomposition do not form a combustible gas mixture due to low ambient oxygen concentration or any other reason, flaming will not occur and just carbonaceous residue will burn. Such combustion is called smoldering. During smoldering, combustible gases evolved by thermal decomposition may be cooled to emit whitish smoke. It is known that, when ambient oxygen concentration becomes higher, the phenomenon of smoldering may turn to flaming and, when oxygen concentration becomes lower, flaming turns to smoldering.

In case of fire of polyurethane foams, even if flame disappears and is believed to have been put out, the foams may be smoldering. The fire must be extinguished to the bottom.

Fig6 Flow of heat and materials on the smoldering



Source: fire VOL.39(5) , JAFSE

Q7. Why does flame spread faster after it reaches the ceiling?

A: After reaching the ceiling by upward propagation, flame is promoted to spread over the ceiling surface by buoyancy. If the ceiling is made of combustibles, the speed of flame spread will increase rapidly. Even if the ceiling is made of incombustibles, the radiant heat source will expand, and intensified radiation of heat toward the furniture and other combustibles and further toward the floor will tend to propagate combustion. People in the room will get into a dangerous situation when flame grows and reaches the ceiling, and should escape from the place immediately. So as to provide an effective measure against spread of flame, it is generally recommended that ceilings made of combustibles should be covered with incombustible or quasi-incombustible materials or be coated with fire protection coatings.

The interior finish restriction clauses of the Building Standard Law set restrictions on the use of finishing materials on the ceiling, wall, etc. of the room in terms of incombustible or flame retardant property for the purpose of preventing spread of fire in the room and assuring time for people to escape from the place.

Fig7-1 example of an assumption of heat release rate for the interior finishings in room corner test

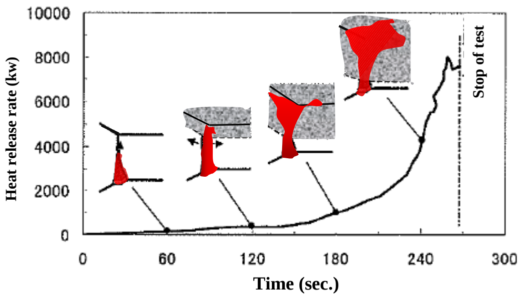
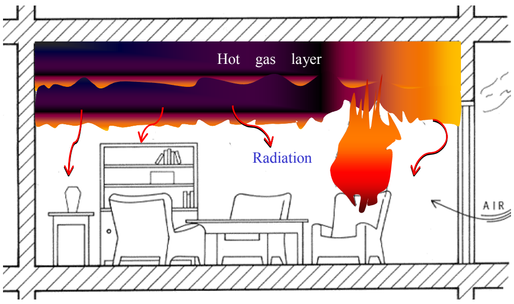


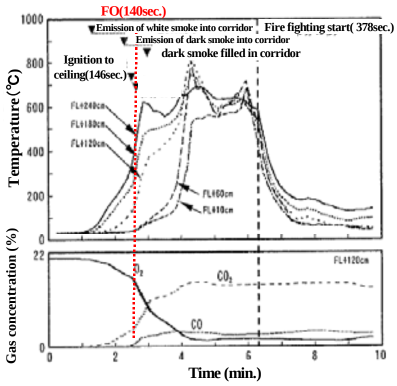
Fig7-2 fire growth in a confined space



Q8. In a fire involving polyurethane foams, to what degree will the room temperature rise?

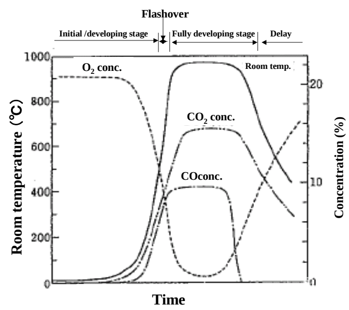
A: As shown in Fig. 8.2, a fire of the building usually goes through the process of igniting →early fire stage , fire growth →fully developed fire → ending stages. The room temperature rapidly rises in the fire grow stage, and, after the flashover, reaches as high as 1,000^{0}C in fully developed fire in which the whole room burns all over. The same is true with a fire involving polyurethane foams.

Fig8-1 Change of temperature and gas concentration in fire test of hotel room



Source: experiment report of hotel fire Osaka fire defense agency Feb. 1992

Figure8-2 Temperature, concentration profiles at a room fire



Source: Fire Engineering Handbook, 3rd Ed. p.8 (1997)

Q9. What should be done when flexible polyurethane foams catch fire?

A: Water is most effective, so immediately pour plenty of water on fire of polyurethane foams. Of course it is effective at an early stage of fire to use a home fire extinguisher (powder type) etc. Be sure, however, to add plenty of water on the extinguished fire to ensure complete extinction of any smoldering portion that may be left inside. If you handle a large quantity of flexible polyurethane foams, immediately call the Fire Department.

Q10. Will you give the ignitability of flexible polyurethane foams?

A: The self ignition point of flexible polyurethane foam is about 410^{0}C, which is nearly on a level with that of cotton, newspaper, pine and other natural timbers, acryl, nylon and other synthetic fibers, and polyethylene, polyvinyl chloride, polystyrene and other plastic materials. Flexible polyurethane products will not undergo spontaneous combustion, and will have no hazard of becoming an ignition source. They may be ignited, however, if exposed to high temperature of a lit cigarette, for example. There are instances of welding sparks sticking to and spreading over flexible foams. Owing to the recently advanced flame proofing technology, difficult-to-burn products are now available, but such products are not perfectly free from burning if they are placed close to an ignition source.

From the viewpoint of safety design of buildings, the temperature at which a certain thing is threatened with catching fire from a fire source commonly present in ordinary architectural space is called its ignition temperature. The ignition temperature is used to evaluate the ease of combustion of materials.

The higher are the critical heat flux for ignition and the thermal inertia of a material, rather than its ignition temperature itself, the lower would its fire risk be. Foams generally have a lower thermal inertia than solid resins, and, once ignited, tend to burn faster. Polyurethane foams, which do not have particularly short time to ignition compared with other materials, will be promoted to burn, due to low inside cooling effect attributable to low thermal inertia, possibly up to deflagration. It is required to keep ignition sources off polyurethane foams.

The thermal inertia : It contributes to thermal conductivity ×bulk density ×specific heat

Table10 ignition point and flash point of the various organic materials

Material	Ignition point (℃)	Flash point (℃)	Material	Ignition point (℃)	Flash point (℃)
Cotton	230-260	254	Acryl textile	—	560
Newspaper	230	230	Nitrate cellulose	141	141
Pine	228-264	260	Acetic cellulose	305	475
Wool	200	—	Nylon 6	421	424
PE	341-357	349	Nylon 66	—	540
PP(fiber)		570	PC	467	580
PP	—	570	Phenol resin/glass laminating board	520-540	571-580
PTFE	—	530	Melamine resin/ glass laminating board	475-500	623-645
PVC	391	454	FRP	346-399	483-488
PS	345-360	488-496	ABS		366
PS(foam beads board)	346	491	Rigid PU foam(ether type)	310	416
PMMA	280-300	450-462	Silicone resin/glass laminating board	490-527	550-564

Test method : ASTM D1929

Source: C,J.Hilado ; Flammability Handbook for plastics,1969(Technolic Pub)

Fig10-1 Ignition temperature of the various plastic materials

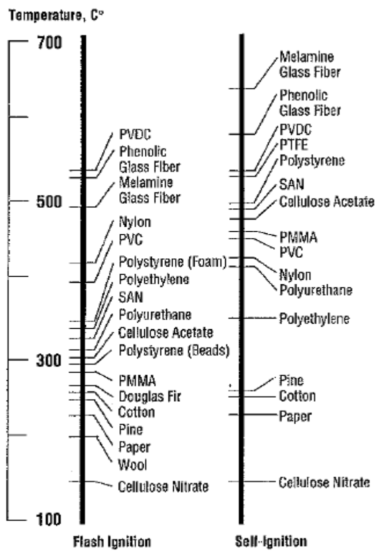
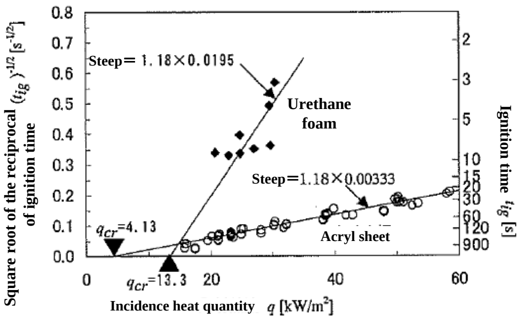
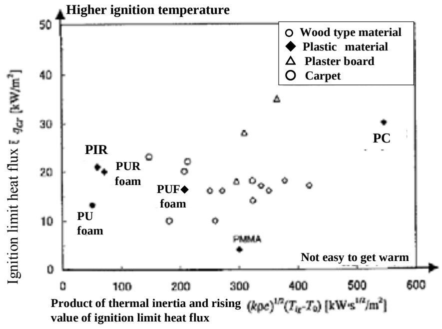


Fig10-2 Ignition time of Polyurethane foam



Source: mechanism of building fire and fire safety design BCJ

Fig10-3 Ignition characteristics of the various materials

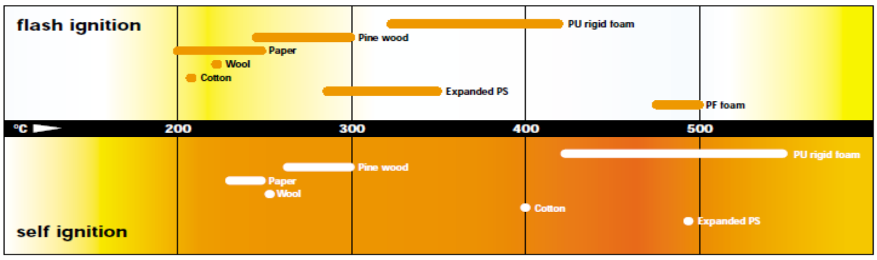


Source: mechanism of building fire and fire safety design BCJ

Q11. Will you give the flash point, ignition point and oxygen index of flexible polyurethane foams?

A: All of them vary with the constituent materials and the test methods used. Table 11 shows measurements of the ignition point and the oxygen index of flexible polyurethane foams. JUII determines the ignition point of flexible polyurethane foams pursuant to ASTM D1929, and have obtained measurements of 350-390^{0}C. Materials with the oxygen index of 21 or less are generally classified as combustibles.

Fig 11 Ignition temperature of various materials



Source: ISOPA "performance of polyurethane building products in fires

Table 11 Material Ignition Temperature

material	LOI	Min. piloted ignition tem.(℃)	Min. non-piloted ignition tem.(℃
Melamine paper laminate standard	29.5	398	433
Natural rubber latex adhesive	19.8	289	330
Epoxy resin	20.9	315	429
Flexible PVC foam	25.6	441	441
Natural rubber latex foam	17.3	274	310
Flexible polyurethane foam	18.1	335	335
Polypropylene	17.5	342	364

ANSI/ASTM D1929

Department of diffence materials research laboratories、commonwealth of Australia

Q12. Will flexible polyurethane foam products combust spontaneously?

A: Polyurethane foam products will not undergo spontaneous combustion.

However, it should be noted that the sun's rays focused with a lens or any other thing exerting a lens effect may ignite them. Since flexible polyurethane foam is a heat accumulative material, it may begin to burn if continuously exposed to a focused beam of light for a long time. The self ignition point of a flexible foam (an example cited here is an ordinary flex-foam not treated with flame retardant) is 456^{0}C.

Q13. Is the combustion rate of flexible polyurethane foams faster than other materials?

A: The ease of combustion of a material used to be generally determined by measuring its combustion rate based on its mass reduction, but now it is getting to be determined by the heat release from the burning object. The total heat release from burning flexible polyurethane foams in terms of the mass reduction and the heat release is not high compared with other materials, but the heat release rate is different with different constituents.

Adding flame retardant to the foam or covering the foam with cover material is an effective means to slow the mass reduction or heat release, but cannot stop its combustion. Sufficient ignition prevention and fire fighting measures are required.

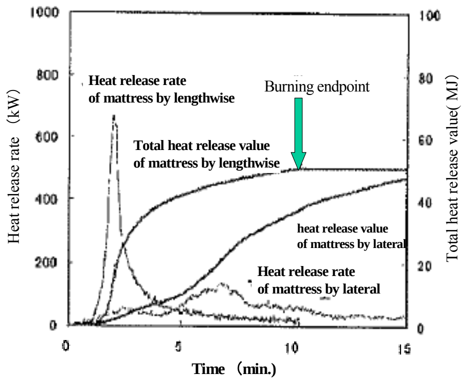
In the United States the fire growth rate of combustibles is classified as 'ultra fast' (α=0.2kw/S^2), 'fast' (0.05), 'medium'(0.015) and 'slow'(0.00313). According to this classification, large cushioned furniture such as sofa falls under 'ultra fast'; ordinary furniture 'fast'; and goods or products covered with incombustible material 'medium' or 'slow'.

Table13-1 Burning rate of the mattress made of the flexible polyurethane foam

Material	Maximum Burning rate max (g/sec)	Burning mass By load cell (g)	Peak heat release value (KJ/g)	Total heat release value (KJ/g)
Mattress1	7. 03	1744	25. 3	27. 3
Mattress3	5. 25	1833	23. 1	24. 7
Mattress4	13. 52	1572	21. 9	23. 3
Mattress5	4. 52	1735	20. 3	20. 2
Mattress6	4. 87	1500	23. 2	23. 3

Source:
Lecture meeting paper of Architectural Institute of Japan p13－14 Aug. 2007

Fig 13-1 Heat release rate of the various storage combustibles (closed space)



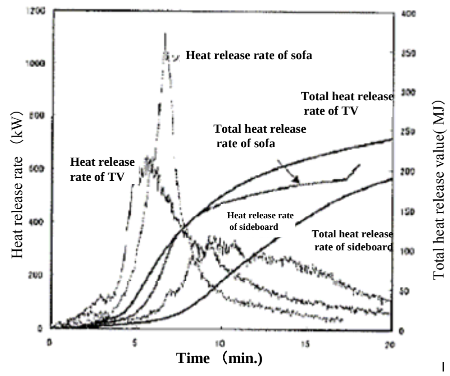
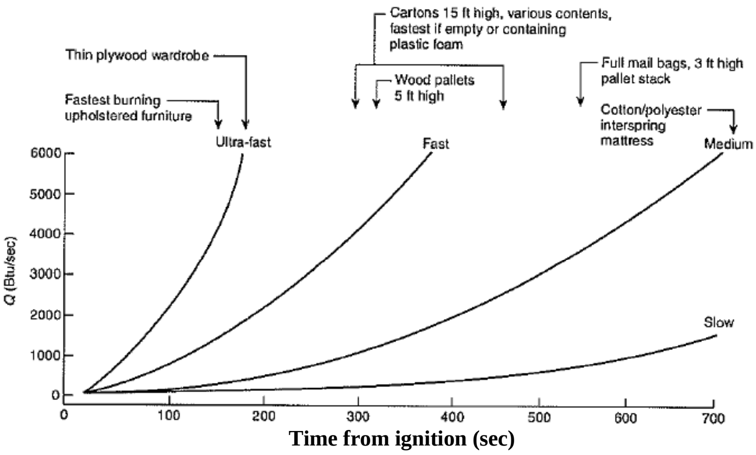


Fig13-2 Standard Fire Growth Rate Curves. (with some examples of fire test fuels)



Source：National Fire Protection Association、National Fire codes, NFPA92B,Figure C.2 (c)

Table13-2 "t-squired" Fire Growth Rates

Classification of Growth Rate	Time to reach 1050kw (seconds)
Ultra Fast	**75**
Fast	**150**
Medium	**300**
Slow	**600**

Table 13-3 Result of measurement of heat release rate for each materials (full size test)

Test method according to ASTM E1354

Specimen	Foil only			Steel Frame			Insulatd Frame		
	T_{ig} (s)	Q"$_{pk}$ (KW/m^2)	Q"$_{180}$ (KW/m^2)	T_{ig} (s)	Q"$_{pk}$ (KW/m^2)	Q"$_{180}$ (KW/m^2)	T_{ig} (s)	Q"$_{pk}$ (KW/m^2)	Q"$_{180}$ (KW/m^2)
PMMA Density=1160 (kg/m^3) T=25mm	23	827	630	24	920	524	24	994	637
Particle board Density=640 (kg/m^3) T=12-13mm	25	304	176	25	239	144	24	288	171
Oak wood blocks Density=735 (kg/m^3) T=32mm	25	248	154	27	198	126	21	233	159
Extruded PS foam Density=50 (kg/m^3) T=26mm	35	579	179	45	388	188	39	475	188
Polyisocyanurate foam Density=28 (kg/m^3) T=45mm	6	83	54	34	67	27	9	74	34
Flexible polyurethane foam Density=23 (kg/m^3) T=50mm	3	801	193	2	453	191	5	675	192
PVC Density=1340(kg/m^3) T=6mm	16	323	235	19	258	192	18	302	232
PE Density=1090 (kg/m^3) T=6mm	47	552	443	58	414	316	56	531	427

Source: Journal of Material, Vol 17, No 2, p51-63, Apr. 1993

Fig13-3 Flexible polyurethane foam

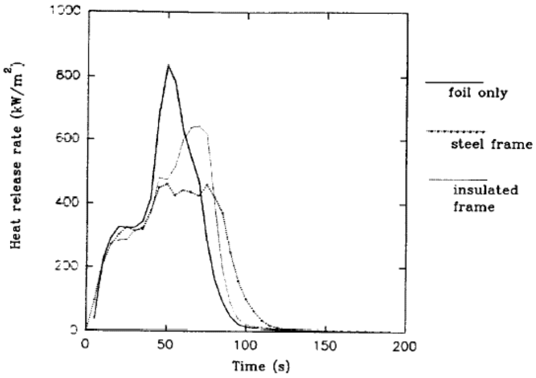


Fig13-4 Rigid polyurethane foam

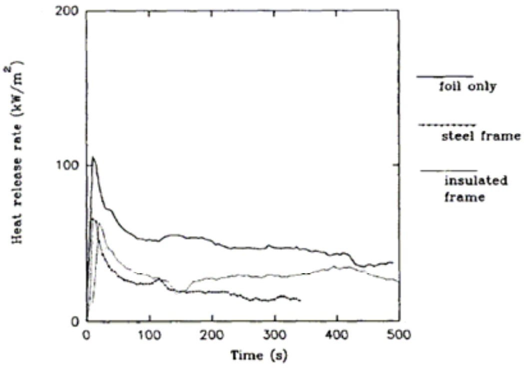


Fig13-5 Polystyrene foam

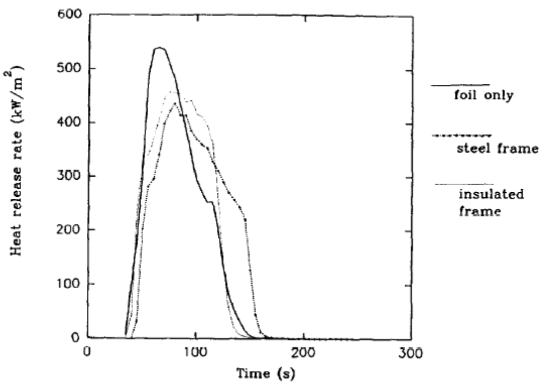
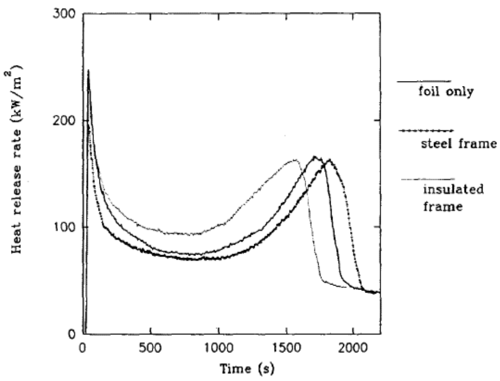


Fig13-6 Oak wood blocks



Source: Vinyl Institute, a Division OF the society of the plastics Industry, Inc.

* Refer to CPI and PFA documents

Q14. It is told that plastic materials emit much smoke when burned. How about polyurethane foams?

A: The quantity of smoke differs considerably with the constituents and shape of the material on fire, and the temperature, oxygen concentration and other ambient conditions. Measurement results do not indicate that the polyurethane foam emits more smoke than other materials (measured at 550 and 850^{0}C).

Table14 Smoke density of the various plastics

Combustion temperature	550℃		850℃	
	Smoke concentration	Smoke coefficient	Smoke concentration	Smoke coefficient
Plastic type	m³	C· m³/g	m³	C· m³/g
Polyurethane foam	0.284	0.710	0.182	0.173
PVC	2.025	0.854	2.062	0.793
PC	0.746	0.386	1.362	0.605
PS foam	0.131	0.815	0.450	0.461
ABS resin	1.640	0.811	1.225	0.569
PE	0.607	0.331	0.550	0.289
PP	0.595	0.457	0.532	0.360

Source: Modern Plastics 119, July 1983

Q15. Do flexible polyurethane foams catch fire easily?

A: The ignition point of organic materials generally ranges from 230 to 390^{0}C and the self ignition point ranges from 230 to 530^{0}C. The flash ignition point and the self ignition point of flexible polyurethane foam (the specimens used here are ordinary flex-foams not treated with flame retardant) are 288^0 and 456^{0}C, respectively, which are nearly commensurate with those of cotton, newspaper, pine and other natural timbers, acryl, nylon and other synthetic fibers, and polyethylene, polyvinyl chloride, polystyrene foams and other plastic materials. Like all these materials, flexible polyurethane foams are immune to spontaneous combustion.

Foams generally have a lower thermal inertia than solid resins, and, once ignited, tend to burn faster. Polyurethane foams, which do not have particularly short time to ignition compared with other materials, will be promoted to burn, due to low inside cooling effect attributable to low thermal inertia, possibly up to a phenomenon of deflagration. It is required to keep ignition sources off polyurethane foams.

Q16. What is the degree of the heat resistance of flexible polyurethane foams?

A: The heat resistance of flexible polyurethane foams varies with the type of foams. The foams can generally be used in a temperature range up to 80^{0}C. The strength of foams is reduced to half during continuous use of 500-700 days at 80^{0}C. There will be no heat resistance problems in ordinary use.

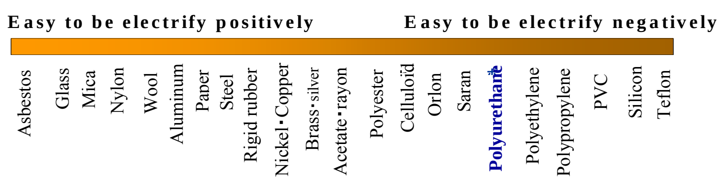
Q17. Won't flexible polyurethane foams ignite by sparks of static charges built up in them?

A: Static charges generate anywhere in any place including production facilities, construction sites and dwelling houses.

Flexible polyurethane foams, which have a low electric conductivity, easily build up static charges by friction, but such static charges will have a low probability of igniting polyurethane foams because of very low discharge energy, that is, ignition energy.

However, when polyurethane foams are being bonded using an adhesive that contains a flammable solvent, or if polyurethane foams containing flammable liquid are present at the job site, it should be noted that flammable vapors may be set to fire by spark discharge, which in turn may ignite the foams. In cutting foams, proper measures should be taken to prevent static ignition risk of foam dust.

Example of electrical charge the various materials



Q18. Can flexible polyurethane foams be made fire retardant?

A: Flexible polyurethane foams can be made fire retardant by selection of the structure of the product and the type of constituents used, and by addition of fire retardant. Foams having the following fire retardant characteristics per application are commercially available:

- Hard to ignite,
- Ignitable; after ignition, fire is slow in spreading (that is, the combustion rate is low), and
- Ignitable; after ignition, fire goes out spontaneously when the fire source (a match or the like) is removed.

The fire retardancy of flexible polyurethane foams is generally evaluated by igniting a specimen using a small fire source such as cigarette, match or methenamine and measuring how soon the fire goes out spontaneously when it is removed. With respect to furniture, bedding and other products composed of a flexible polyurethane core covered with other materials, the fire retardancy of the product differs with the materials of the cover used. In Europe and the US, the fire retardancy of furniture and bedding is evaluated in full size test. (See Q33 andQ34)

Q19. Do flexible polyurethane foams differ in combustibility from plastic foams used as building interior materials?

A: Rigid polyurethane foams used as building materials are fire retardant, and isocyanurate foams which exhibit higher fire retardancy are also used. Rigid polyurethane foams are composed of closed cells which contribute to thermal insulation performance. In contrast, the cells of flexible polyurethane foams are so structured as to allow air ingress, and this makes a difference in combustibility of the materials.

Q20. Do flexible polyurethane foams for upholstery application differ in combustibility from other plastic foams?

A: Flexible polyurethane foams for upholstery applications are used in mattresses, pillows, carpet backing, sofa padding, backrests, chair cushions, 'kotatsu' mats, floor cushions, dishwashing sponges, doll stuffing, diapers, bath mats, ironing board covers, clothes brushes and other products. The combustibility of these flexible foams is quite similar to that of other plastic foams.

Ref: ISO 871:2006--Flash and Fire Points of Plastics

Q21. When flexible polyurethane foams burn, what gases will be emitted?

A: The fire of polyurethane foams is basically not different from ordinary fires. Just like other organic materials, burning polyurethane foams emit mainly carbon dioxide, carbon monoxide and moisture vapor. Other trace gases vary with the combustion conditions such as temperature and air supply during the course of fire. Shown in the following are combustion gases emitted by various materials measured in small experiment equipment, but it is generally considered that gas components found in a small experiment would not represent all the gases emitted in actual fires. Literature lists varying measurements of gas components in varying combustion conditions (temperature and air supply), and mentions carbon dioxide and carbon monoxide as main combustion gas components, together with combustible hydrocarbons and nitrogen compounds produced by thermal decomposition.

Table21-1 combustion products of polyurethane foam

Combustion gas mg/sample 1g

		Literature A	Literature B	Literature C *1	Literature D		
Combustion condition	℃	700	500	800	350	500	750
Air supply	L/hr	100	13.2				
	L/min	(1.7)	0.22		4.0	4.0	4.0
Combustion gas	CO_2	666	88	320	264	644	1236
	CO	173	57	970	26	138	353
	HCN	3.3	<2	8	1	6	8
	Methane	21	4.6				
	Ethylene	43	3.9				
	Acetylene	14		120			
	Ethane		1.3				
	Propylene		29				
	Butene		0.38				
	Acetaldehyde		32				
	Acetone		13				

Source: Fire Engineering Handbook, 3rd Ed. (1997) *1: in 5l flask

Table21-2 Combustion gases from polyurethane foam

Tester	Morimoto 1)		Sumi、Tsuchiya 2)						Kishiya 、Nakamura3)		
combustion condition	700℃		800℃ in 5l flask						350℃	500℃	700℃
	1.7 L/min	0.8 L/min	0.4g	0.6g	1.2g	1.6g	2.0g	2.4g	4 L/min		
CO_2	0.666	0.625	1.4	0.7	0.47	0.43	0.32	0.28	0.264	0.644	1.236
CO	0.173	0.16	0.2	0.23	0.157	0.142	0.97	0.092	0.026	0.138	0.353
HCN	0.0033	0.001	0.008	0.008	0.008	0.008	0.008	0.008	0.001	0.006	0.008
CH_4	0.021	0.017									
C_2H_4	0.043	0.037									
C_2H_2	0.014	0.0064	0.12	0.13	0.12	0.12	0.12	0.10			

Source : 1) High polymer Vol 22, No253, p190-195 , 1973
2) J.fire and flamm, 4, p15-, 1973
3) Plastic 25(11) 1974

Table 21-3　Combustion test products (mg/g)

Fire Product	CEL*1	PES*2	Silk	Wool	Nylon	PAN*3	PU foam	PE*4	PP*5	PMMA*6	PVC*7
CO_2	202	290	170	69	35	73	88	120	21	99	< 8
CO	88	85	13	21	13	12	57	120	25	61	7.0
HCl	-	-	-	-	-	-	-	-	-	-	230
NH_3	-	-	21	12	6	2.6	-	-	-	-	-
HCN	-	-	1.3	1.8	-	6.6	< 2	-	-	-	-
COS	-	-	-	1.8	-	-	-	-	-	-	-
CH_4	2.4	1.7	1.7	1.9	0.84	3.4	4.6	2.5	1.5	0.56	1.7
C_2H_4,C_2H_2	2.8	2.7	0.57	1.6	3.6	0.6	3.9	18	2.1	0.51	0.98
C_2H_6	0.52	0.14	0.62	0.91	0.92	0.79	1.3	1.6	3.1	0.08	1.7
C_3H_6	0.88	0.18	0.6	2.0	2.6	0.27	29	12	27	1.23	0.73
C_3H_8	0.11	-	-	1.3	0.7	1.4	-	2.5	-	-	0.83
C_4H_8	-	-	-	1.1	2.9	-	0.38	-	4.8	-	-
C_6H_6	-	2.7	-	-	-	-	-	-	-	-	11
$C_6H_5CH_3$	-	0.23	-	-	-	-	-	-	-	-	-
CH_3OH	-	-	-	-	0.68	2.0	-	6.2	5.6	-	-
CH_3CHO	2.5	14	-	-	0.81	-	32	10	7.9	-	0.3
CH_2=CHCHO	2.1	-	-	-	-	-	-	8.4	3.9	-	-
CH_3COCH_3	-	-	-	-	-	-	13	-	-	-	-
CH_3CN	-	-	5.7	1.6	1.2	3.0	-	-	-	-	-
CH_2=CHCN	-	-	-	0.83	-	5.6	-	-	-	-	-
MMA*8	-	-	-	-	-	-	-	-	-	89	-
Residue	4.1	9.1	19.3	12.7	4.3	19.5	4.3	32.3	4.0	0	15.5

*1.Cellulose　*2.Polyester　*3.Polyacrylonitrile　*4.Polyethylene　*5.Polypropylene

*6.Polymethylmethacrylate　*7.Polyvinylchloride　*8.Methymethacrylate

Decomposition temperature；500℃,　O_2 concentration；21%, Air flow；0.22ml/min.

Decomposition time；4min.　Sample weight；100 mg

Table21-4 Combustion gases from high polymers

Specimen (0.1g)	Air supply (L/h)	Combustion gas (mg/ specimen1g)											Gas rate %
		HCL	CO_2	CO	COS	SO_2	N_2O	NH_3	HCN	CH_4	C_2H_4	C_2H_2	
PE	100 50		738 502	210 195						72 65	185 187	34 9.5	62.5 51.2
PS	100 50		619 590	178 207						6.5 6.5	18 16	13 6.4	30 29.7
PVC	100 50	286 279	657 594	177 207						 6.5	 2.3	11 6.4	69.3 68.8
Nylon66	100 50		590 563	206 194				9.8 3.5	31 26	40 39	94 82	15 7.4	60.7 55.7
Polyacrylic amide	100 50		796 738	157 173				17 32	18 21	16 20	10 13	8.5 4.2	63.3 62.1
Polyacryliro nitril (PAN)	100 50		556 630	108 132					56 59	5.9 7.8		7.4 4.2	37.7 42.7
Polyurethane (PES/TDI type)	100 50		666 625	173 160					3.3 1.1	21 17	43 37	14 6.4	51.4 44.5
PPS	100 50		1796 1892	161 219	2.5 2.5	423 451						2.1 1.1	85.1 92.7
Epoxy resin	100 50		1136 961	153 228					2.2 3.3	16 33	2.3 4.6	7.4 6.4	52.9 52.7
Urea resin	100 50		1193 980	 80					 22				96.7 92.5
Melamine resin	100 50		576 702	194 190			34 27	84 136	96 59				81.8 86.8

Q22. If gas or smoke emitted by flexible polyurethane foams on fire is inhaled, what influences will occur to the body of the inhaler and what measures should be taken?

A: Gas or smoke inhaled first irritates the throat. If inhaled in abundance, it is generally assumed that it causes headache and some symptoms that resemble those of carbon monoxide intoxication such as difficulty of moving, and disturbances of perception and thinking. The first thing to do when gas or smoke is inhaled is to breathe in fresh air and lie quietly. If the symptoms are grave, consult a doctor promptly.

Much remains unknown as to how such disturbances develop when a person breathes gases emitted by fire, as well as how such poisonous gases are produced and in what conditions such gases are exposed to human bodies.

＊ The subjective symptom appears to become 10% or more, and the lethal concentration is assumed to be 60～70% when depending on the CO-Hb concentration in blood in principle, though the poisoning symptom is controlled by the inhalation concentration of the carbon monoxide, the exposure time, and the breathing state, the amount of circulating blood, and the hemoglobin content in blood etc. when bloody mesne of breath.

Table22 Symptoms associated with a given concentration of COHb

Carboxyhemoglobin (COHb)	Symptoms
～10%	No symptoms
10～20 %	Mild headache、expansion of skin blood vessel
20～30%	Headache, nausea, vomiting, and trouble making decisions
30～40%	Dizziness, muscle weakness, vision problems, confusion, and increased heart rate and breathing rate
40～50%	Dizziness, muscle weakness, vision problems, confusion, and increased heart rate and breathing rate
50 ～60%	Loss of consciousness、coma, cheyne-stokes breathing, sometime death
60～70%	Loss of consciousness、coma, cheyne-stokes breathing, breath weakening , sometime death
70%～	Breathing stop, circulation lethargy, death

http://biology.about.com/od/molecularbiology/a/carbon_monoxide.htm

Q23. When flexible polyurethane foams are set on fire, what is the amount of smoke emission compared with other plastic materials?

A: The amount of smoke emission differs considerably with the constituents and shape of the material on fire, and the temperature, oxygen concentration and other ambient conditions. Polyurethane foams will not emit more smoke compared with other plastics.

Safety measures against smoke are said to be one of the most important items in fires of organic materials. Exposure to smoke is a great menace to the safety of people.

The Fire Service White Paper mentions that failure to escape in fires occupies a high rank in the list of the causes of death. Smoke emission will induce loss of visual field, smoke inhalation, impaired judgment, reduced ability to take action and psychological impact, possibly leading to failure to escape and death. Firefighting in the earliest stage is badly needed.

Table23-1 Smoke density of the various plastics

Combustion temperature	550℃		850℃	
	Smoke concentration	Smoke coefficient	Smoke concentration	Smoke coefficient
Plastic type	m^3	C· m^3/g	m^3	C· m^3/g
Polyurethane foam	0.284	0.710	0.182	0.173
PVC	2.025	0.854	2.062	0.793
PC	0.746	0.386	1.362	0.605
PS foam	0.131	0.815	0.450	0.461
ABS resin	1.640	0.811	1.225	0.569
PE	0.607	0.331	0.550	0.289
PP	0.595	0.457	0.532	0.360

Source: Modern Plastics 119, July 1983

Q24. What sort of products are 'low-combustibility' polyurethane foams?

A: Flexible polyurethane foams, which are organic materials just like other plastics, are subject to combustion (classified as combustibles in the Fire Service Law).

Low-combustibility foams are such products as have been made flame resistant by various means, and generally have the following characteristics:

- Hard to ignite,
- Ignitable; after ignition, fire is slow in spreading (that is, the combustion rate is low), or
- Ignitable; after ignition, fire goes out spontaneously when the fire source (a match or the like) is removed.

What are called low-combustibility polyurethane foams are those products that are judged to have sufficiently low combustibility in tests made per application, and may have different ratings for different applications

The fire retardancy (also called combustion resistance or flame resistance) of polyurethane foams and other plastic materials, which are organic compounds, is quite different from the fire resistance of concrete and steel. Polyurethane foams are threatened with burning if exposed to flame for a long time. 'Low combustibility' indicates the degree of flame intensity and the extent of exposure time that the foams can withstand.

Q25. Do combustion gases of flexible polyurethane foams contain toxic constituents?

A: All combustibles, whether they are natural materials or synthetic materials, will, while burning, emit toxic gases of some kind. Main toxic gases that have been identified are carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen compounds such as hydrogen cyanide (HCN) and nitrogen oxides (NOx). Polyurethanes will produce trace amounts of some additional compounds.

There is misunderstanding that smoke emitted in a fire that involves polyurethane goods implicitly has a higher health hazard than in a fire of other synthetic resin materials or natural materials because the former contains hydrogen cyanide gas. Hydrogen cyanide gas is produced in fires involving any nitrogen-compound-containing materials (wool, acryl, nylon and ABS, for example).

Flexible polyurethane foams, which contain nitrogen compounds, emit cyanide gas, depending on the combustion conditions, but it is not on the high side, as shown in the following tables. It is reported that carbon monoxide is the most hazardous gas, in terms of toxicity, in every combustion condition of fire.

Table 25-1 Combustion products*1 of organic materials

(mg/sample1g)

Material	CO_2	CO	HCN	NH_3	HCL	Other hydro-carbons
PU foam*2	666	173	3.3			78
Polyethylene	738	210				291
Polystyrene	619	178				37.5
Polyvinylchloride	657	177			286	11
Nylone 66	590	205	31	9.8		149
Polyacrylamide	796	157	18	17		34.5
Polyacrylnitri	556	108	56			13.3
Epoxy resin	1138	153	2.2			25.7
Cedar	1573	16				

＊1 Combustion parameters： temperature 700℃、 air flow 100l/hr
＊2. Polyester polyurethane (from TDI)

Table 25-2 Generation of HCN at combustion of N-containing materials

Material	HCN peak conc. ppm	Peak temp. ℃
Nylon	328 – 520	485 – 429
Wool	368	567
Polyacrylonitrile	445	381
Urea formaldehyde resin	458	321
Rigid PU foam	321 －467	587 － 549
Flexible PU foam	181	388

F.M. Esposito et al., Journal of Fire Sciences, 6, 195-242 (1988)

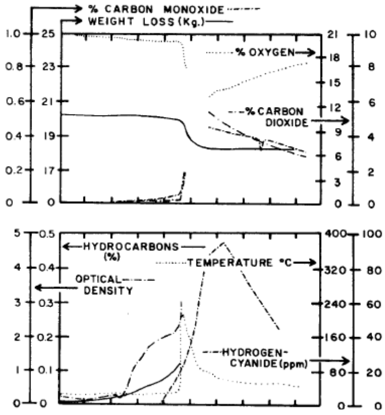
Q26. What gases will be emitted during smoldering?

A: Main gases emitted during smoldering (for example, when a 'futon' ignited by a lit cigarette is smoldering), are carbon dioxide and carbon monoxide, and they are produced in abundance. Thus carbon monoxide is generally the greatest cause of danger. Depending on the constituents of smoldering materials, a variety of slight amounts of thermal decompositions will also be produced, such as low molecular hydrocarbons, hydrogen chloride, nitrogen oxides and a trace amount of hydrogen cyanide (HCN).

It is said that organic substances containing nitrogen would hardly emit acrolein or formaldehyde.

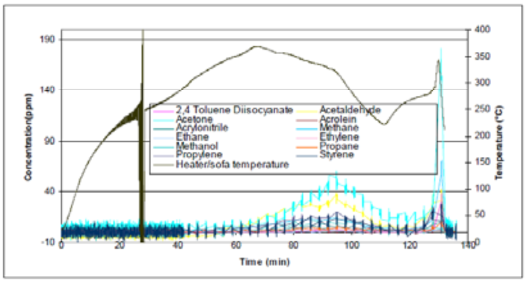
The temperature at the incipient and growing stages of fire is 400-700^{0}C, and, when the materials are flamed, gases emitted by oxidizing flame at such temperature are mostly carbon dioxide and water vapor. The amount of carbon monoxide and irritant gases are relatively small, but as the fire grows, emission of toxic gases including carbon monoxide will increase. The temperature at the blazing and ending stages of fire exceeds 800^{0}C. As oxygen concentration is low at such high temperature, thermal decomposition products will be low molecular and form carbon monoxide and other toxic gases. As the concentrations of these gases increase, they will be more dangerous.

Fig26-1 Toxicity of smoke during Chair smoldering tests for Polyurethane foam



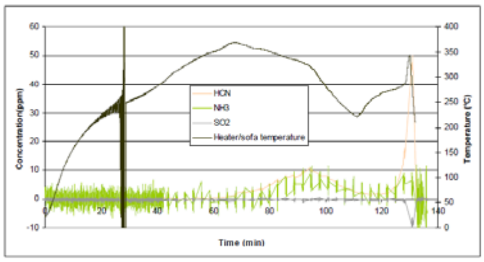
Source: Fundamental and Applied Toxicology 3 :619-626 (1983)

Fig26-2 VOC concentrations versus time at the ceiling



Source: 12th International Conference on Fire and Materials, San Francisco, CA January 26-28,2009 p12

Fig26-3 Concentrations of inorganic gases Vs time at the ceiling



Source: 12th International Conference on Fire and Materials, San Francisco, CA January 26-28,2009 p12

Source: 12th International Conference on Fire and Materials, San Francisco, CA January 26-28, 2009 p12

Q27. What are typical combustion tests of flexible polyurethane foams?

A: There are combustion tests specified for automobiles, railroad cars, aircraft seats, furniture and other applications. The following table lists the specification numbers and designations of such tests.

Table27-1 combustion test for flexible polyurethane foam

Regulation No	Title	Category	Remark
FMVSS No302	United States car safety standard	Lower combustibility	
	Flame resistive standard of the Ministry of Transport for car interior material		
UL-94	Standard by which combustibility degree of material is recognized	Lower combustibility	HF etc.
A-A standard	Material combustion examination for railway vehicle	Lower combustibility	
	Flame retardant performance test standard for bedding such as mattress	Lower combustibility	
FAR25.853	air-proof examination points	Lower combustibility	
UL900 class2	National Fire Protection Association No.90A and No.90B	Lower combustibility	
	California law 117	Lower combustibility	

Reference

Flexible foam	BS4735(UK), ＵＬ94－HF1 (USA), CSE-RF4(Italy), BS5852 crib5, consumer safety law in 1988, California law 117
Foam for car	FMVSS-302
Rigid foam	Performance required in BS476 part6, 7 , NFP92-501(France), DIN-4102(Germany)

Q28. Can we find the combustibility of polyurethane foams by simple means?

A: There may be cases in which the combustibility of foam materials under MVSS or UL Standards is roughly estimated by heating pieces of foam with a lighter or match, but such a simple means will not be good enough as a method for determining whether such foams conform to such standards or for making comparisons of fire retardant foams conforming to MVSS or UL Standards with each other.

The reason is that, if a small fire source like a lighter is used, polyurethane foams will not always exhibit the same burning behavior as under UL or other standards in which a heat source of high calorific value (gas burner) is used.

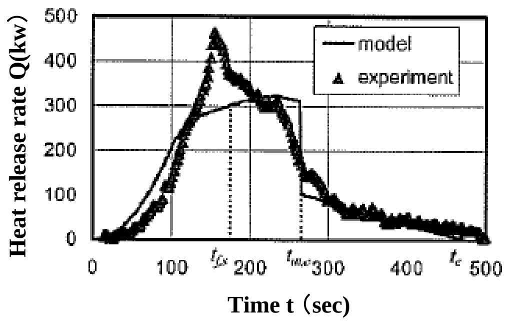
In addition, there are presently no simple means to properly evaluate a number of combustibility characteristics such as ignitability, smoke emission, heat release and combustion rate.

Understanding the burning behavior of combustibles in the incipient stage of fire is important in preparing fire safety design.

The combustion of polyurethane matting is divided into the melting of the material occurring

immediately after ignition and the burning of vapors arising simultaneously. There is an example of simplified
modeling that is proposed to predict, by use of small cubic specimens, the heat release rate of urethane foam based on such data as the growth rate of the radius of melting, the rate of the growth of residue and the rate of heat release in terms of oxygen consumption.

Fig28 Model vs Experiment in comparison



Source:
Lecture meeting paper of Architectural Institute of Japan、 Aug. 2002
“simple forecating method of heat release rate for urethane mat”

Q29. What materials fall within the interior finishing certified by test under the Building Standard Law?

A: Commonly used interior finishes are wood, plastic, wall covering and gypsum board materials. Buildings subject to the regulations and restrictions on interior finishes are designated buildings and large wooden buildings, and portions of those buildings subject to such restrictions are walls and ceilings (or roofs, if the building has no ceilings). Incombustible, quasi-incombustible or fire retardant materials must be used as interior finishes in such portions of such buildings. Presently no flexible polyurethane foams fall within this category.

Note: Buildings free from such restrictions are “houses that meet the prescribed conditions of building structure and total floor space.”

Depending on the use and the construction, buildings are generally subject to legally prescribed restrictions on the structure and the room and corridor interior finishes. The purpose of such restrictions is to hold back the danger in fire by using fireproof materials. Required fireproofness of interior finishing differs with the use, the structure and the floor space of the building, and is certified by tests conducted under the law so that the interior will be finished with “fire retardant or better,” “quasi-incombustible or better,” or “incombustible” materials. These interior finishing materials are approved by the Ministry of Land, Infrastructure ,Transport and Tourism.

Q30. What does 'interior finish restriction' signify?

A: There are restrictions on materials used for interior finishing, depending on the use and the scale of the building (Ref. Table 31). Such restrictions are prescribed by the Building Standard Law so as to prevent fierce combustion of interior materials leading to fast growth of fire, emission of toxic gases and jeopardizing escape of people.

The danger of indoor fire comes from a flashover in particular, which is a phenomenon of instantaneous combustion of the whole room by heat accumulated in it. The purpose of the restrictions on interior finishes is to hold back ignition of the interior finishes and control occurrence of a dangerous flashover so that people inside may have an escape.

The Building Standard Law imposes interior finishing restrictions on houses, designated buildings such as theaters, clubhouses, hospitals, hotels and other public buildings, buildings of three or more stories or with a total area exceeding 1,000m^2, buildings that have a room without windows or similar openings, and buildings equipped with a kitchen or other equipment that uses fire. It is required to construct these buildings so that the standards of interior finish restrictions (Article 35-2 of the Building Standard Law and from Article 128-3, Paragraph 2 to Article 129 of the Enforcement Ordinance of the Building Standard Law) will be met by using such heat insulating materials as are designated as incombustibles or quasi-incombustibles or by covering the surface of heat insulating materials with legally approved incombustibles.

- Applicable laws and regulations: Article 35-2 of the Building Standard Law, and from Article 128-3, Paragraph 2 to Article 129 of the Enforcement Ordinance of the Building Standard Law

Article 35-2 (Interior Finishes of Designated Buildings, Etc.) of the Building Standard Law prescribes restriction of interior finishing materials per use and scale of the building so that the growth of fire may be held back and escape and firefighting activities may be facilitated. As prescribed by the provision, the restriction applies to the portions of walls and ceilings facing the rooms.

Reference: Article 35-2 (Interior Finishing of Designated Buildings, Etc.) of the Building Standard Law: "Except as prescribed by government ordinance, buildings for uses designated in Column A of Exhibit 1, buildings of three or more stories, buildings that have a room without windows or similar openings designated by government ordinance, buildings with a total area exceeding 1,000m^2, and buildings with a kitchen, bathroom or other rooms equipped with a stove, cooking range or other equipment that uses fire shall have the portions of walls and ceilings (or roofs, if the building has no ceiling) that face any room finished as per the technical standards prescribed by government ordinance so that hindrance or obstruction to the prevention and control of fire will not arise."

Q31. Are flexible polyurethane foams regulated by the interior finishing restriction?

A: Since flexible polyurethane foams are not used as interior finishing, they are usually not subject to the interior finishing restriction under the Building Standard Law. However, furniture and other things placed in buildings are regulated by the flame retardant standards stipulated under the Fire Service Law. Commonly used are flame retardant products certified by the Flame Retardant Products Certification Committee as per the performance test standards authorized by the Japan Flame Retardant Association. For example, the fire retardancy of flexible polyurethane foams used in bedding is evaluated by 45^0 methenamine method

Ref: Q31A Table 31: Tabulated List of Interior Finish Restriction

Q32. Does the Fire Service Law regulate the interior materials?

A: The Fire Service Law prescribes measures for prevention and control of fire of interior goods and products. The intention of the Law is to ensure prevention of fire, firefighting at the earliest stage, rescue of people and extinction of fire, and to provide full fire protection by making proper use of firefighting equipment under good fire control practice. With the aim of protecting people from fire exposure, the Law specifies objects of fire retardancy regulation and prescribes restriction of fire retardant goods and products for use for such objects.

In particular, definite fire safety measures are required for public buildings provided for use by many unspecified persons.

The laws governing the matters regarding the fire prevention of interior materials, products and goods are the Building Standard Law and the Fire Service Law. The Building Standard Law prescribes restriction on interior finishing with intent to ensure safety and escape of people. The Fire Service Law requires fire safety measures which will work synergistically with the relevant provisions of the Building Standard Law for the achievement of safety of people and protection of property up to a certain level.

Table32 Interior finishing restriction of Building Standard Law and Fire Service Law

Name of material	Fire prevention material	Flame retardant product
Performance standard	･Noncombustible materials ･Quasi noncombustible materials ･Fire retardant materials	Flame retardant performance (Numerical values of after flame, after glow, charring length,and the area, etc. by each plywood ,a thin cloth, thick cloths, and the carpets etc, have been decided).
Object building of material	Special building etc (See the list of Interior finishing restriction)	Fire prevention object (See fire prevention object given flame retardation regulation)
Object	Part that faces room of wall and ceiling	Carpet such as rug , curtains, black curtains, blind made of cloth, plywood used on stage setting at the scene, plywood for exhibitions or sheet for construction
Law, Cabinet order	･Building standard law ･Order for enforcement of building standard law ･Regulation for enforcement of building standard law	･Fire service law ･Order for enforcement of fire service law ･Regulation for enforcement of building standard law
Department concerned	Ministry of Land, Infrastructure、Transport and Tourism	･Ministry of internal Affairs and communications (MIC) ･Fire and Disaster Management Agency

Q33. Are there any differences in the combustion test of interior materials in Japan and in foreign countries?

A: Yes. Different concepts of expected fires make differences in the combustion tests in Japan and in America and Europe. Test and evaluation methods of interior products and goods for use in houses differ accordingly, and the test of bedding in particular is conducted by different methods in different countries. In Japan the flame retardancy performance of household interior products and goods is evaluated in small tests using small fire sources in accordance with the pertinent provisions of the Fire Service Law and the pertinent clauses of the standard of Japan flame Retardant Association. In the UK the flame retardancy test is conducted as per BS5852 using different fire sources (seven kinds of fire sources) with different uses of the products. In the US a number of test standards for furniture including Cal TB117, TB129, TB133, ASTM1590 and CFR1663 are used, depending on the required fire retardancy performance, the use of the products and the scale of the tests conducted.

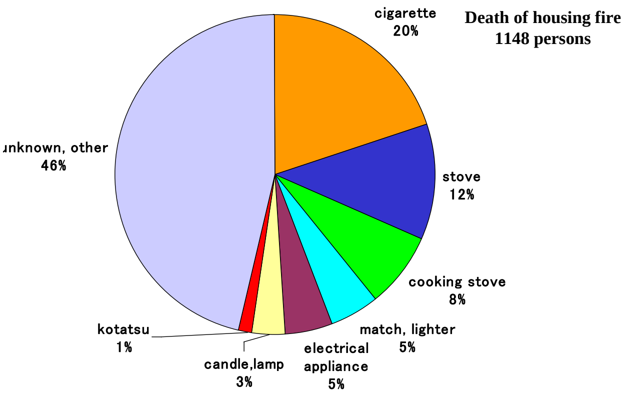
Q34. What care is required to prevent fire?

A: There are a number of instances of fire in houses and vehicles in which flexible polyurethane foams used in sofas, mattresses and seats burned, but polyurethane foams have scarcely been the cause of fire. Most common cause of house fire except arson is careless handling of lit cigarettes. Never smoke while lying on sofa, mattress, bed or 'futon,' and keep naked flame off these things.

Use of flame retardant mattresses, curtains and other goods that satisfy the requirements of the

Qualification Guideline of the Japan Fire Retardant Association is recommended. The surface of vehicle seats is covered with materials that provide MVSS conforming products.

Fig34-1　Death toll of housing fire by Ignition material in 2008
(except arson/suicide)



Source： fire white paper in 2008

Q35. What educational activities for fire prevention is JUII engaged in?

A: In ordinary houses flexible polyurethane foams scarcely become the cause of fire, but arson or wrong use of fire may lead to fire of the building. For the purpose of preventing such fire, we publish and utilize fire prevention booklets and contribute educational articles to trade journals.

Table35 Documents for fire prevention and fire safety

Reference	Title	Publisher
1	Guidance of safety handling of rigid urethane foam July, 1995	・Japan urethane insulation institute ・Guidance : Tokyo Fire Department Multilingual
2	Let's prevent a urethane fire.	・Building Contractors Society Construction departmental Meeting urethane measures task force
3	Guidance of the fire prevention in construction site with plastic foam thermal insulation	・Japan Construction Occupational Safety and Health Association
4	Flame resistive grade 3 simplified confirmation test method of rigid spray urethane foam	・Japan Urethane Industry Institute
5	Guidance of polyurethane raw material safety handling	・Japan Urethane Raw Materials Association
6	Fire safety on polyurethane foam March,2008	・Japan Urethane Industry Institute
7	Guidance on fire safety assessment of polyurethane foam March,2008	・Japan Urethane Industry Institute
8	Q&A concerning flexible urethane foam 2009 edition	・Japan Urethane Foam Association
9	Q&A on fire and fire prevention of rigid polyurethane foam May, 2009	・Japan Urethane Industry Institute

Q36. What other points require attention in handling flexible polyurethane foams?

A: The following matters should be kept in mind:

(1) Measures against static charges

Flexible polyurethane foams, which have a low electric conductivity, easily build up static charges by friction, but such static charges will have a low probability of igniting polyurethane foams because of very low discharge energy. Attention is required, however, during bonding operations of polyurethane foams using an adhesive that contains flammable solvents, because solvent vapors are apt to ignite by static sparks and the foams may catch fire.

Measures for ignition prevention are required such as using an aqueous adhesive or an adhesive containing fire retardant solvents, preventing penetration of the foams with liquid or vaporized thinner, gasoline, benzine, alcohol or other low flash point solvents, keeping the foams off such solvents, reducing the concentration of vaporized flammable solvents in the workshop, removing or suppressing (by humidification, etc.) static charges from the environment.

(2) Goods impregnated with oils

Flexible polyurethane foams impregnated with oils may generate smoke or fire in relatively low temperature. Pour water, and take care that such foams will not be heated. This is a phenomenon found not only in polyurethane foams but in cotton and fabrics in general. It is reported that oils that have permeated into these materials exposed to air are subject to autoxidation, which will lead to increased inner temperature, possibly causing emission of smoke and production of fire from the oils first and then from the impregnated materials, just like garbage getting burned by hot cooking oil. There are instances of fire breaking out of welding or cutting sparks sticking to polyurethane foams. Ensuring absence of foams in the neighborhood before setting to work is strongly recommended.

APPENDIX

Q25A Table 25-3 Major fire gases and their toxic effect

Fire gas	Toxic effects	Toxicity *
Narcotic gas 1) Carbon monoxide (CO)	Combining with hemoglobin in blood to form carboxy -hemoglobin, CO reduces oxygen supply to brain tissue, resulting in loss of consciousness and incapacitation.	LC_{50} =5000~6600 ppm(v/v) [1]
2) Hydrogen cyanide (HCN)	Traces of HCN can generate in fires of nitrogen containing materials. It is carried rapidly to body (brain) and inhibits the utilization of O_2 at cells. HCN, like CO, finally depresses cerebral function, and its intoxication takes effects rapidly.	LC_{50} =110~200 ppm(v/v) [1]
3) Carbon dioxide (CO_2)	CO_2 is present always in fires. It is not toxic up to 5%, but it stimulates breathing and increases uptake of other toxicant gases. It is a narcotic at about 5% and subjects become intolerable within 20 min. at approximately 6%.	
4) Hypoxia (low O_2)	O_2 concentration decreases in a compartment fire. Low concentration below 18% is dangerous for humans. Their motor coordination is impaired at about 14% and they may exercise faulty judgement at about10%.[2) 3)]	
Irritant gas 1) Hydrogen chloride (HCl)	HCl generates at fires of chlorine containing materials. Irritating extremely eyes and upper respiratory tracts (as low as 100ppm), it impairs activities such as escape from fires.	LC_{50}=1600~6000 ppm [2] RD_{50}=309 ppm [2]
2) Acrolein and other organics	Many organic irritant materials are formed in pyrolysis and/or incomplete combustion of organic materials. Acrolein, which irritates eyes and upper respiratory tracts strongly at a few ppm, is found to be present in many fire atmospheres.	LC_{50}=140~170 ppm [2] RD_{50}=1.7 ppm [2]
3) Ammonia (NH_3)	NH_3 irritates eyes and upper respiratory tracts. It may cause pulmonary edema.	LC_{50}=1400~8000 ppm [2] RD_{50} =303 ppm [2]
4) Nitrogen oxides (NO_x)	NO_x is primarily a pulmonary irritant.	NO_2: LC_{50}=60 ~ 250 ppm [2] RD_{50}=349 ppm [2]

* LC_{50} : Concentration statistically calculated to cause the death of one half of the animals exposed to a toxicant for a specified time(e.g.10, 30 min.). Above data are taken for 30 min.

* RD_{50} : Statistically calculated concentration of a sensory irritant required to reduce the breathing rate of laboratory rodents by 50%.

1)ISO/TR 9122-5 (1993)

2)D.A. Purser, SFPE Handbook of Fire Protection Engineering Section 2/ Chapter 8 (1995)

3)G.E. Hartzell, Toxicology, 115, 7-23 (1996)

Postscript

In line with people's growing interest in polyurethane products, there is in recent years a lot of interest in fires involving polyurethane materials among consumers in general as well as manufacturers and suppliers. As for rigid polyurethane foams used mainly as building materials, Japan Urethane Industry Institute (JUII) previously published Q&As concerning hazards and prevention of fire, which we believe have provided people with a great help to understand. Many flexible polyurethane foams are used in furniture, mattresses and other products placed in the dwelling space, and full consideration should be paid to these materials in case fire should break out. We would be delighted if these Q&As published this time would be a contribution to reducing occurrences of fire involving flexible polyurethane foams and provide another help to people to understand hazards and prevention of such fire.

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