

# Test Method for Flame Resistance of Plastics

R&D Center

## 1. Outline

Plastics employed using in fields such as automotive, electric & electronics, and construction face the risk of combusting by prolonged at high temperatures and contact with outside heat sources. To prevent combustion, flame-retardant materials have been developed. The UL method is a representative test for measuring the properties of flame retardant. This report contains an explanation about the UL test method and the Oxygen Index.

## 2. UL Test Method

### (1) Classification of UL tests for Plastics

Test method	Explanation	Typical test
UL 94	Standard for flammability tests of plastics materials for parts in devices and appliances	V, 5V, VTM, HB, HBF/HF
UL 746A	Standard for polymeric materials – short-term property evaluations	HWI, HAI, CTI, HVTR, D495
UL 746B	Standard for polymeric materials – long-term property evaluations	RTI
UL 746C	Standard for polymeric materials – outdoor suitability	UV & Water exposure
UL 746D	Standard for polymeric materials – fabricated parts	-

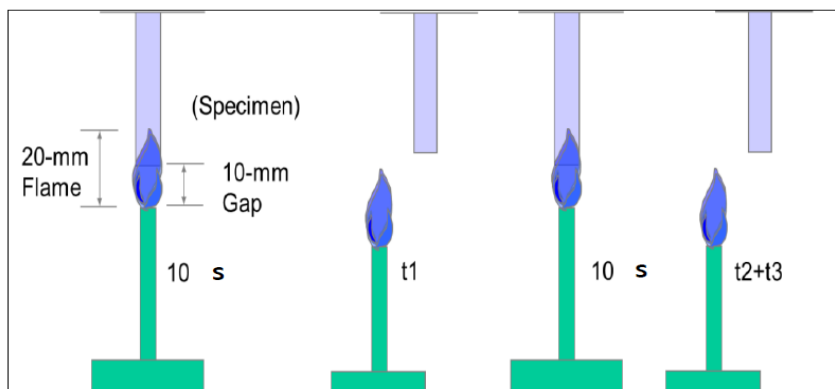
### (2) UL 94 : Standard for flammability tests of plastics materials for parts in devices and appliances

1) Typical test of UL 94 : V, 5V, VTM, HB, HBF/HF.

2) Vertical Burning Test : V-0, V-1, V-2

#### ① Test method

- Once the sample has been mounted, a carefully controlled flame is placed under the specimen for 10 seconds and then removed. When the flame is no longer in contact with the specimen, any residual flaming combustion of the plastic sample is observed and recorded (t1).
- When the plastic sample finally self-extinguishes, the controlled flame is immediately reapplied for another 10 seconds, and then removed. Again, the specimen's flaming combustion (in the absence of flame exposure) is recorded. (t2: afterflame and t3: afterglow)
- Lastly, a piece of dry surgical cotton is placed 12 inches below the combusting sample, if any drips fall onto the cotton and cause it to ignite, this detail is also recorded.



<Figure 1. Test method of vertical burning test>

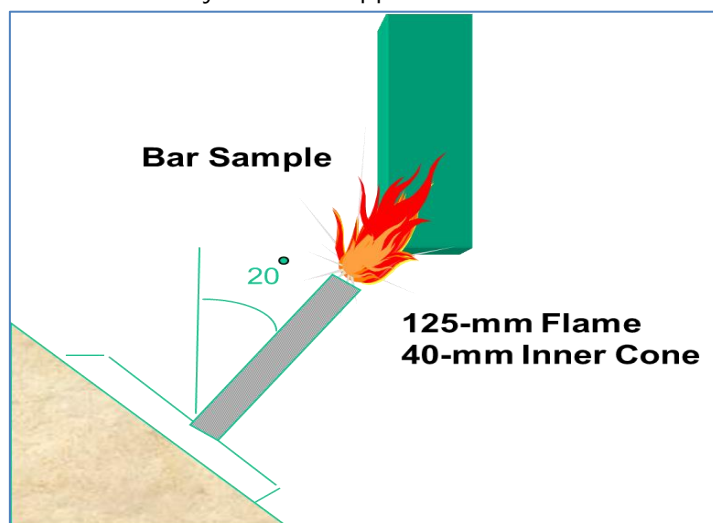
② Classification

	V-0	V-1	V-2
Individual afterflame time, t1 or t2	≤ 10 s	≤ 30 s	≤ 30 s
Total afterflame time for any condition set, t1 + t2 for the 5 specimens	≤ 50 s	≤ 250 s	≤ 250 s
Afterflame plus afterglow time for each individual specimen after the second flame application, t2 + t3	≤ 30 s	≤ 60 s	≤ 60 s
Burning up to the holding clamp	No	No	No
Cotton ignition	No	No	Yes

3) 5V Test (125 mm Vertical Burning Test) : 5VA (bar), 5BV (plaque)

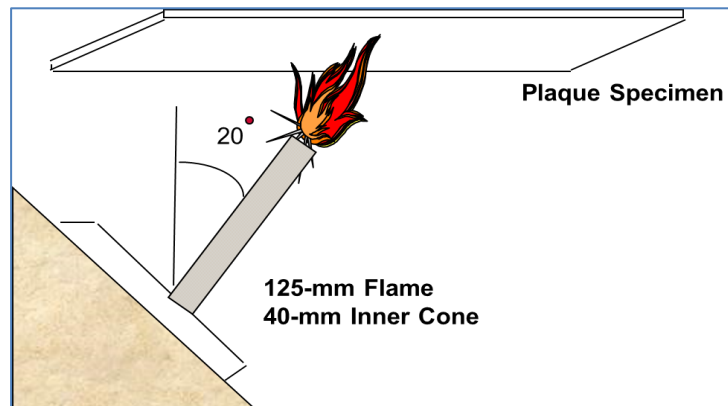
① Test method

- 5VA (bar) : Set each specimen and burner flame as in the below picture. The flame is applied for 5 seconds and removed for 5 seconds. The operation is to be repeated until each specimen has been subjected to 5 applications of the test flame.



<Figure 2. Test method of 5VA (bar)>

- 5VB (plaque) : Same as for bars except that the plaques are to be mounted on the horizontal plane with the flame applied to the center of the bottom surface of the plaque.



<Figure 3. Test method of 5VB (plaque)>

② Classification

	5VA	5VB
Afterflame plus afterglow time after fifth flame application for each individual bar specimen	$\leq 60$ s	$\leq 60$ s
Cotton ignition for any bar specimen	No	No
Burn-through of any plaque specimen	No	Yes

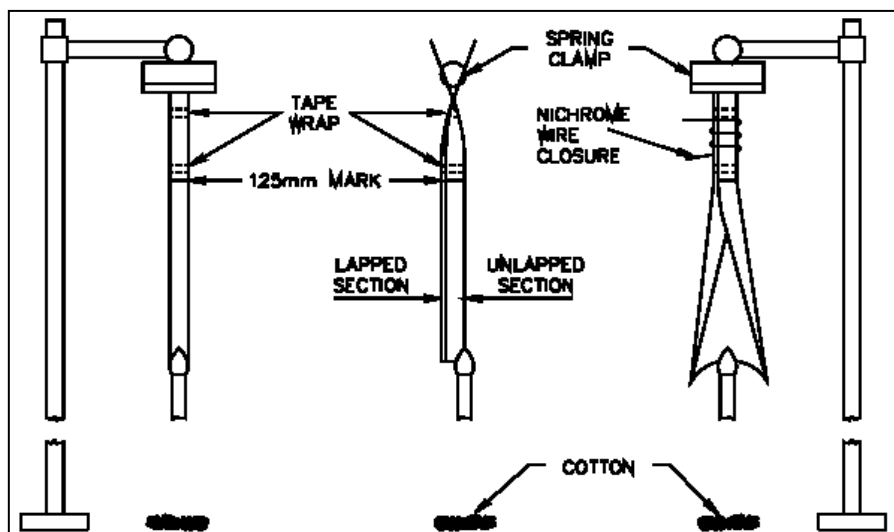
4) Thin Material Vertical Burning Test : VTM-0, VTM-1, VTM-2

- ① This test for thin materials that are not capable of supporting themselves in a horizontal position.

- $0.025\text{mm} \leq \text{thickness of specimen} \leq 0.25 \text{ mm}$  : Both VTM and V can be tested.
- Thickness of specimen  $\leq 0.025 \text{ mm}$  : Only VTM can be tested.

② Test method

- Once the sample has been mounted, a carefully controlled flame is placed under the specimen for 3 seconds and then removed. When the flame is no longer in contact with the specimen, any residual flaming combustion of the plastic sample is observed and recorded ( $t_1$ ).
- When the plastic sample finally self-extinguishes, the controlled flame is immediately reapplied for another 3 seconds, and then removed. Again, the specimen's flaming combustion (in the absence of flame exposure) is recorded. ( $t_2$  : afterflame and  $t_3$  : afterglow)
- Lastly, a piece of dry surgical cotton is placed 12 inches below the combusting sample, if any drips fall onto the cotton and cause it to ignite, this detail is also recorded.



<Figure 4. Test method of VTM>

### ③ Classification

	VTM-0	VTM-1	VTM-2
Individual afterflame time, t1 or t2	≤ 10 s	≤ 30 s	≤ 30 s
Total afterflame time for any condition set, t1 + t2 for the 5 specimens	≤ 50 s	≤ 250 s	≤ 250 s
Afterflame plus afterglow time for each individual specimen after the second flame application, t2 + t3	≤ 30 s	≤ 60 s	≤ 60 s
Burning up to the holding clamp	No	No	No
Cotton ignition	No	No	Yes

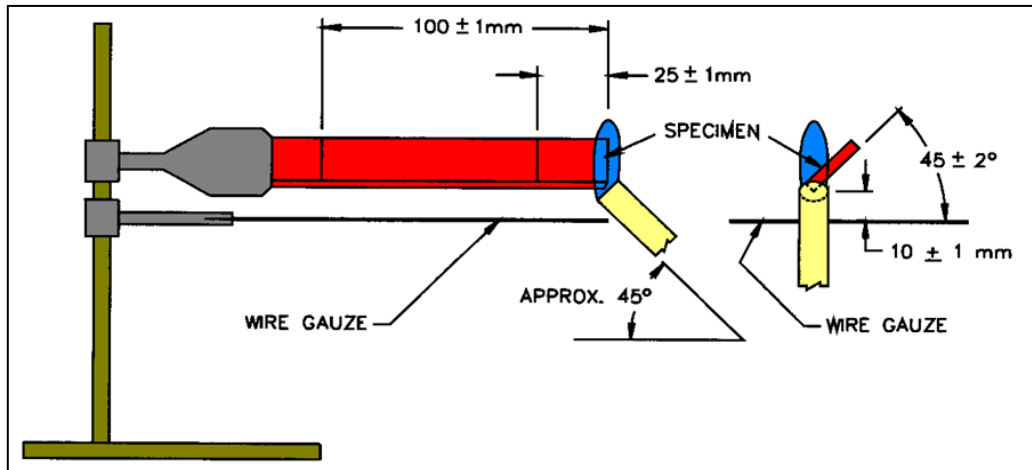
### 5) Horizontal Burning Test : HB

#### ① Test method

- The flame is applied to the free end of the specimen for 30 seconds. The length of the test specimen is 125 mm with benchmarks at 25 mm and 100 mm position. The time for the flame front to move between the benchmarks is measured.

Thickness of specimen	Burning Rate
> 3.0 mm	< 40 mm/min
< 3.0 mm	< 75 mm/min

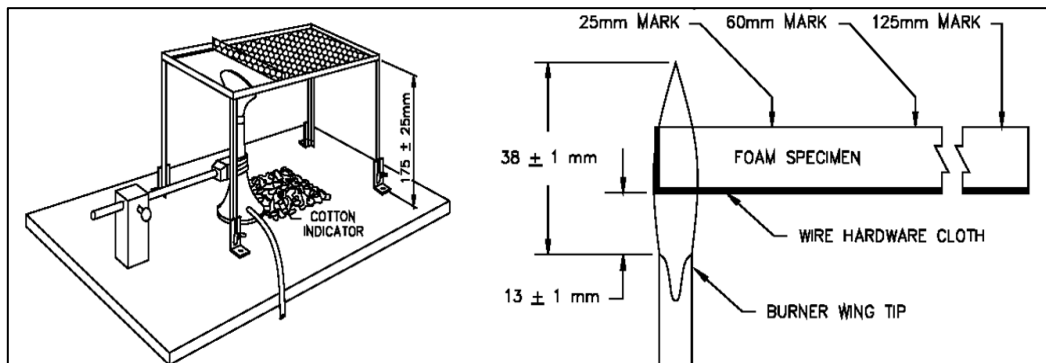
- When the material passes the test with a thickness of 3.0 mm, it can be approved until a thickness of 1.5 mm. (UL can be approved, yet cUL cannot be approved.)



<Figure 5. Test method of HB>

#### 6) Horizontal Burning Test : HBF/HF

- ① Specifically designed for formed polymers which have a density below 0.25 g/cc.
- ② Test method
  - The flame application time is increased to 60 seconds. The 150 mm long test specimen is marked on the 25 mm, 60 mm and 125 mm positions and the burning rate is measured between a 100 mm span.



<Figure 6. Test method of HBF/HF>

#### ③ Classification

		HF-1	HF-2
Afterflame time	4 specimens of 5 specimens in a set	≤ 2 s	≤ 2 s
	1 specimen of 5 specimens in a set	≤ 10 s	≤ 10 s
Afterglow time for each individual specimen		≤ 30 s	≤ 30 s
Cotton ignition		No	Yes
Damaged length for each individual specimen		< 60 mm	< 60 mm
<b>HBF</b>			
- Material does not have a burning rate exceeding 40 mm per minute over a 100 mm span. - It ceases to burn before flaming or glowing reach the 125 mm mark.			

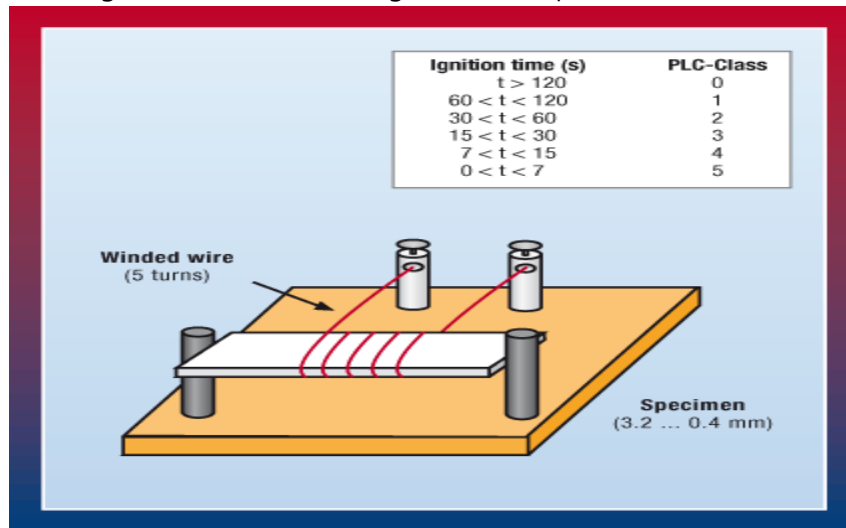
(2) UL 746A : Standard for polymeric materials – short-term property evaluations

1) Typical test of UL 746A : HWI, HAI, CTI, HVTR, D495

2) Hot Wire Ignition Test (HWI)

① Test method

- Set a specimen by using nichrome wire and 5.4 N pendulum.
- Apply 0.26 W/mm energy on the nichrome wire and then observe ignition of specimen
- Measure the ignition time and melting time for 5 specimens.



<Figure 7. Test method of HWI>

② HWI performance level

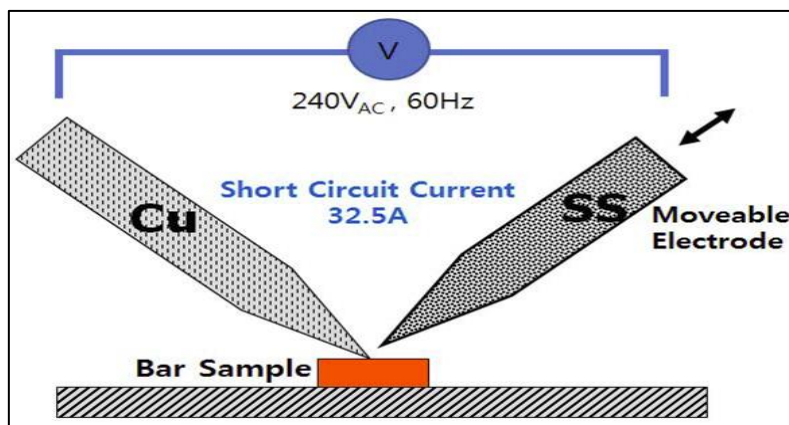
Range – mean ignition time (sec)	Assigned PLC*
$120 \leq \text{mean ignition time}$	0
$60 \leq \text{mean ignition time} < 120$	1
$30 \leq \text{mean ignition time} < 60$	2
$15 \leq \text{mean ignition time} < 30$	3
$7 \leq \text{mean ignition time} < 15$	4
$0 \leq \text{mean ignition time} < 7$	5

\*PLC : Performance Level Categories

3) High-Current Arc Ignition Test (HAI)

① Test method

- Install both electrodes both fixed and moving that can be touched after setting a specimen.
- If an electric current between both electrodes reaches 32.5 A, the fixed electrode makes an arc moving toward 45 degrees. Apply the arc 40 times in a minute and maximum 150 of times.
- Measure the number of arcs that spark ignition of the specimen for 5 separate specimens.



<Figure 8. Test method of HAI>

② HAI performance level

Range – mean number of arcs to cause ignition (NA)	Assigned PLC
$120 \leq NA$	0
$60 \leq NA < 120$	1
$30 \leq NA < 60$	2
$15 \leq NA < 30$	3
$0 \leq NA < 15$	4

4) Comparative Tracking Index (CTI)

① Test method

- Ammonium Chloride in water : 0.1 %  $NH_4Cl$
- Measure voltage

ASTM	The voltage which causes tracking after 50 drops of 0.1 % ammonium chloride solution has fallen on the material every 30 seconds.
IEC	The voltage which causes tracking after 50 drops or 100 drops of 0.1 % ammonium chloride solution has fallen on the material. (50 drops for maximum voltage, 100 drops for 25V lower voltage than maximum voltage)

- After measuring the number of drops on 3 to 4 different voltages, then compute the voltage of 50 drops via extrapolation.

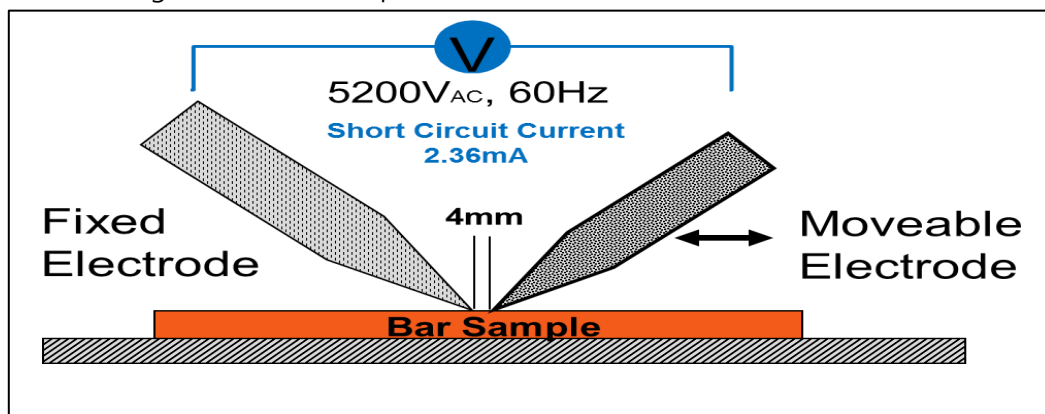
② CTI performance level

CTI Range – Tracking Index	Assigned PLCh
$600 \leq \text{Tracking Index}$	0
$400 \leq \text{Tracking Index} < 600$	1
$250 \leq \text{Tracking Index} < 400$	2
$175 \leq \text{Tracking Index} < 250$	3
$100 \leq \text{Tracking Index} < 175$	4
$0 \leq \text{Tracking Index} < 100$	5

5) High-Voltage Arc-Tracking-Rate (HVTR)

① Test method

- After installing a specimen and electrode as indicated below, apply voltage to make carbonized path. Then, shift the moveable electrode toward the back side to make the carbonized path continuously for 2 minutes or by a maximum 50 mm.
- Measure ignition rate for 3 specimens.



<Figure 9. Test method of HVTR>

② HVTR performance level

HVTR Range – Tracking rate (mm/min)	Assigned PLC
$0 \leq \text{Tracking rate} < 10$	0
$10 \leq \text{Tracking rate} < 25.4$	1
$25.4 \leq \text{Tracking rate} < 80$	2
$80 \leq \text{Tracking rate} < 150$	3
$150 \leq \text{Tracking rate}$	4

6) High-Voltage, Low Current Arc Resistance (D495)

① Test method

- Apply 12,500 V and step current between both electrodes, then test under more severe conditions with changes of the current.
- Measure an end-point time.  
(End-point : formation of conducting path)

② ASTM D495 performance level

D495 Range – mean time of arc resistance	Assigned PLC
420 ≤ mean time of arc resistance	0
360 ≤ mean time of arc resistance < 420	1
240 ≤ mean time of arc resistance < 360	2
240 ≤ mean time of arc resistance < 300	3
180 ≤ mean time of arc resistance < 240	4
120 ≤ mean time of arc resistance < 180	5
60 ≤ mean time of arc resistance < 120	6
0 ≤ mean time of arc resistance < 60	7

(3) UL 746B : Standard for polymeric materials – long-term property evaluations

1) RTI (Relative Thermal Index)

- ① Definition : A relative thermal index (RTI) of a material is an indication of the material's ability to retain a particular property (physical, electrical, etc.) when exposed to elevated temperatures for an extended period of time. It is a measure of the material's thermal endurance.
- ② The value of RTI will be different according to thickness of specimen and specified properties.
- ③ Generic Thermal Indices
  - General value according to previous test results and chemical structure of a material.

<Table 1. Generic thermal indices of various materials>

Material	ISO designation	Generic thermal index, °C
Acrylonitrile – butadiene – styrene <sup>d</sup>	(ABS)	60
Silicone – molding resin <sup>c,d</sup>		150
Silicone rubber – molding resin	(SIR)	150
room-temperature vulcanizing or heat-cured paste	(RTV)	105
Epoxy – molding resin <sup>c,d</sup>		130
powder coating materials		105
casting or potting resin <sup>b,i</sup>	(EP)	90
Molded diallyl phthalate <sup>c,d</sup>		130
Molded unsaturated polyester <sup>c,d</sup>	(UP)	
alkyd (AMC), bulk (BMC), dough (DMC), sheet (SMC), thick (TMC), and pultrusion molding compounds	(electrical) (mechanical)	105 <sup>e</sup> 130
Liquid crystalline thermotropic aromatic polyester <sup>d</sup>	(LCP)	130
Ligno-cellulose laminate		60
Vulcanized fiber		90
Cold-molded phenolic, melamine or melamine-phenolic compounds <sup>d</sup> – specific gravity < 1.55		130
specific gravity ≥ 1.55		150
Cold-molded inorganic (hydraulic-cement, etc.) compounds		200
Integrated mica, resin-bonded – epoxy, alkyd or polyester binder		130
phenolic binder		150
silicone binder		200

④ Primary properties

- RTI Elec. : Electrical RTI related with electric insulation
- RTI Mech. Imp. : Mechanical RTI related with impact strength, elasticity, and flexibility
- RTI Mech. Str. : Mechanical RTI unconnected with impact strength, elasticity and flexibility

⑤ Example

- Elec. 150 : The retention rate of electrical properties is over 50 % after 100,000 hours at 150°C.
- Mech. With Imp. 150 : The retention rate of impact strength is over 50 % after 100,000 hours at 150°C.
- Mech. W/O Imp. 150 : The retention rate of mechanical strength with the exception of impact strength is over 50 % after 100,000 hours at 150°C.

(4) UL 746C : Standard for polymeric materials – outdoor suitability

1) Test method

① UV and water spray exposure

- Equipment : Xenon-arc lamp or twin enclosed carbon-arc lamp aging program
- Conditions : 340 nm wavelength (0.35 W/m<sup>2</sup>), black panel temperature (63°C ± 3°C)
- In the case of Xenon-arc lamps, 1 cycle takes 120 minutes. (102 minutes : UV exposure, 18 minutes : UV exposure and water spray)
- Total 1,000 hours exposure, then measure strength, impact, and flame retardant properties.

② Water exposure and immersion

- Perform conditioning under 70°C distilled water or deionized water for 7 days.  
(If material has 5V grade, perform conditioning under 82°C water)
- After 7 days, immerse the specimen into 23°C distilled water or deionized water for 30 minutes.
- In the case of physical property, conduct a test without conditioning and in the case of flame retardant, conduct a test after conditioning at 23°C, 50% RH for 2 weeks.

## 2) Indication standard

<Table 2. Indication standard of UL 746C>

Property	Ultra-violet light <sup>a</sup>	Water immersion <sup>b</sup>
Flammability Classification	Unchanged	Unchanged
Tensile or Flexural Strength <sup>c</sup>	70 Percent	50 Percent
Tensile, Izod or Charpy Impact <sup>c</sup>	70 Percent	50 Percent
<sup>a</sup> 720 hours twin enclosed carbon-arc or 1000 hours xenon-arc exposure. See 57.1.1 – 57.2.11. <sup>b</sup> 7 days at 70°C. See 58.1. <sup>c</sup> For functional support, the test methods are tensile strength and flexural strength. For Impact Resistance the test methods are Tensile, Izod, or Charpy impact. See Table 57.1.		

## 3) Classification

- ① f1 : Suitable for outdoor use with respect to exposure to UV, water exposure, and immersion in accordance with UL 746C
- ② f2 : Subjected to one or more of the following test; UV, water exposure, or immersion in accordance with UL 746C, where the acceptability for outdoor use is to be determined by UL

## (5) UL 746D : Standard for polymeric materials – fabricated parts

1) These requirements cover a program applicable to parts that have been molded or fabricated from polymeric material and describe the material-identity control system intended to provide traceability of the material used for the polymeric parts through the handling, molding or fabrication, and shipping operations. Guidelines are also provided for acceptable blending or simple compounding operations that may affect risk of fire, electrical shock, or injury to persons

- ① Combined resins : In the case of Same HB flame class, same manufacturer, and same generic materials, it can be used without additional testing.
- ② Co-Molding : In the case of Same flame class, same manufacturer, and same generic materials, it can be used without additional testing.
- ③ Regrind
  - In the case of thermoplastics resins, those can be used without additional tests if the ratio of regrind materials in below 25 % in terms of weight.
  - In the case of thermoset resins and thermoplastics resins recycled more than 2 times, they should not be used.
  - Regrind should be done immediately after injection or keep the materials for regrind in a container which can prevent some dust from entering.
  - Regrind materials via chopping are impossible to use.

- ④ Recycled plastics
  - Recycled plastics by making from discarded products are a required QA program.
  - The QA program is costly and needs a significant number of properties.

(6) Yellow card

iq.ul.com

Component - Plastics [guide info]

E120354

KOREA ENGINEERING PLASTICS CO LTD

450 KONGDUK-DONG, MAPO-KU, SEOUL KR

F20-(xx)(+)

Acetal "Polyoxymethylene" (POM), "KEPITAL", furnished as pellets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
ALL	0.75	HB	-	-	110	95	100
	1.5	HB	4	0	110	95	100
	3.0	HB	3	0	110	95	100
	6.0	HB	3	0	110	95	100

Comparative Tracking Index (CTI): 1

Dielectric Strength (kV/mm): 27

High-Voltage Arc Tracking Rate (HVTR): 0

Dimensional Stability (%): 0

Inclined Plane Tracking (IPT): -

Volume Resistivity (10<sup>9</sup> ohm-cm): 9

High Volt, Low Current Arc Resis (D495): 5

(xx) - May be replaced by one or two digits.


+ - May be replaced by one, two, three, four, or five letters and/or one, two, or three digit numbers

ANSI/UL 94 small-scale test data does not pertain to building materials, furnishings and related contents. ANSI/UL 94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by UL.

Report Date: 1989-01-13

Last Revised: 2004-06-16

© 2016 UL LLC

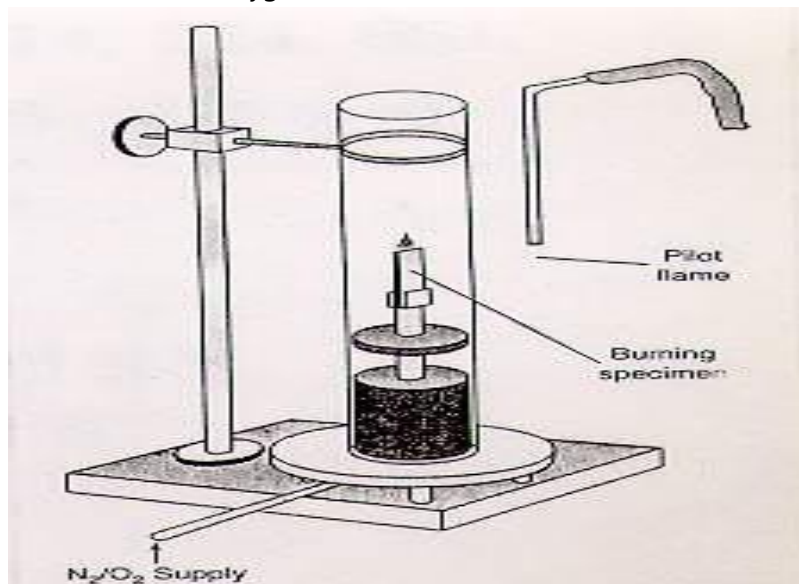


IEC and ISO Test Methods

Test Name	Test Method	Units	Thk (mm)	Value
Flammability	IEC 60695-11-10	Class (color)	0.75	HB75 (ALL)
			1.5	HB75 (ALL)
			3.0	HB40 (ALL)
			6.0	HB40 (ALL)
Glow-Wire Flammability (GWI)	IEC 60695-2-12	C	-	-
Glow-Wire Ignition (GWIT)	IEC 60695-2-13	C	-	-
IEC Comparative Tracking Index	IEC 60112	Volts (Max)	-	-
IEC Ball Pressure	IEC 60695-10-2	C	-	-
ISO Heat Deflection (1.80 MPa)	ISO 75-2	C	-	-
ISO Tensile Strength	ISO 527-2	MPa	-	-
ISO Flexural Strength	ISO 178	MPa	-	-
ISO Tensile Impact	ISO 8256	kJ/m <sup>2</sup>	-	-
ISO Izod Impact	ISO 180	kJ/m <sup>2</sup>	-	-
ISO Charpy Impact	ISO 179-2	kJ/m <sup>2</sup>	-	-

### 3. Oxygen Index or Limited Oxygen Index

- (1) Test method : The Limited Oxygen Index is the minimum concentration of oxygen, expressed as a percentage, that will support combustion of a polymer. It is measured by passing a mixture of oxygen and nitrogen over a burning specimen and reducing the oxygen level until a critical level is reached.
- (2) The high value of the limited oxygen index means that the material is difficult to ignite.



<Figure 10. Test method of limited oxygen index>

(3) Limited Oxygen Index of each material

Polymer	Limited Oxygen Index (%)	Polymer	Limited Oxygen Index (%)
POM	14.9 ~ 15.7	PA66	21.0 ~ 24.3
PS	17.0 ~ 18.1	PA6/10	25.0
PE	17.3 ~ 17.5	PA6	23.0 ~ 28.0
PP	17.4	MPPO	24.3
HIPS	18.2	PC	25.0 ~ 28.0
ABS	16.7 ~ 25.1	Polyimide	36.5
SAN	18.0 ~ 19.1	PVC	45.0
PBT, PET	20.0 ~ 20.6	PTFE	95.0

#### 4. Reference

- (1) ULK Chemical Team, UL, Plastics Recognition (2013)
- (2) UL, [www.ul.com](http://www.ul.com)

**HQ**

Mapo-daero 119 (Gongdeok-dong) Hyeoseong Bldg.  
Mapo-gu, Seoul, Korea  
Tel 82-2-707-6840 ~ 8, Telefax 82-2-714-9235

**KEP Americas**

106 North Denton Tap Road Suite 210-202 Coppell,  
TX 75019, USA  
Tel +1 888 KEPITAL, Telefax +1 888 537-3291

**KEP Europe GmbH**

Rheingaustrasse 190-196 D-65203 Wiesbaden, Germany  
Tel +49 (0)611 962-7381, Telefax +49 (0)611 962-9132

**KEP China**

A1905, HongQiao Nanfeng Plaza, 100 Zunyi Road,  
Shanghai, China  
Tel +86 21 6237-1972, Telefax +86 21 6237-1803

---

*Disclaimer:* The information contained in this data sheet is based on our current knowledge and experience, so it may change as new knowledge and experience becomes available. This information is based on only above-mentioned product produced in Korea Engineering Plastics Co., Ltd. ("KEP") through relevant test methods and conditions and doesn't relate to any products made of this product with the inclusion of other additives, such as processing aids or colorants. This information should not be construed as a promise or guarantee of specific properties of this product described or its suitability for a particular application, so users make their own determination as to its suitability to their purposes prior to use this product. It is the sole responsibility of the users to investigate whether any existing patents are infringed by the use of this product. This product is not intended for use in medical and dental implants and users should meet all safety and health standards. KEP makes no warranty and assumes no liability in connection with any use of this information.