

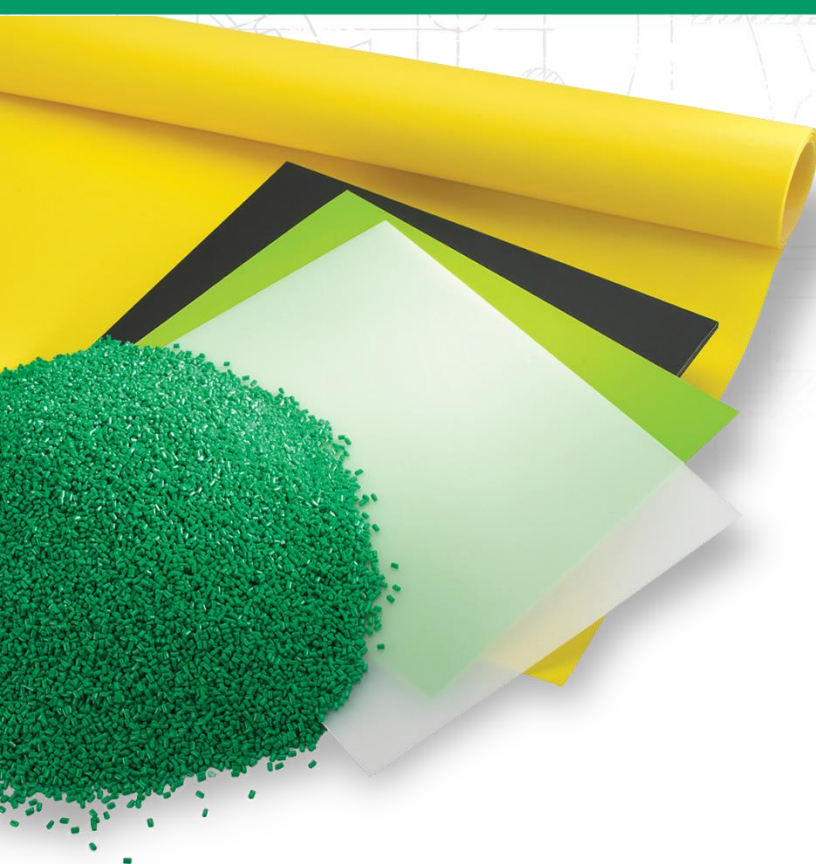


Answers to Your Burning Questions: Flame Retardants



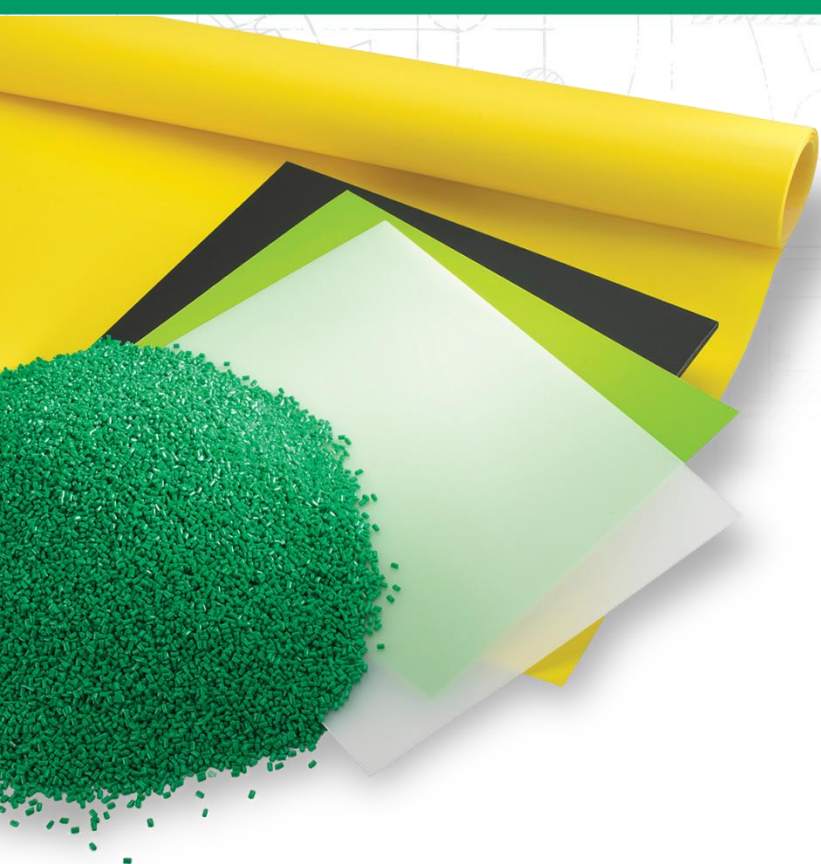
Michael Bennick

*Product Development Engineer,
Flame Retardants*



Overview:

- Goals of FR Compounds
- Thermoplastic flammability
 - FR additive chemistries and mechanisms
- Testing standards for E&E and the Building Industry
 - Relating small to large scale flame tests
- UL Listing processes and ratings



Overview:

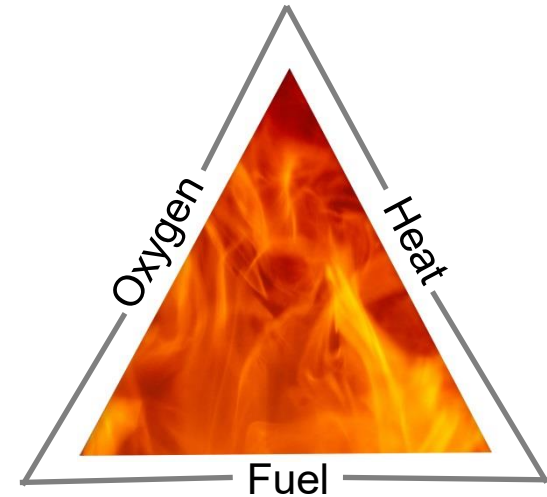
- **Goals of FR Compounds**
- Thermoplastic flammability
 - FR additive chemistries and mechanisms
- Testing standards for E&E and the Building Industry
 - Relating small to large scale flame tests
- UL Listing processes and ratings

FLAME RETARDANT (FR) MATERIALS

Definition

Materials that do not ignite readily or propagate flames under small to moderate fire exposures

- Thermoplastic materials are combustible
- Flame retardants reduce the intensity and spread of flames
- Reduces smoke and toxic by-products of combustion



Fire Triangle

GOALS OF FLAME RETARDANT COMPOUNDS

1. Increase resistance to ignition
2. Reduce rate of flame spread
3. Reduce rate of heat release
4. Reduce smoke emission

End Goals:

- Meet FR specifications
- Make the world a safer place!



FR TECHNOLOGY OVERVIEW

Our FR materials include a wide range of established products across multiple resin systems that allow us to meet the specific product FR needs in variety of end-use markets



Automotive



Electrical/
Electronics



Industrial



Power & Data
Storage



Appliances



Energy



Consumer Goods



Medical

FLAME RETARDANT COMPOUNDS

Diverse Product Portfolio

- Multiple FR chemistries available across various resin systems
- Unfilled & reinforced compounds to meet mechanical requirements
- Global manufacturing & supply



Solutions to meet requirements based on

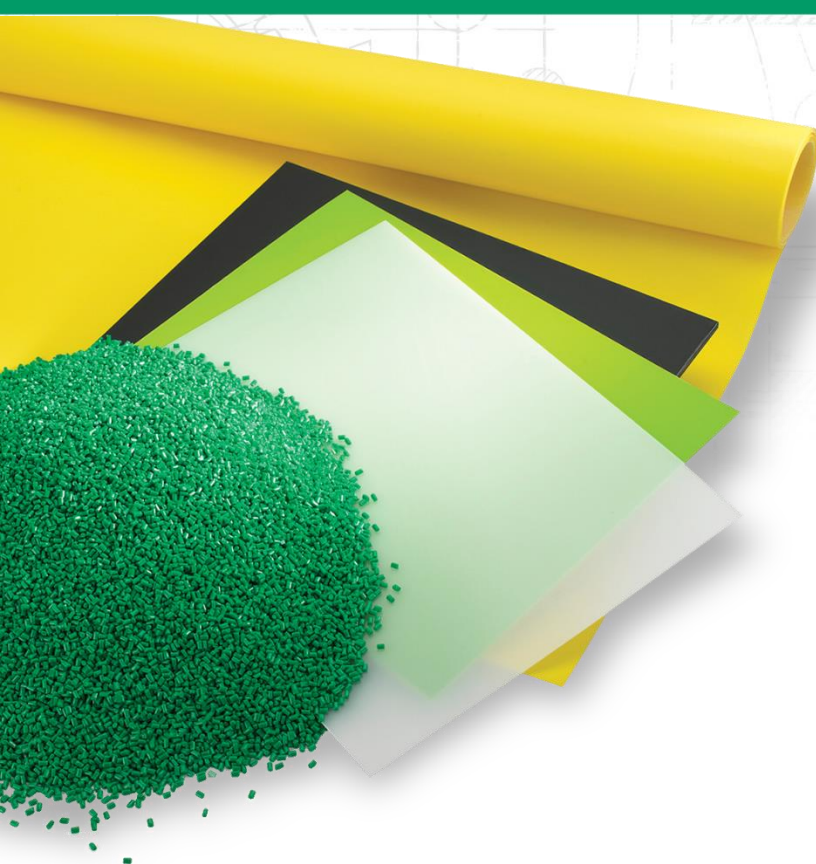
- Flame spread
- Time to ignition
- Smoke and toxicity
- Heat release
- Risk mitigation



Regulatory Compliance

- UL
- Auto and non-automotive transportation
- Building and construction
- Support global environmental standards





Overview:

- Goals of FR Compounds
- **Thermoplastic flammability**
 - **FR additive chemistries and mechanisms**
- Testing standards for E&E and the Building Industry
 - Relating small to large scale flame tests
- UL Listing processes and ratings

THERMOPLASTIC RESIN FLAMMABILITY

Flammable

- Polyolefins
- Nylons
- Polycarbonate
- Polyesters
- Styrenics
- TPEs

Inherently Flame Resistant

- Polysulfones
- Polyphenylene Sulfide
- Polyetheretherketone
- Polyetherimide
- Fluoropolymers

FR ADDITIVES: HALOGEN VS. HALOGEN-FREE

Halogenated

- **Types**
 - Brominated & Chlorinated
 - Synergist
 - Antimony Trioxide
 - Alternative solutions available
- **Attributes**
 - Lower cost
 - Better processing & efficiency
 - Better physical properties

Halogen Free

- **Types**
 - Metal hydroxides
 - Phosphorus based
 - Melamine based
- **Attributes**
 - Low smoke & toxicity
 - Less corrosive
 - Lower specific gravity

HALOGENATED FR MECHANISM

- Halogenated technology inhibits the chemical reaction in the gas/vapor phase
- Various molecules that efficiently get large amounts of free radicals to the gas phase

Additive Type

- Higher halogen content
- Lower loadings
- High thermal stability

Polymeric Type

- Melt blendable (not a particulate)
- Less effect on physical properties
- Enhanced flow

Halogenated flame retardants are compatible in most resin systems with the exception of Acetal (POM)

NON-HALOGEN MECHANISMS

Phosphorous

- Various forms
- Contributes to the condensed phase char formation

Hydrated Minerals

- Produce water during combustion process, dilute flammable vapors
- Insulative char formation

Melamine Cyanurate

- Endothermic decomposition
- Physical removal of flame from surface

Resin Systems

Polyolefins, Polyamides, Polyesters, Polycarbonate and alloys

Polyolefins, Polyamides

Polyamides, used as a synergist for other Phosphorous technologies

CHOOSING AN FR SYSTEM

How do we decide which FR mechanism to use?

1. Resin system
2. FR specification
3. Part function
4. Fillers/Additives
5. Regulatory concerns
 - Halogen, RoHS, etc.

PORTFOLIO OF POSSIBILITIES

PP

- Unfilled
- Glass fiber
- Mineral



Nylons

- Unfilled
- Glass fiber



PBT

- Unfilled
- Glass fiber



PC and PC Alloys

- Unfilled
- Glass fiber



ABS

- Unfilled
- Glass fiber

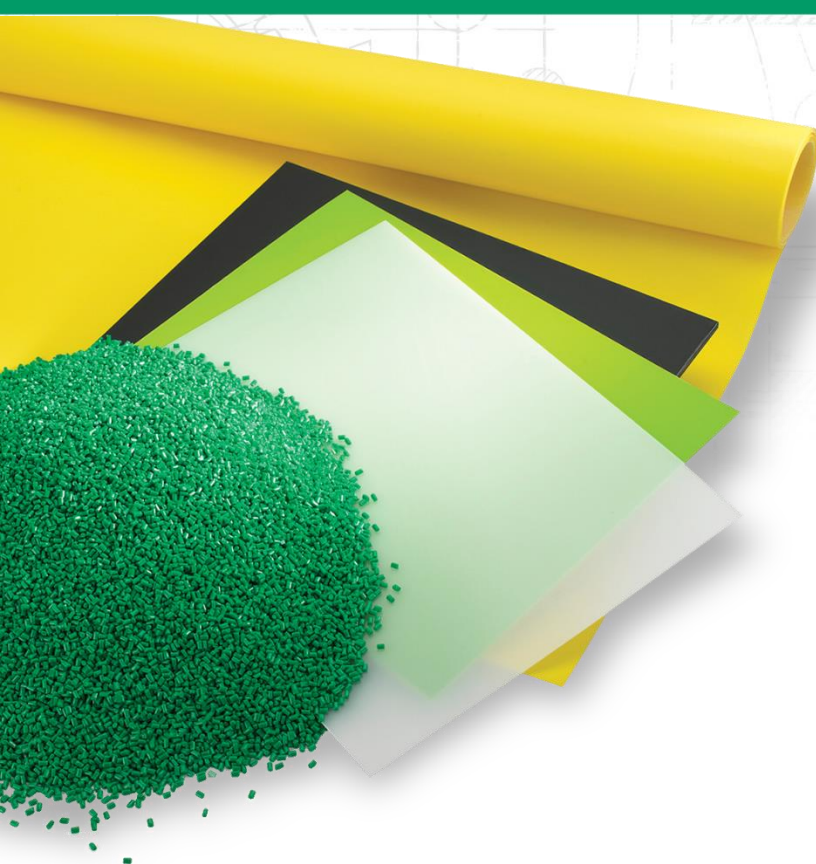


Multiple flammability ratings available (V-2, V-0, 5VA)

Property profiles can be tailored (flow, impact, UV, etc.)

30% GF NYLON 6/6

Mechanical Properties	RTP 205 FR	RTP 205 FR Halogen Free
Tensile Strength, psi	21000	19500
Tensile Modulus, psi E6	1.65	1.45
Tensile Elongation, %	2-4%	2-4%
Flexural Strength, psi	33000	31500
Flexural Modulus, psi E6	1.55	1.45
Impact Notched, ft-lb/in	2	1.8
Impact Un-notched, ft-lb/in	16	16
HDT @ 264 psi	470	470
Specific Gravity	1.66	1.41
Flammability	V-0 @ 1/32	V-0 @ 1/32



Overview:

- Goals of FR Compounds
- Thermoplastic flammability
 - FR additive chemistries and mechanisms
- **Testing standards for E&E and the Building Industry**
 - **Relating small to large scale flame tests**
- UL Listing processes and ratings

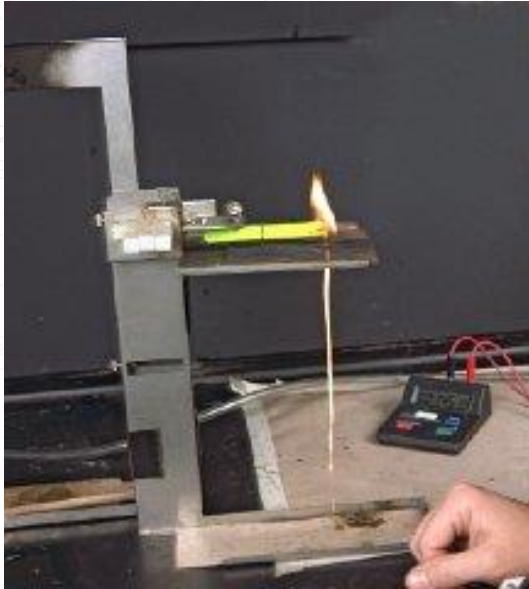
INDUSTRY AND MARKET DRIVEN

Electrical and Electronics (E&E)

- UL 94
 - HB, V, 5V,
- UL 746
 - HAI, HWI, CTI



UL94 RATINGS



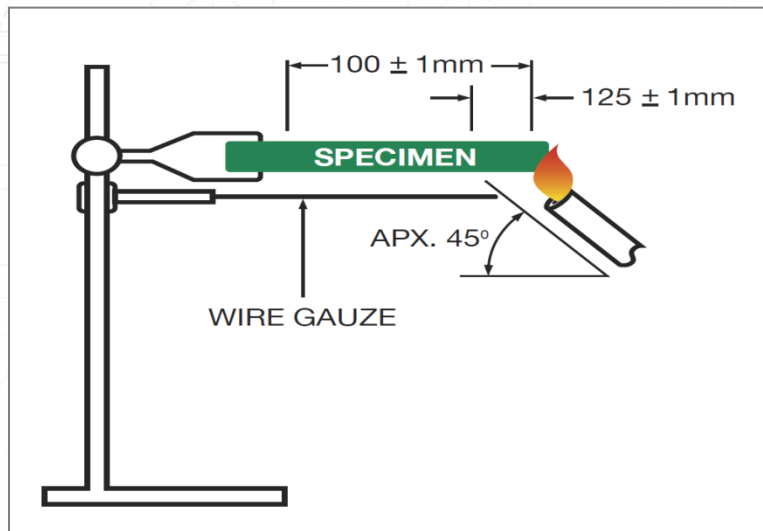
UL94 Ratings

HB
V-2
V-1
V-0
5VB
5VA



Ratings in order of difficulty to meet!

UL94 - HB



Classification Criterion

3.0 mm to 13.0 mm thickness

- slower than 40 mm/minute or...
- combustion ceases prematurely

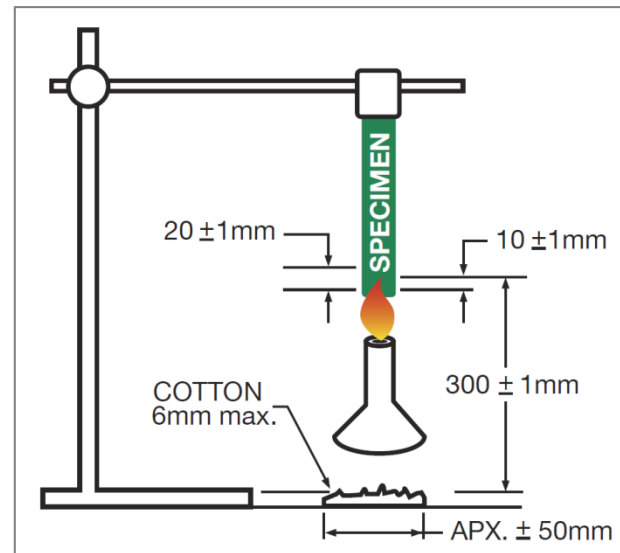
< 3.0 mm thickness

- slower than 75 mm/minute or...
- combustion ceases prematurely

**** In general, most thermoplastics meet this criteria****

UL94 - VB

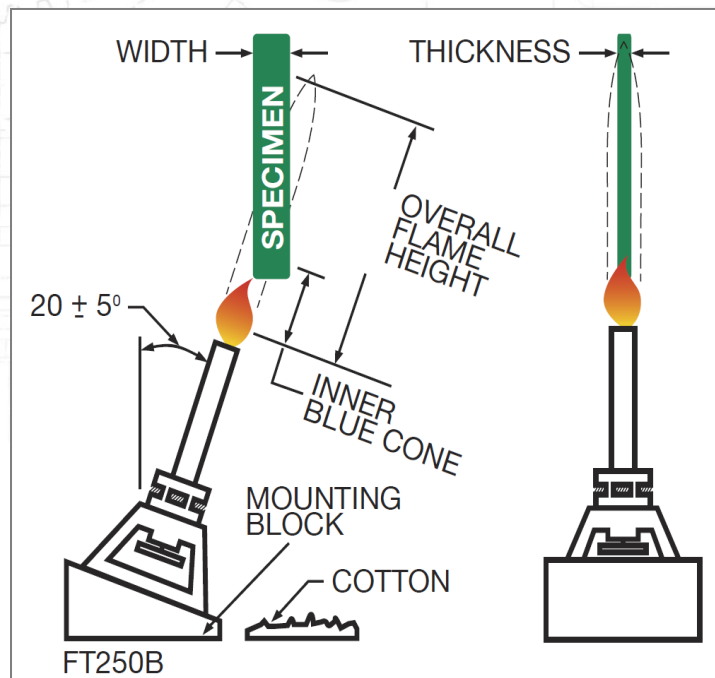
Classification Criteria	V-0	V-1	V-2
Number of bar specimens	5	5	5
Maximum flame time per specimen per flame application, sec	10	30	30
Maximum total flame time 5 specimens, 2 ignitions, sec	50	250	250
Specimen drips, ignites cotton	No	No	Yes
Maximum afterglow time per specimen, sec	30	60	60
Burn to holding clamp	NO	NO	NO



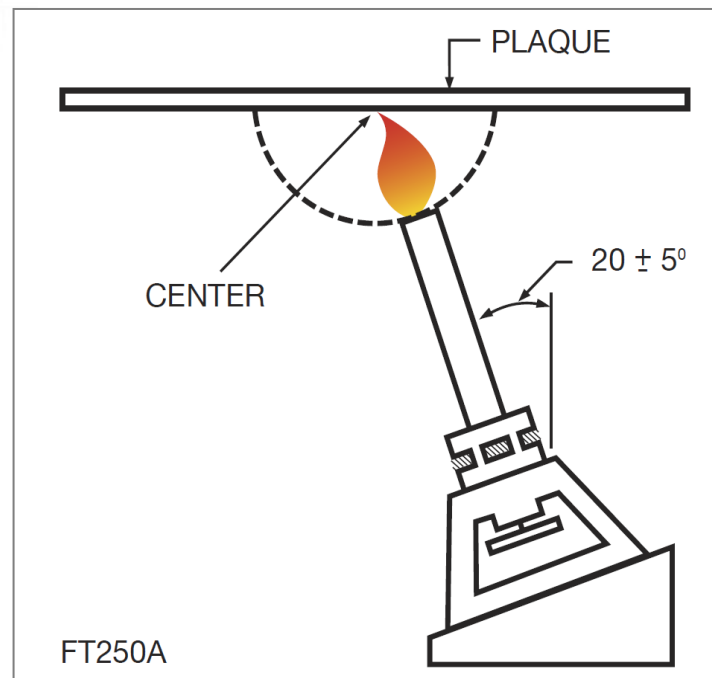
*****Thickness dependent ratings*****

5V TESTING

Bar Burn



Panel Burn



5V TESTING

- 500 Watt flame vs. 50 watt flame
- 5 – 5 Second flame applications (5 seconds on / 5 seconds off)
- Bar burn and panel burn

Criteria	94-5VA	94-5VB
Afterflame time plus afterglow time for each individual bar specimen	≤60s	≤60s
Cotton indicator ignited by flaming particles or drops from any bar specimen	No	No
Burn-through (hole) of any plaque specimen	No	Yes

UL94 RATINGS

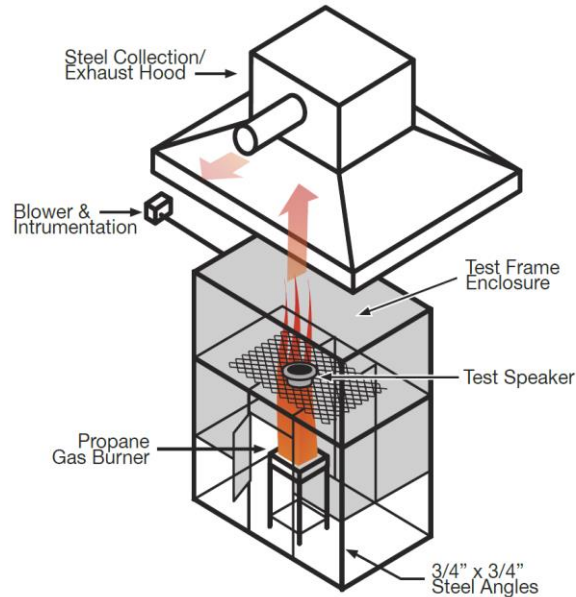
How are these ratings applied:

Rating	Usage	Example
HB	Handheld electronics	Cell phone
V-2	Low voltage, attended	Electric shaver
V-1/V-0	High voltage, un-attended	Electrical connectors
5VB/A	Electronic enclosures	Control housing

BUILDING / INDUSTRIAL

- Requirements focus on:
 - Low Smoke, Heat Release, Burn Rate, Flame Spread
- Various standards that apply:
 - UL2043, UL723/ASTM E84, ASTM E1354, NFPA 701, CAL TB133
- Applications
 - Wall coverings, Furniture, Plenum, Pallets, Storage systems, Roofing, Floor coverings, Ventilation

UL 2043 - DETAILS



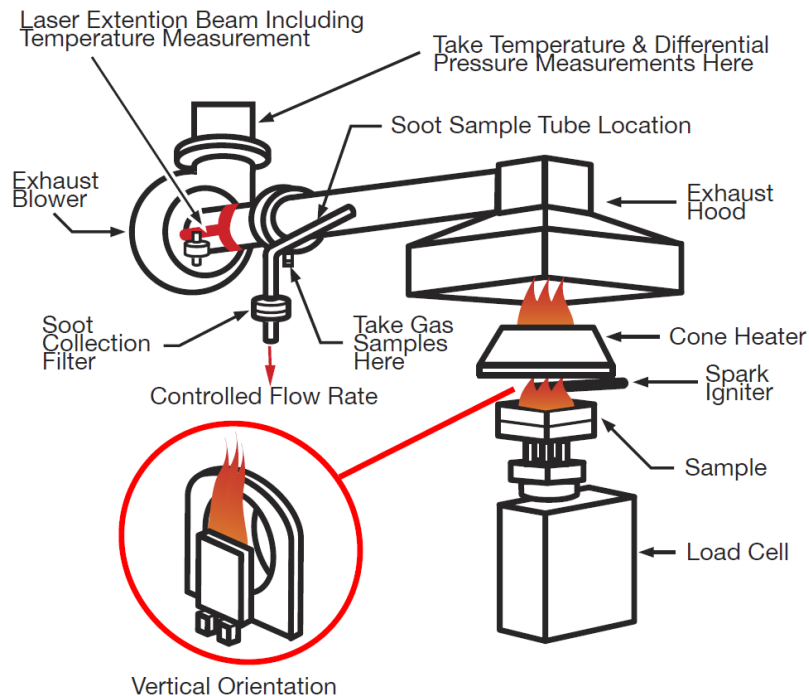
- For components that live in air-handling spaces (Plenum)
- End-product test
 - Not a material certification
- Heat Release & Smoke Density

	Peak Heat Release Rate (kW)	Peak Normalized Optical Density	Average Normalized Optical Density
MAX	100	.50	.15

PREDICTING PERFORMANCE

ASTM E 1354 Cone Calorimetry

- More quantitative results
- Measures smoke generation, heat release, and mass loss
 - Heat generation is aligned with the severity of a fire, such as fire growth rate
- Can test at varying heat fluxes
- Useful for comparative testing
- Relatively inexpensive



PREDICTING PERFORMANCE

UL 94 as an indicator for large scale testing

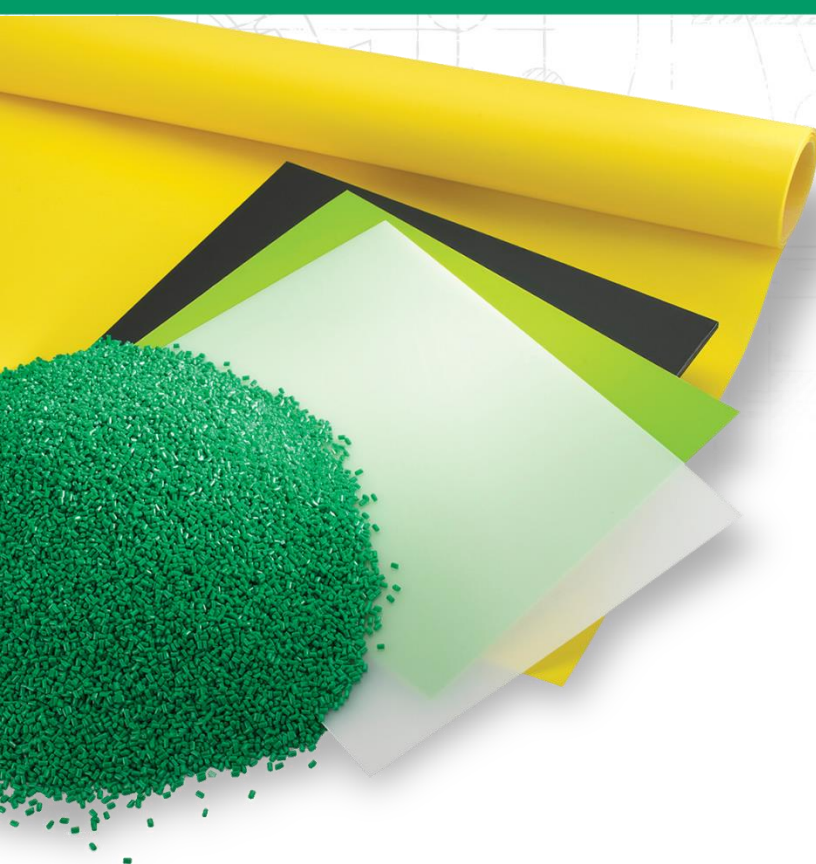
Pros

- Quick indication of FR performance
- Higher ratings likely to test better
- May be able to determine the mechanism of FR

Cons

- Poor indicator of heat release
- No measurement of smoke generation
- Rating alone does not give much information

No direct correlation between UL 94 burn testing to other larger scale tests due to differences in flame intensity and source of heat/flame



Overview:

- Goals of FR Compounds
- Thermoplastic flammability
 - FR additive chemistries and mechanisms
- Testing standards for E&E and the Building Industry
 - Relating small to large scale flame tests
- **UL Listing processes and ratings**

RTP COMPANY UL SOLUTIONS

- RTP Company has 800+ UL Yellow Cards
 - Continuous expansion of UL listed products
 - Range listings in multiple product technologies/resins
- UL Certified Laboratory under Client Test Data Program (CTDP)
 - Short term properties to UL94
 - Long term thermal aging (RTI)
- RTP Company offers custom UL certifications to achieve full commercialization
 - Quick turnaround
 - ***Compress your Time to Market!***



YELLOW CARD EXAMPLE - FLAMMABILITY



Component - Plastics
File Number: E84658

RTP CO
580 E FRONT ST, PO BOX 5439, WINONA MN 55987-0440



RTP 104 CC FR A UV (f1)

Polypropylene (PP), pellets, glass fiber reinforced

(f1) - Suitable for outdoor use with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C.

Flammability	Value	Test Method
Flame Rating		UL 94
0.75 mm, ALL	V-0	IEC 60695-11-10, -20
2.0 mm, ALL	V-0, 5VA	
3.0 mm, ALL	V-0	
Electrical	Value	Test Method
Hot-wire Ignition (HWI) (0.75 mm)	PLC 3	UL 746
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746
Comparative Tracking Index (CTI)	PLC 0	UL 746
Dielectric Strength	23 kV/mm	ASTM D149 IEC 60243-1
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746
Volume Resistivity	1.0E+15 ohms-cm	ASTM D257 IEC 60093
Thermal	Value	Test Method
RTI Elec		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Imp		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Str		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
Physical	Value	Test Method
Dimensional Stability	0.0 %	ASTM D1042 ISO 2796
Outdoor Suitability	f1	UL 746C

Flammability Ratings

- Thickness dependent
- Contains applicable colors
- Assigned Rating(s)
- Test Method
 - UL94

YELLOW CARD EXAMPLE - SHORT TERM ELECTRICALS



Component - Plastics
File Number: E84658

RTP CO
580 E FRONT ST, PO BOX 5439, WINONA MN 55987-0440



RTP 104 CC FR A UV (f1)

Polypropylene (PP), pellets, glass fiber reinforced

(f1) - Suitable for outdoor use with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C.

Flammability	Value	Test Method
Flame Rating		UL 94
0.75 mm, ALL	V-0	IEC 60695-11-10, -20
2.0 mm, ALL	V-0, 5VA	
3.0 mm, ALL	V-0	
Electrical	Value	Test Method
Hot-wire Ignition (HWI) (0.75 mm)	PLC 3	UL 746
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746
Comparative Tracking Index (CTI)	PLC 0	UL 746
Dielectric Strength	23 kV/mm	ASTM D149 IEC 60243-1
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746
Volume Resistivity	1.0E+15 ohms-cm	ASTM D257 IEC 60093
Thermal	Value	Test Method
RTI Elec		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Imp		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Str		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
Physical	Value	Test Method
Dimensional Stability	0.0 %	ASTM D1042 ISO 2796
Outdoor Suitability	f1	UL 746C

SHORT-TERM ELECTRICALS

- UL 746 A
- Properties rated in PLC (Performance Level Category)
- Electrical Properties
 - Comparative Tracking Index (CTI)
 - High Voltage Tracking Rate (HVTR)
 - High Voltage / Low Current / Dry Arc Resistance (D 495)
- Ignition Resistance Properties
 - Hot Wire Ignition (HWI)
 - High-Current Arc Ignition (HAI)
 - Glow Wire Ignition Testing (GWFI & GWIT)



YELLOW CARD EXAMPLE - RTI



Component - Plastics
File Number: E84658

RTP CO
580 E FRONT ST, PO BOX 5439, WINONA MN 55987-0440



RTP 104 CC FR A UV (f1)

Polypropylene (PP), pellets, glass fiber reinforced

(f1) - Suitable for outdoor use with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C.

Flammability	Value	Test Method
Flame Rating		UL 94
0.75 mm, ALL	V-0	IEC 60695-11-10, -20
2.0 mm, ALL	V-0, 5VA	
3.0 mm, ALL	V-0	
Electrical	Value	Test Method
Hot-wire Ignition (HWI) (0.75 mm)	PLC 3	UL 746
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746
Comparative Tracking Index (CTI)	PLC 0	UL 746
Dielectric Strength	23 kV/mm	ASTM D149 IEC 60243-1
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746
Volume Resistivity	1.0E+15 ohms-cm	ASTM D257 IEC 60093
Thermal	Value	Test Method
RTI Elec		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Imp		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Str		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
Physical	Value	Test Method
Dimensional Stability	0.0 %	ASTM D1042 ISO 2796
Outdoor Suitability	f1	UL 746C

ELEVATED RTI PROCESS - UL 746B

- All materials will have a generic RTI rating specific to the base polymer
- Must age a known “control” material that is similar in composition and carries an elevated RTI
- 3 Ratings – Electrical, Mechanical Impact, Mechanical Strength
- Trying to find 50% property point at 4 different temperatures
- **No specified end date**, aging must continue until 50% property point is determined



YELLOW CARD EXAMPLE – F1/F2



Component - Plastics
File Number: E84658

RTP CO
580 E FRONT ST, PO BOX 5439, WINONA MN 55987-0440



RTP 104 CC FR A UV (f1)

Polypropylene (PP), pellets, glass fiber reinforced

(f1) - Suitable for outdoor use with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C.

Flammability	Value	Test Method
Flame Rating		UL 94
0.75 mm, ALL	V-0	IEC 60695-11-10, -20
2.0 mm, ALL	V-0, 5VA	
3.0 mm, ALL	V-0	
Electrical	Value	Test Method
Hot-wire Ignition (HWI) (0.75 mm)	PLC 3	UL 746
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746
Comparative Tracking Index (CTI)	PLC 0	UL 746
Dielectric Strength	23 kV/mm	ASTM D149 IEC 60243-1
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746
Volume Resistivity	1.0E+15 ohms-cm	ASTM D257 IEC 60093
Thermal	Value	Test Method
RTI Elec		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Imp		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
RTI Str		UL 746
0.75 mm	115 °C	
2.0 mm	115 °C	
3.0 mm	115 °C	
Physical	Value	Test Method
Dimensional Stability	0.0 %	ASTM D1042 ISO 2796
Outdoor Suitability	f1	UL 746C

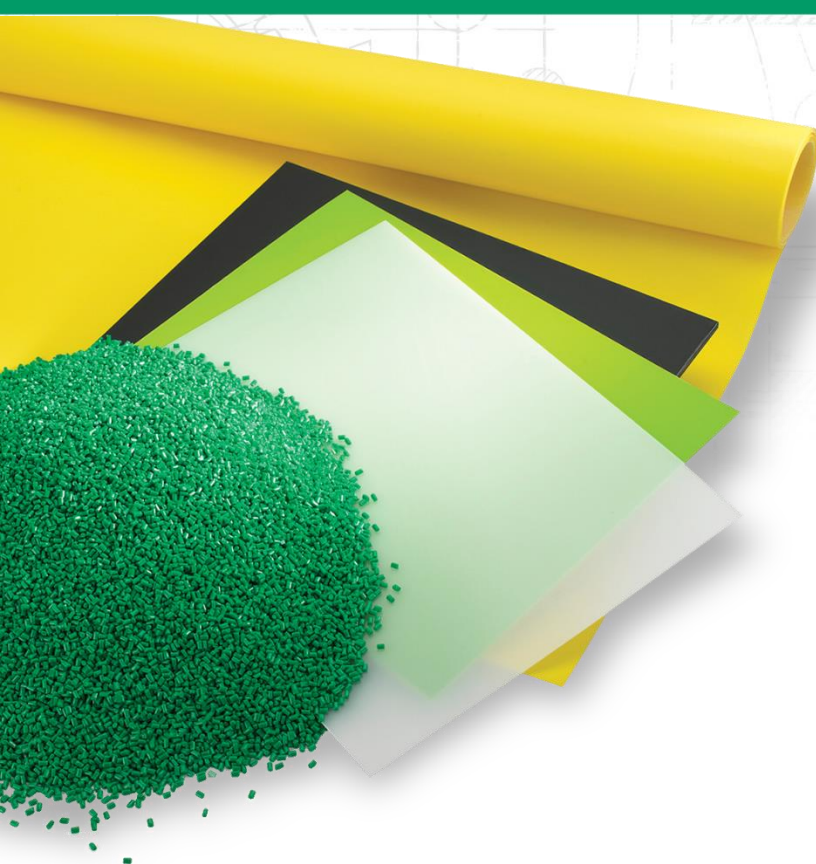
F1 TESTING DETAILS

- UL 746C Outdoor Suitability
- Water Immersion and UV testing
 - (f1) – Material has passed both UV and water exposure
 - (f2) – Material has passed either UV or water exposure
- Water Immersion
 - 7 days @ 70°C (5V rated materials @ 82°C)
- UV Test
 - 1000 hours (ASTM G-151 or G-155)
- **Strength, Impact, and Flammability** are tested before and after exposure
 - Flammability must be maintained
 - After UV, 70% property retention
 - After water immersion, 50% property retention
 - **Color is not a factor**

SUMMARY



- Goals of flame retardants
- Flame retardant additives and how we formulate with FR additives
 - Halogen & halogen free
- Testing
 - Building/Industrial, E&E, UL94, small vs. large scale testing
- What can RTP Co offer?
 - 800+ Yellow Cards
 - UL accredited laboratory & testing



THANK YOU!

Questions?

Michael Bennick

mjbennick@rtpcompany.com

rtpcompany.com

© 2025 RTP Company

