

RTP COLOR • CONDUCTIVE • FILM/SHEET • FLAME RETARDANT
STRUCTURAL • THERMOPLASTIC ELASTOMERS • WEAR

Answers to Your Burning Questions: Flame Retardants, UL and Building

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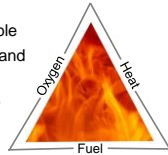
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RTP FLAME RETARDANT (FR) MATERIALS

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

RTP 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

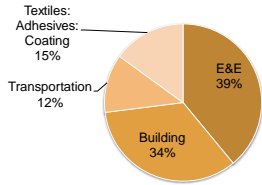
End Goals:

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



RTP MARKETS FOR FR THERMOPLASTICS

Segmentation of FR Consumption by Value



- Electrical Parts
- Electronic Enclosures
- Wire and Cable
- Appliances
- Transportation
- Building and Construction

RTP OVERVIEW

- **Thermoplastic Flammability**
 - **Flame Retardant Additive Chemistries and Mechanisms**
- **Regulatory Landscape**
- **Testing Standards**
- **UL Listing Processes and Ratings**
- **Building industry**
- **Relating small to large scale Flame tests**

RTP OVERVIEW

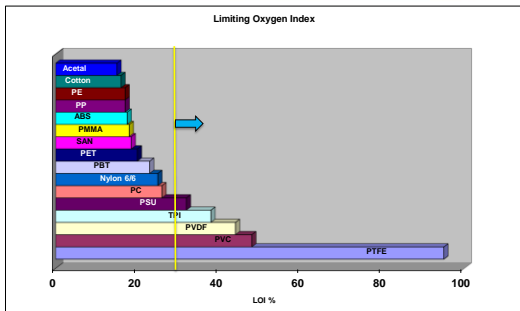
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RTP THERMOPLASTIC RESIN
FLAMMABILITY

- Flammable**
- Polyolefins
 - Nylons
 - Polycarbonate
 - Polyesters
 - Styrenics
 - TPEs

- Inherently Flame Resistant**
- Polysulfones
 - Polyphenylene Sulfide
 - Polyetheretherketone
 - Polyetherimide
 - Fluoropolymers

RTP CHALLENGES OF
FLAME RETARDING PLASTICS



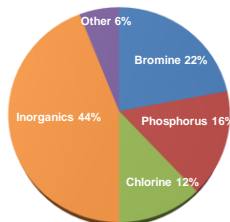
RTP COMMON TYPES OF FR
ADDITIVES

Halogenated FR's

- Brominated
- Chlorinated

Halogen Free FR's

- Metal hydroxides
- Phosphorous Based
- Melamine Based



RTP 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
<ul style="list-style-type: none"> • Higher Halogen Content • Lower Loadings • High Thermal Stability

Polymeric Type
<ul style="list-style-type: none"> • Melt Blendable • Less effect on physical properties • Enhanced Flow

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

RTP NON-HALOGEN MECHANISMS

Phosphorous
<ul style="list-style-type: none"> • Various forms • Contributes to the condensed phase char formation

Hydrated Minerals
<ul style="list-style-type: none"> • Produce water during combustion process, dilute flammable vapors • Insulative char formation

Melamine Cyanurate
<ul style="list-style-type: none"> • 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

RTP HALOGEN VS. HALOGEN-FREE

Halogenated
<ul style="list-style-type: none"> • Lower Cost • Better Processing • Better Efficiency • Better Physical Properties

Halogen Free
<ul style="list-style-type: none"> • Evolving Economics • Improved Processing • Wide Variety of Products • Low Smoke • Lower Toxicity • Less Corrosive • Lower Specific Gravity

RTP CHOOSING A 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

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RTP EVOLUTION OF HALOGEN-FREE TECHNOLOGIES

- More “self-policing”/customer driven bans
- New FR standards
- Green Movement
- More Effective/Economical FR Chemicals
- Increased Performance
- Competition in the Market

RTP HALOGEN RESTRICTIONS

OEM Driven Ban on Halogenated Chemicals

- HP, DELL, IBM etc.

Eco Labels

- Blue Angel, White Swan, Ecolabel etc.



RTP IMPACT OF HALOGEN-FREE

- Resin Limitations
- Physical Properties
 - Strength/Impact
 - Flow
 - Heat Resistance
 - Resin Dependent
- Flammability
- Cost
- Reduction in Specific Gravity

RTP 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

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RTP INDUSTRY AND MARKET DRIVEN

Electrical and Electronics (E&E)

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



RTP GLOW WIRE

- GWT – IEC 60695-2-11
 - Glow Wire Test
 - Performed on end product
 - Pass/Fail criteria similar to GWFI
- GWFI – IEC 60695-2-12
 - Glow Wire Flammability Index
 - Property associated with raw material
 - GWFI is the highest temperature at which the material does not ignite or self-extinguishes within 30 seconds after removal of the heated element
- GWIT – IEC 60695-2-13
 - Glow Wire Ignition Temperature
 - Property associated with raw material
 - GWIT is the lowest temperature (+25°C) at which the material ignites and burns for longer than 5 seconds while the heated element is in contact with the test plate



RTP AEROSPACE

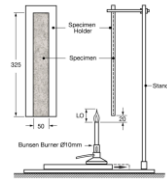
FAR 25.853

- Flammability:
 - 15-Second Horizontal Burn
 - 12-Second Vertical Burn
 - 60-Second Vertical Burn
- Smoke Density:
 - $D_s @ 4min < 200$
 - ABD0031 or BSS 7238 or ASTM E-662
- Ohio State University Heat Release:
 - Calorimetry Test Measures Peak and Total Heat Release
 - $< 100/100, < 65/65, \& < 55/55$ are common

OEM Driven Requirements

- Toxic Gas Emission:
 - Varies by OEM
 - ABD0031 or BSS 7239

FAR Part 25 testing in a vertical position.



****Requirements vary by part size and location****

RTP 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, FM 4996, CAL TB133
- Applications
 - Wall coverings, Furniture, Plenum, Pallets, Storage systems, Roofing, Floor coverings, Ventilation

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RTP YELLOW CARD EXAMPLE - FLAMMABILITY

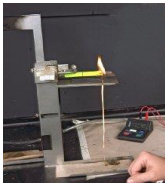
UL Component - Plastics
File Number: E84658

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

RTP 104 CC FR A UV (F1)
Polyethylene (PE), 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.

Requirement	Value	Test Method
Flame Rating	0.75 mm, ALL	V-0
	2.0 mm, ALL	V-0, 5VA
	3.0 mm, ALL	V-0
Electrical	Volume Resistivity	UL 746C
	High Amp Arc Ignition (HAI) (0.75 mm)	UL 746C
High Amp Arc Ignition (HAI) (2.0 mm)	UL 746C	UL 746C
	Comparative Tracking Index (CTI)	UL 746C
Dielectric Strength	UL 746C	ASTM D149
	High Voltage Arc Tracking Rate (H-TR)	UL 746C
Volume Resistivity	1.0E+15 ohms cm	ASTM D227
	UL 746C	IEC 60093
RTI (mm)	0.75 mm	115 °C
	2.0 mm	115 °C
	3.0 mm	115 °C
RTI (sq)	0.75 mm	115 °C
	2.0 mm	115 °C
	3.0 mm	115 °C
RTI (6)	0.75 mm	115 °C
	2.0 mm	115 °C
	3.0 mm	115 °C
Moisture	UL 746C	UL 746C
	Dimensional Stability	0.0%
Outdoor Suitability	UL 746C	ASTM D1492
	UL 746C	IEC 60728

RTP UL94 RATINGS



UL94 Ratings

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



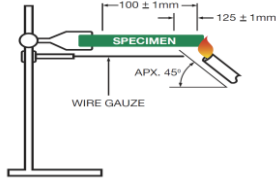
Ratings in order of difficulty to meet!

RTP 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

RTP UL94 - HB



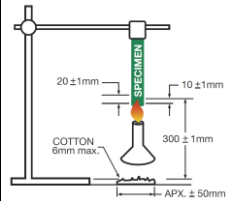
Classification Criterion

- 3.0 mm to 13.0 mm thickness** **< 3.0 mm thickness**
- slower than 40 mm/minute or...
 - combustion ceases prematurely
 - slower than 75 mm/minute or...
 - combustion ceases prematurely

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

RTP 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



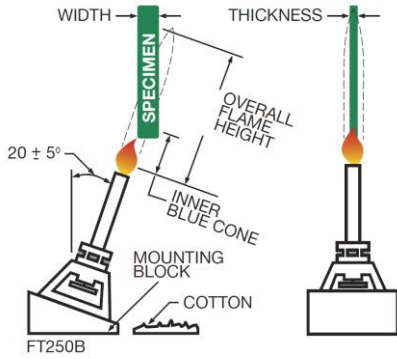
****Thickness dependent ratings****

RTP 5V TESTING

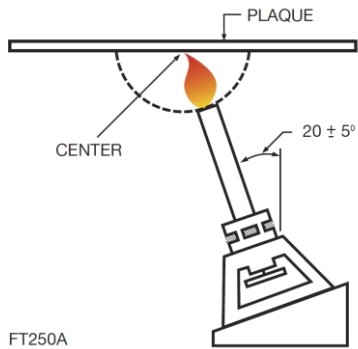
- 500 Watt flame vs. 50 watt flame
- 5 – 5 Second flame applications (5 seconds on / 5 seconds off)
- Bar burn and panel burn

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

RTP 5V – BAR BURN

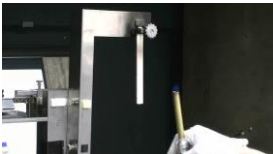


RTP 5V – PLAQUE BURN



RTP UL94 VERTICAL BURN DEMO

Flame Retardant – V-0



Non-Flame Retardant – No Rating



RTP YELLOW CARD EXAMPLE - F1

UL Component - Plastics File Number: E84658			
RTP CO 680 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 Ultra-violet Light, Water Exposure and Immersion in accordance with UL 746C			
Property	Value	Test Method	
Flame Rating	0.75 mm, ALL	V-0	UL 94
	2.0 mm, ALL	V-0, SVA	ISO 9800-11-10, -20
	3.0 mm, ALL	V-0	
Electrical	Value	Test Method	
Insulation Resistance (IRMI) (0.75 mm)	PLC 0	UL 746	
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746	
Comparative Tracking Index (CTI)	PLC 0	UL 746	
Dielectric Strength	23kV/mm	ASTM D149 IEC 60243-1	
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746	
Volume Resistivity	1.0E+15 ohms-cm	ASTM E227 IEC 60093	
Thermal	Value	Test Method	
RTI Elec.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
RTI Imp.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
RTI Sp.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
Mechanical	Value	Test Method	
Dimensional Stability	0.0%	ASTM D1642 ISO 2768	
Outdoor Suitability	F1	UL 746C	

RTP 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**

RTP YELLOW CARD EXAMPLE - RTI

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RTP CO 680 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 Ultra-violet Light, Water Exposure and Immersion in accordance with UL 746C			
Property	Value	Test Method	
Flame Rating	0.75 mm, ALL	V-0	UL 94
	2.0 mm, ALL	V-0, SVA	ISO 9800-11-10, -20
	3.0 mm, ALL	V-0	
Electrical	Value	Test Method	
Insulation Resistance (IRMI) (0.75 mm)	PLC 0	UL 746	
High Amp Arc Ignition (HAI) (0.75 mm)	PLC 0	UL 746	
Comparative Tracking Index (CTI)	PLC 0	UL 746	
Dielectric Strength	23kV/mm	ASTM D149 IEC 60243-1	
High Voltage Arc Tracking Rate (HVTR)	PLC 0	UL 746	
Volume Resistivity	1.0E+15 ohms-cm	ASTM E227 IEC 60093	
Thermal	Value	Test Method	
RTI Elec.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
RTI Imp.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
RTI Sp.			
0.75 mm	115 °C	UL 746	
2.0 mm	115 °C		
3.0 mm	115 °C		
Mechanical	Value	Test Method	
Dimensional Stability	0.0%	ASTM D1642 ISO 2768	
Outdoor Suitability	F1	UL 746C	

RTP 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

RTP RTI OVENS



RTP YELLOW CARD EXAMPLE - SHORT TERM ELECTRICALS

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RTP 104 CC FR A UV (F1) Polypropylene (PP), pellets, glass fiber reinforced (F1) - Suitable for outdoor use with respect to exposure to Ultra-violet Light, Water Exposure and Immersion in accordance with UL 746C			
Environmental	Value	Test Method	
Flame Rating	V-0	UL 94	
0.75 mm, ALL		ISO 9000-11-10, -20	
2.0 mm, ALL	V-0, SVA		
3.0 mm, ALL	V-0		
Electrical	Value	Test Method	
Insulation Resistance (IRMI) (0.75 mm)	PLC B	UL 746	
High Amp Arc Ignition (HAI) (0.75 mm)	PLC B	UL 746	
Comparison Tracking Index (CTI)	PLC 0	UL 746	
Dielectric Strength	23 kV/mm	ASTM D149	
High Voltage Arc Tracking Rate (HVTR)	PLC II	UL 746	
Volume Resistivity	1.0E+15 ohms-cm	ASTM D257	
Mechanical	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		
Dimensional	Value	Test Method	
Dimensional Stability	0.0%	ASTM D1642	
Outdoor Suitability	F1	UL 746C	

RTP 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)

RTP SHORT TERM ELECTRICAL TESTS

- CTI – Accelerated simulation of conditions leading to possible tracking and failure (i.e. a “short”).
- HVTR – Tracking test at high voltage to determine the rate of tracking spread
- D 495 – High-voltage, low current arc used to simulate material breakdown due to electrical arcing



RTP SHORT TERM ELECTRICAL TESTS

- HWI – Electrically heated wire is put into contact with test specimens until either ignition or burn-through occurs
- HAI – Electrodes placed on the surface of test specimens, providing a series of arc cycles until failure criteria is met (ignition, burn-through, melting, etc.)

RTP RTP COMPANY UL CERTIFICATION

RTP Company has 700+ UL Yellowcards
 • Continuous expansion of UL listed products

UL Certified Laboratory under Client Test Data Program (CTDP)

- Short term properties to UL94
- Long term thermal aging (RTI)



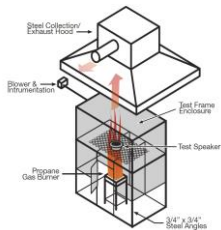
RTP Company offers custom UL certifications to achieve full commercialization

- Quick turnaround
- **Compress your Time to Market!**

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RTP 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

RTP UL 723/ASTM E 84



Size of Chamber

RTP UL 723/ASTM E 84

	Flame-Spread Index (FSI)	Smoke Development Index (SDI)
Class 1 or Class A	0 – 25	450 Maximum
Class 2 or Class B	26 - 75	450 Maximum
Class 3 or Class C	76 -200	450 Maximum

- For materials considered to be continuous (i.e. walls and flooring)
- Material certification

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RTP PREDICTING PERFORMANCE

UL 94 as an indicator for large scale testing

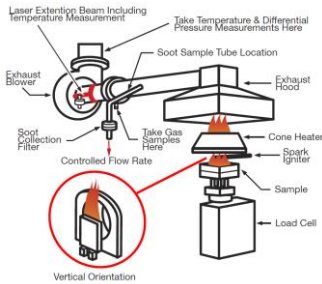
Pros	Cons
<ul style="list-style-type: none"> • Quick indication of FR performance • Higher ratings likely to test better • May be able to determine the mechanism of FR 	<ul style="list-style-type: none"> • Poor indicator of heat release • No measurement of smoke generation • Rating alone does not give 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

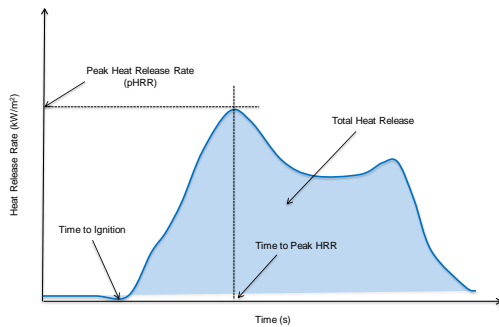
RTP PREDICTING PERFORMANCE

ASTM E 1354 Cone Calorimetry

- More quantitative results
- Measures smoke generation, heat release, and mass loss
- Can test at varying heat fluxes
- Useful for comparative testing
- Relatively inexpensive



RTP ANATOMY OF A HEAT RELEASE CURVE





Questions?

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