UL FLAMMABILITY – WHAT IT MEANS IN THE UL PRODUCT RECOGNITION PROCESS

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November 8, 2013
TOPICS

- Scale of fire tests
- UL standards & material properties
- Determining risk of fire and steps taken to mitigate effects
- Pre-selection testing
- Focus on UL 94 V Test
RELATIVE SCALE OF SOME FIRE TESTS

1 Inch or Less
- UL94 “V” Test
- ASTM D635
- Cig. Lighter

1 kW or less
- App 40 kW
- Waste paper basket
- 1st 5 min in NFPA 286

88 kW
- Steiner Tunnel

App 160 kW
- Cushioned office chair
- 10 min in NFPA 286

Smaller Tests Can Be Appropriate Based On Threat
UNDERWRITERS LABORATORIES METHODOLOGY
USE OF STANDARDS - RECOGNITION/COMPLIANCE

Underwriters Laboratories, Inc

End products

- End Product Standards (PCs, copiers, phones, dishwashers, etc.)
- UL746C (Electrical Enclosures, Barriers, etc.)
- Material Pre-selection Guidance

Polymeric Materials

- UL 94 (Flammability)
- UL 746A (short-term properties)
- UL746B (long-term properties)
- UL746C (Use of polymer mat'ls in electrical equipment)
- UL746D (Finished Parts)

Recognition, Listing, & Compliance

- Recognition Files (Organization, Control & Maintenance)
- Factory ID
- Follow-up Service - compliance to current recognition
- Publicly available information
HOW UL DETERMINES PROPERTIES OF A PLASTIC PART IN ELECTRICAL EQUIPMENT

Does an End Product Standard Exist? Example UL 6703 PV Connectors

No

Use UL 746C - Polymeric Materials - Use In Electrical Equipment Evaluations

Material properties


Device Properties

Gather properties directly from standard and any referenced standards such as UL 746C

Yes

Flammability of materials is a concern when there is a “Risk of Fire”
3.34 Risk Of Fire – A risk of fire is considered to exist at any two points in a circuit where:
   a) The open circuit voltage is more than 42.4 V peak and the energy available to the circuit under any condition of load, including short circuit, results in a current of 8 A or more after one minute of operation, or
   b) A power of more than 15 watts can be delivered into an external resistor connected between the two points.

Then, UL 746C takes steps to mitigate the effect of a fire:

- Limits ignitability of materials
- Limits spread of flame, if ignition occurs
- Reduces chance of flame breaching certain enclosures

Underlying assumption: A small fire of electrical origin will happen. Tries to keep fire from growing out of control.
FIRE/SHOCK RISKS NEED AN ENCLOSURE*

Can be single “box”

1) “Primary” safety enclosure – fire and/or shock

2) “Secondary” enclosure: keep out the elements (water, UV), prevent accidental contact, provide insulation/grounding, as needed.

Or, “box-within-box”

* Defined term in UL 746C
<table>
<thead>
<tr>
<th>Application</th>
<th>Minimum Flame Rating</th>
<th>Alternative Testing**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable* Attended* Household* Equipment</td>
<td>UL 94 HB</td>
<td>- GWIT per par. 3.20 of at least 575°C or a GWFI per par. 3.21 of at least 550°C, or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- enclosure complies with 12 mm or 20 mm end-product flame tests per Sections 15 and 16 respectively</td>
</tr>
<tr>
<td>All other Portable Equipment</td>
<td>UL 94 V (V-0, V-1, or V-2)</td>
<td>- Enclosure complies with 12 mm or 20 mm end-product flame tests per Sections 15 and 16 respectively.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Exception: An HB enclosure material may be used in portable unattended household equipment that complies with the criteria specified in Section 5.</td>
</tr>
<tr>
<td>All other Equipment</td>
<td>UL 94 5VA</td>
<td>- Enclosure complies with 127 mm end-product flame tests per Section 17</td>
</tr>
</tbody>
</table>

* - Defined terms in UL 746C  
** - If area > 10 ft², then spread of flame per UL 723 (similar to ASTM E84) or ASTM E162 (Radiant Panel)  
See section 19.

**UL 94 tests are “pre-selection tests” for alternative end product tests…. a hallmark of UL flammability methodology**
## END PRODUCT TESTS FOR UL 94 V & 5V TESTING

<table>
<thead>
<tr>
<th>Test Name/Section</th>
<th>Criteria</th>
<th>Details</th>
</tr>
</thead>
</table>
| 12 mm flame per Section 15 and 20 mm flame per Section 16 | - Not flame for more than 1 minute after either of two 30-second applications of test flame, with an interval of 1 minute between  
- Not be completely consumed | - Tested on inside, if possible, near sources of ignitions  
- 3 samples tested  
- If 1 fails, another set of 3 must pass.  
- Internal components are left in place, if possible |
| 127 mm (5 inch) flame per section 17 | - Not flame for more than 1 minute after fifth 5-second flame application, with interval of 5 seconds between  
- No drops igniting cotton  
- No flame on protected side or > 3mm hole formation | Same as above |

**Can be cumbersome:**
- Actual equipment tested  
- Change in internal design, shape, thickness, etc. could prompt re-testing  
- Equipment manufacturer responsible for flame testing

Complications associated with end-product flame testing tend to cause OEMs to look for materials with pre-selection (UL 94V / 5V) test ratings
How UL 746C Uses Flammability with “Ignitability”

Insulation / Support of Live Parts: Live parts in close proximity** to combustible materials prompt additional “ignitability” tests

<table>
<thead>
<tr>
<th>Flame</th>
<th>HWI</th>
<th>HAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>V-2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>V-1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>V-0</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

HWI = Hot Wire Ignition. Measure of ignition resistance when exposed to heated wire.

HAI = High-current Arc Ignition. Measure of ignition resistance when exposed to electrical arcs

** 9 generalized diagrams in UL 746C to define when these test may be needed

HWI and HAI are pre-selection tests with their own end-product test alternatives.
UL 94 TESTING – FOCUSING ON “V” TEST
# UL94 SMALL SCALE FLAMMABILITY – RELATIVE COMPARISON

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
<th>Area of Use</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB</td>
<td>Not ignite, or VTM series (excluding drips) must extinguish during test</td>
<td>Generally used in “lowest concern” areas: decorative trim, enclosures for attended household items (ex., hair dryer), etc.</td>
<td></td>
</tr>
<tr>
<td>VTM-2</td>
<td>Thin films only – usually 0.010” or less – electrical insulation or “barrier films”. Never used for Enclosures.</td>
<td>Usually found in “higher concern” areas: enclosures for un-attended household items, commercial items, material directly supporting live parts, electrical insulation, etc. The specific V-0, V-1, or V-2 requirement is either based upon end-product Standard or product design evaluation taking into account additional material “ignitability” properties.</td>
<td></td>
</tr>
<tr>
<td>VTM-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTM-0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-2</td>
<td></td>
<td>Usually found in “highest concern” areas: enclosures in stationary or “fixed” equipment. A or B requirement is function of product design. Products now need to be V-0 or V-1, before a 5VA or 5VB rating is granted.</td>
<td></td>
</tr>
<tr>
<td>V-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5VB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5VA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increasing In Severity (Generally)

See appendix for details on HB, VTM, and 5V tests.
THE UL 94V TEST

CONDITIONING
- Two sets of five specimens at 23 ± 2°C/50 ± 5% RH/48 hrs.
- Two sets of five specimens at 70 ± 1°C for seven days and cooled in desiccator for 4 hours.
- Lab atmosphere of 15-35°F/45-75% RH.

PROCEDURE
- Calibrate flame.
- Two 10-second applications of flame.
- If flaming of the first application ceases, immediately reapply flame.
- If only 1 out of 5 fails, re-test another set of 5. All must pass

<table>
<thead>
<tr>
<th>Criteria</th>
<th>94V-0</th>
<th>94V-1</th>
<th>94V-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>After flame time for each individual specimen ( t_1 ) or ( t_2 )</td>
<td>&lt; 10s</td>
<td>&lt; 30s</td>
<td>&lt; 30s</td>
</tr>
<tr>
<td>Total afterflame time for any condition set (( t_1 ) plus ( t_2 ) for the 5 specimens)</td>
<td>&lt; 50s</td>
<td>&lt; 250s</td>
<td>&lt; 250s</td>
</tr>
<tr>
<td>Afterflame plus afterglow time for each individual specimen after the second flame application (( t_2 + t_3 ))</td>
<td>&lt; 30s</td>
<td>&lt; 60s</td>
<td>&lt; 60s</td>
</tr>
<tr>
<td>Afterflame or afterglow of any specimen up to the holding clamp</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cotton indicator ignited by flaming particles or drops</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
TO BE LISTED AS V-0, TEST SPECIMENS MUST...

- Not ignite during V test, or
- Ignite but extinguish during the test

AND

- Not drip during test, or
- Drip but not ignite cotton

Key Wording is “During the Test”

- Pitfalls exist if too much is assumed from test results
- A “V-0” rating does not mean the material is “self extinguishing”
- Example: Bar of basic magnesium can be V-0 based on not igniting during test. When ignited, it is not self extinguishing

A V-0 listing means a V-0 test has been met, not that the material has flame retardant additives
SPECIMEN REACTION-TO-FIRE BEHAVIOR: V-0 AND V-2

V-2 & V-0 fire behaviors can be very similar:

- 0 sec. Burn time, dripping with no cotton ignition = V-0
- 0 sec. Burn time, one drip igniting cotton = V-2

Also can be very far apart:

- 0 sec. Burn time, dripping with no cotton ignition = V-0
- 0 sec avg. Burn times, continuous flaming dripping = V-2
- 20 sec avg. Burn times, continuous flaming dripping = V-2

V-2 criteria allows for a wide range of reaction-to-fire behavior, including a “pool” fire provided the bar drips to extinguishment.
NO SUCH THING AS A “V-0 MATERIAL”

- Materials listed at specific thicknesses
- Materials listed in specific colors, or an “All-Color” listing
- UL uses “Bracketing” methods for product variables (including thickness & pigment levels)
- Formulations are “fingerprinted”, variations must follow specific guidelines which can lead to re-testing
- Follow-up testing is done for specific properties

Plastics recognitions are maintained through testing and most are freely available on UL’s website
SUMMARY

Small scale reaction-to-fire tests can be informative, based on threat.

UL methodology focuses on reducing certain risks in end products.

UL standards often allow “pre-selection” material tests to avoid end-product testing.

Understanding the nuances of the “V” test ratings and how UL standards use the ratings will aid in making better judgments of their suitability beyond UL standards.

Any material’s “V, 5V, HB, or VTM” rating is based on thickness, color, and other variables. If one seeks a correlation test, understand the boundaries of the correlation.

Knowing the details helps to make better decisions.
Thank you for attending.
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APPENDIX
CONDITIONING

- Two-day and seven-day
- Calibrate flame temp; test flame bars.
- Five/5-second applications of flame
- Test plaques to establish A or B rating.

PROCEDURE

- Calibrate flame temp; test flame bars.
- Five/5-second applications of flame
- Test plaques to establish A or B rating.

VERTICAL BURNING TEST FOR 94-5VA, B CLASSIFICATION

<table>
<thead>
<tr>
<th>Criteria Conditions</th>
<th>94-5VA</th>
<th>94-5VB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afterflame plus afterglow time after the fifth flame application for each individual bar specimen</td>
<td>≤ 60s</td>
<td>≤ 60s</td>
</tr>
<tr>
<td>Cotton indicator ignited by flaming particles or drops from any bar specimen</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Burn-through (hole) of any plaque specimen</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
VERTICAL BURNING TEST FOR 94VTM-0, -1, -2

Specimen 2" by 8" by thickness (generally .010” max). Specimen first wrapped around 1/2 bar and taped into cylinder shape.

**Criteria Conditions**

<table>
<thead>
<tr>
<th>Condition</th>
<th>94VTM-0</th>
<th>94VTM-1</th>
<th>94VTM-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>After flame time for each individual specimen t₁ or t₂.</td>
<td>≤ 10s</td>
<td>≤ 30s</td>
<td>≤ 30s</td>
</tr>
<tr>
<td>Total afterflame time for any condition set (t₁ plus t₂ for the 5 specimens)</td>
<td>≤ 50s</td>
<td>≤ 250s</td>
<td>≤ 250s</td>
</tr>
<tr>
<td>Afterflame plus afterglow time for each individual specimen after the second flame application (t₂ + t₃)</td>
<td>≤ 30s</td>
<td>≤ 60s</td>
<td>≤ 60s</td>
</tr>
<tr>
<td>Afterflame or afterglow of any specimen up to the 5” mark</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cotton indicator ignited by flaming particles or drops</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Conditioning**

- Two sets of five specimens at 23 ± 2°C/50 ± 5% RH/48 hrs.
- Two sets of five specimens at 70 ± 1°C for seven days and cooled in desiccator for 4 hours.
- Lab atmosphere of 15-35°F/45-75% RH.

**Procedure**

- Calibrate flame.
- Two 3-second applications of flame.
- If flaming of the first application ceases, immediately reapply flame.
- If only 1 out of 5 fails, re-test another set of 5. All must pass.
HORIZONTAL BURNING TEST FOR 94HB CLASSIFICATION

**CONDITIONING** - Specimens conditioned at 23±2°C and 50±5 percent RH for a minimum of 48 hours.

**PROCEDURE**

- Three specimens tested.
- Flame applied for 30±1 seconds or until combustion front reaches 25mm reference mark.
- Flame spread is timed.

A material classed 94HB shall:

a) Not have a burning rate exceeding 40 mm per minute over a 75 mm span for specimens having a thickness of 3.0-13.0 mm, OR
b) Not have a burning rate exceeding 75 mm per minute over a 75 mm span for specimens having a thickness less than 3.0 mm, OR

c) Cease to burn before the 100 mm reference mark.