# FR-4 OVERVIEW

**June, 2013**

**JPCA**

# Contents



# 8,956 EMPLOYEES

**97**
INSPECTION CENTERS

SERVICING CUSTOMERS IN

**104**
COUNTRIES

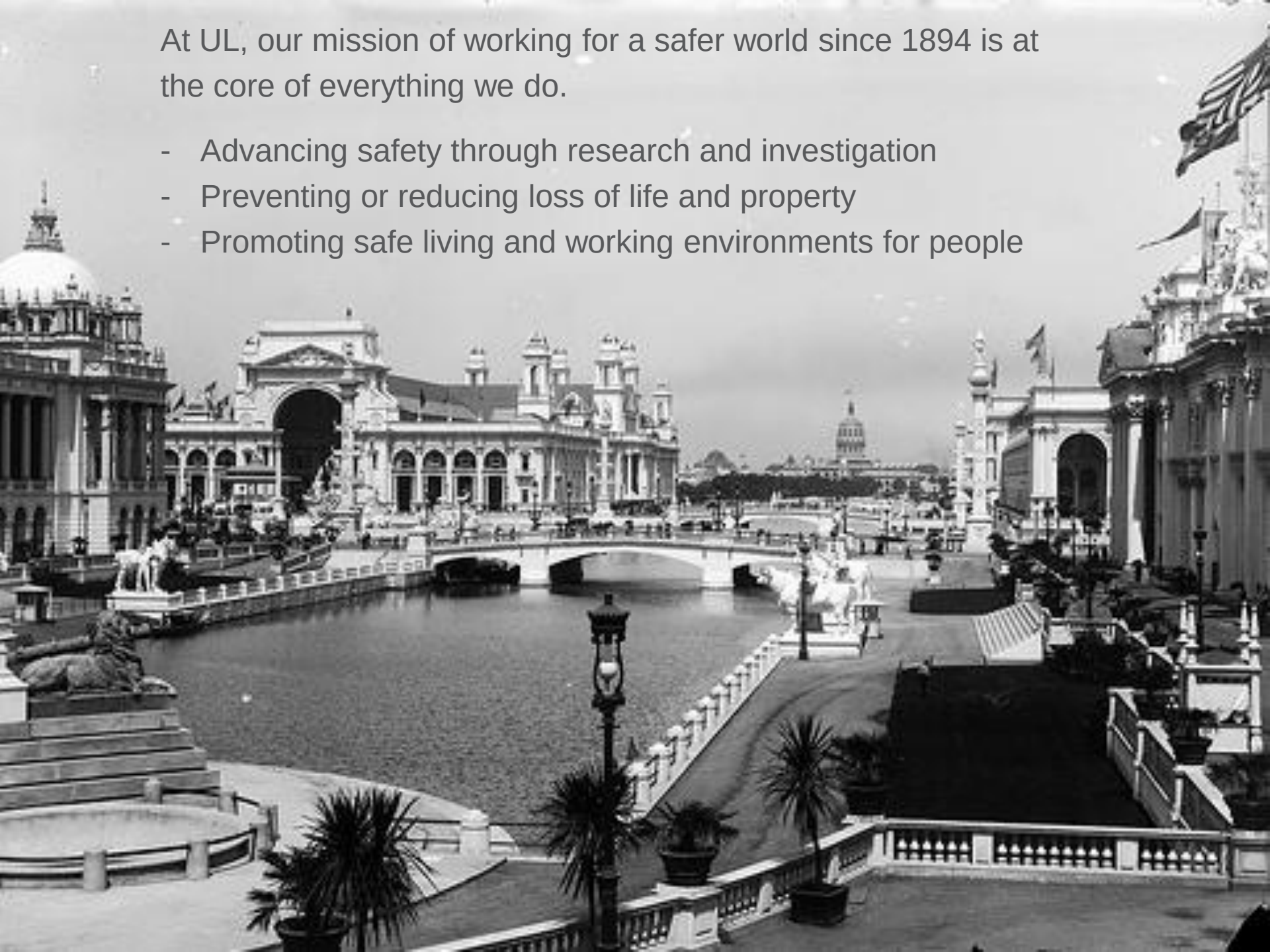







At UL, our mission of working for a safer world since 1894 is at the core of everything we do.

- Advancing safety through research and investigation
- Preventing or reducing loss of life and property
- Promoting safe living and working environments for people



## WE PROVIDE GLOBAL MARKET

# ACCEPTANCE

Our Marks are on more than 22 billion products worldwide, per year, signaling peace of mind to consumers, customers, businesses and governments.

**22 BILLION** UL MARKS APPEAR ON PRODUCTS ANNUALLY

**3 BILLION** CONSUMERS WERE REACHED BY UL IN ASIA, EUROPE AND NORTH AMERICA

MORE THAN **560K** FOLLOW-UP INSPECTION VISITS WERE CONDUCTED BY UL

**86,972** PRODUCT EVALUATIONS CONDUCTED BY UL

**67,798** MANUFACTURERS PRODUCING UL CERTIFIED PRODUCTS

**19,909** TYPES OF PRODUCTS EVALUATED BY UL

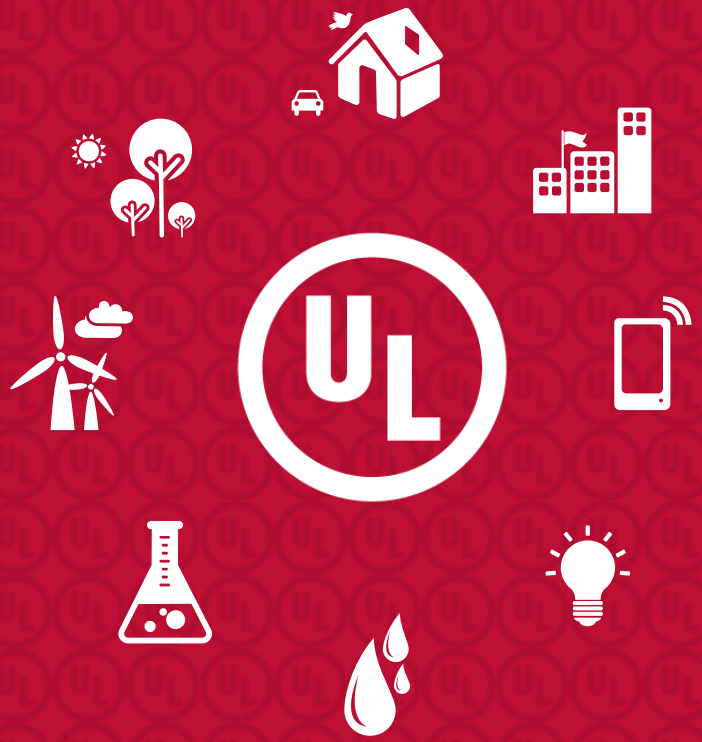
**1,464** CURRENT STANDARDS FOR SAFETY PUBLISHED BY UL

## THE DEFINITION OF SAFETY IS CONSTANTLY

# EVOLVING

Safety is evolving. Complex issues of today have replaced concerns of the past. And the safety landscape of tomorrow is yet to be defined.

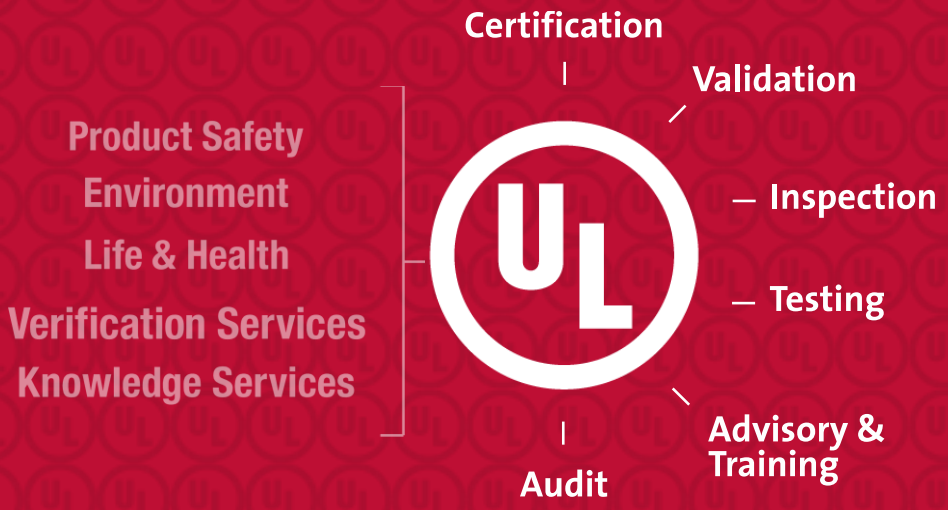
- Electricity
- Fire
- Chemicals
- Food and water
- Infrastructure
- Medical devices
- Nanotechnology
- Sustainability
- Renewable energy
- Wireless integration



PROVIDING SERVICES FOR

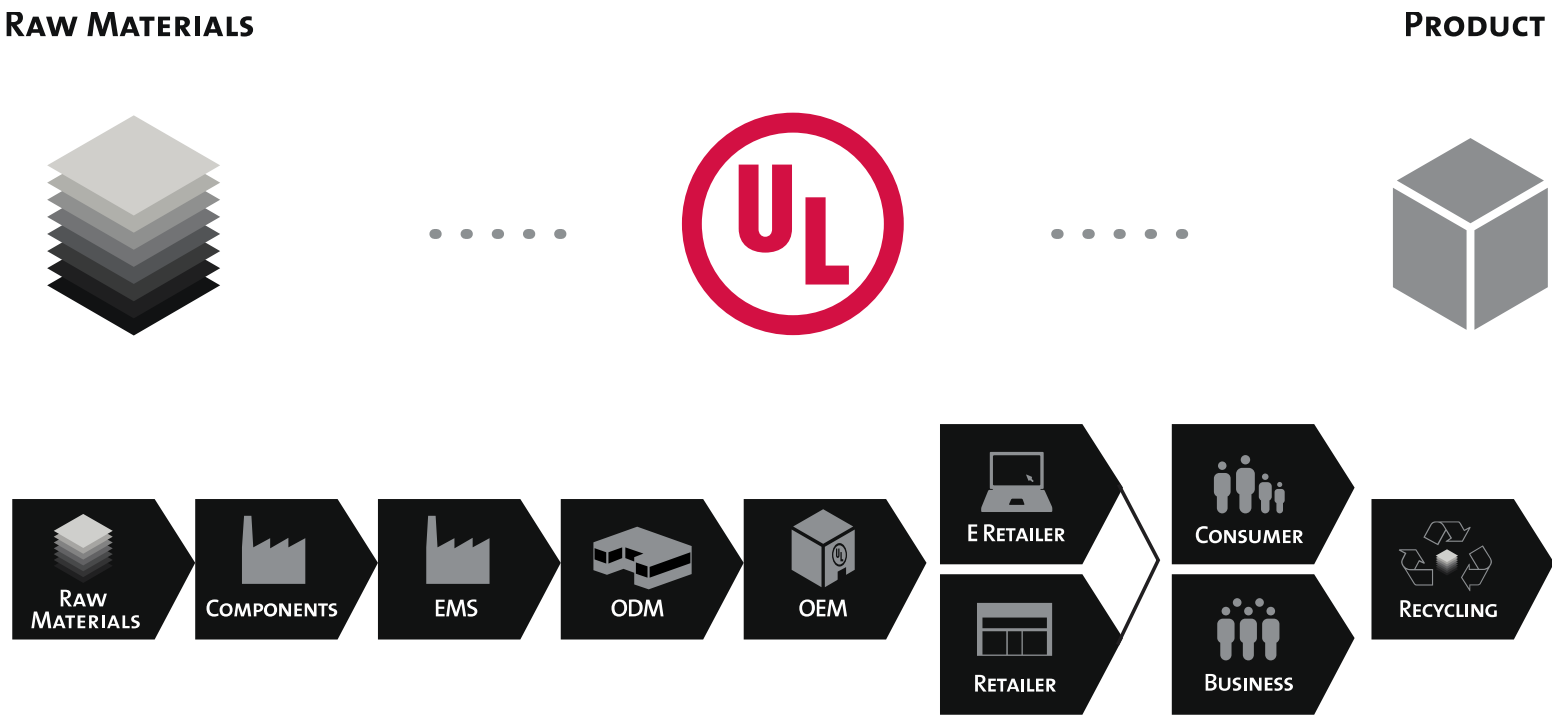
# A SAFER WORLD

UL offers an extensive array of services to our diverse customers that support every stage of the product life cycle, from the testing of new technologies to market access.



# Contents

# We play a critical role in fostering supply chain integrity



# Recognition leads to product safety listing

UL Recognition is driven by end product safety concerns around:

- Fire: added fuel; ignitability
- Electric Shock: reduced spacings; insulation breakdown
- Mechanical Strength: ability to support components

Many end-product Standards require UL Recognized PWBs, for example:

IEC 60065 (Audio & Video Equipment)
- V-0 or V-1 based on power requirements

IEC 60950 (Information Technology Equipment)
- V-1, MOT for application, and Direct Support compliant

IEC 62368 (ITE and Audio/Video Equipment)

IEC 60335 (Appliances)

IEC 60601 (Medical Equipment)
- V-1, MOT for application

IEC 61010 (Equipment for Laboratory Use)
- V-1, 105C MOT

# Demand Driver for UL Certification

| Hazard | Failure Mechanism | Board Feature | Test | Test Method | PWB Parameter |
|---|---|---|---|---|---|
| Electric Shock | Reduce Spacings | Metal type conductor adhesion | Bond strength | UL796 | MOT |
| | | | Blistering/Delam | UL796 | MOT |
| | | Paste type conductor adhesion | Conductive Paste Adhesion | UL796 | MOT |
| | | Silver conductors | Silver Migration | UL796 | MOT |
| | | Plating adhesion | Plating adhesion | UL796 | MOT |
| | | Warping / Cracking | Delam | UL796 | MOT |
| | | Environmental Contamination | CTI | UL746E/UL746A | DSR |
| | Insulation Breakdown | Board thickness | Dielectric Strength | UL746E/UL746A | RTI/MOT/DSR |
| | | | Volume Resistivity | UL746E/UL746A | DSR |

MOT – Maximum Operating Temperature
DSR – Direct Support Requirement
RTI – Relative Thermal Index

# Demand Driver for UL Certification

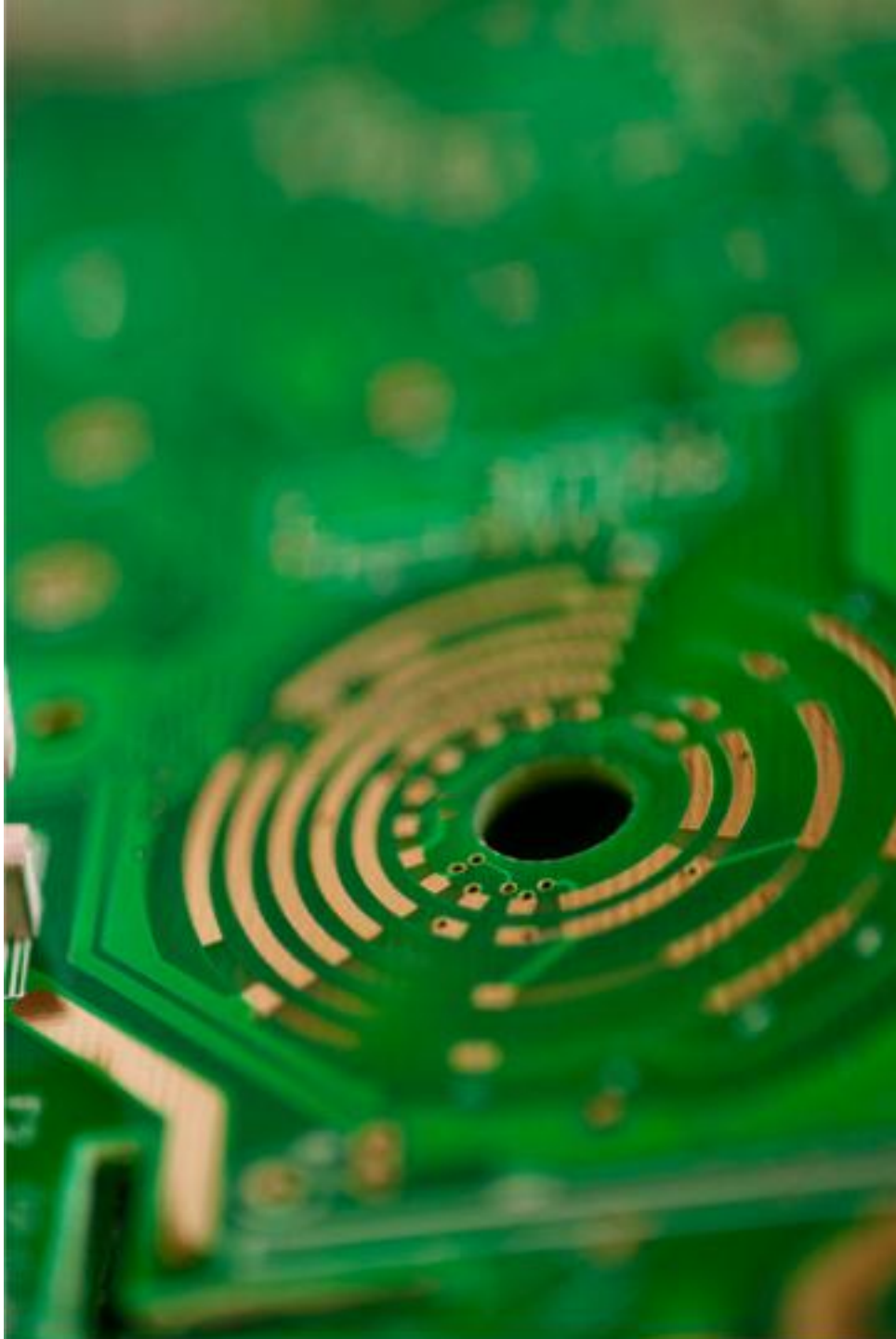
| Hazard | Failure Mechanism | Board Feature | Test | Test Method | PWB Parameter |
|---|---|---|---|---|---|
| **Flammability** | Fuel for the fire/burn time | Board thickness | Self Extinguishing or Slow burn | UL94 | RTI/Flame |
| | | Coatings | Self Extinquishing or Slow burn | UL94 | Flame |
| | Ignitability | Hot wire Ignition Or Glow wire | HWI | UL746E/UL746A | DSR |
| | | High Arc Ignition | HAI | UL746E/UL746A | DSR |
| **Mechanical Strength** | Ability to support components | Board thickness | Flexural Strength | UL746E/UL746A | RTI |
| | | | Tensile Strength | UL746E/UL746A | RTI |
| | | | Inner layer Delamination | UL746E/UL746A | RTI/MOT |

MOT – Maximum Operating Temperature
DSR – Direct Support Requirement
RTI – Relative Thermal Index

# Benefits of UL PWB Recognition

PWBs are covered under UL's Component Recognition Program

- Type Testing
  - Provides user with confidence component initially complies with requirements
  - Pre-selection allows for less testing by OEMs, data compared against requirements
  - UL Recognized PWBs may be used Globally
- On-going compliance (FUS – Follow-up Service)
  - Audit Surveillance of materials and PWBs during production
  - Provides confidence the component continues to meet standard requirements moving forward



# FR-4 History and UL746E Standard Revision

# Historical FR-4 Modifications

Traditional FR-4s composed of brominated epoxy resin have also evolved based on the following changes:

1) Modification of resin to improve reliability
   - Heat resistance, humidity resistance, and heat expansion, etc.

2) Environmental substances for the EU RoHS Directive
   - Halogen free flame retardants

3) Modification of resin for higher electrical performance
   - Advancement of IT technology and new material for market needs have been developed

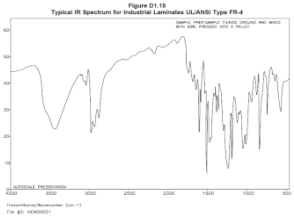
# UL Aims to Reduce Risks in Products

- Flammability – Ignition properties change due to PCB materials
  - Different flame retardant systems – physical or chemical action
  - Adding fuel to fire – solder mask does not contain flame retardant
- Electric shock - Due to changes in PCB materials
  - Spacing – conductor adhesion, delamination or silver migration
  - Insulation – board thickness, brittleness, filler
  - Mechanical strength – ability to support components
- Traditional and non-traditional FR-4 materials have different behavior characteristics, e.g., thermal stability and flammability
  - data available from industry and UL Corporate Research

***For the purpose of testing, traditional and modified FR-4 materials do not represent each other***

# UL 746E Standard - Timeline

**< 2001**
- FR-4 defined by 6 IR spectra



**2001**
- STP approves standard change
- FR-4 definition updated to 14 IR spectra

**2004**
- IFR effective date postponed: many non-traditional FR-4s found in file review

Continued to apply 2000 version of 746E:
- Laminates: abbreviated testing or LTTA
- PCBs: accepting non-traditional FR-4 by CCIL

**2012**
- Published 746E applied
- Laminates: no additional testing; non-traditional FR-4 are non-ANSI
- PCBs: non-traditional FR-4 required full testing

**Today**
- New Requirements
- Laminates: Split FR-4.0, FR-4.1
- PCBs: CCIL ok

UL's communication with industry: IPC, JTPIA, JPCA, TPCA, CPCA

Exploring testing alternatives: T260, Oxygen Index

✖ **2011**
- JTPIA proposal:
- 13 Yes, 15 No

✖ **2012**
- UL proposal:
- 15 Yes, 15 No

✔ **2013**
- IPC proposal:
- 29 Yes, 6 No

***Continuous modifications to FR-4 materials***

# New FR-4 Proposal from IPC

## Summary of IPC UL 746E Proposal for STP Ballot: Two New UL/ANSI Types Replacing FR-4

| UL/ANSI Type | Primary Resin | Secondary Resin(s) | Filler[1] | Flame Retardant | Reinforcement |
|---|---|---|---|---|---|
| **FR-4.0 (Proposed Brominated FR-4)** | Epoxy[2] | Any | Inorganic Max 45% | Bromine | Woven Glass |
| **FR-4.1 (Proposed Non-Halogen FR-4)** | Epoxy[2] | Any | Inorganic Max 45% | Non-Halogen | Woven Glass |

[1] Examples of inorganic fillers include, but are not limited to: Silica, Clay, Talc, Ceramic, Calcium Carbonate, Aluminum Hydroxide, Fumed Silica and Titanium Oxide.

[2] Epoxy functionality, minimum 50% by weight of organic resin.

# UL 746E Published Requirements for FR-4

**Table 7.3**
**Industrial laminate constituents**

Revised Table 7.3 effective June 30, 2014

| UL/ANSI type | Resin | Reinforcement material |
|---|---|---|
| FR-1 | Phenolic | Paper |
| FR-2 | Phenolic | Paper |
| FR-3 | Epoxy | Paper |
| FR-4.0[a] | Brominated Epoxy | Continuous filament woven glass fabric |
| FR-4.1[a, b] | Non-Halogenated Epoxy | Continuous filament woven glass fabric |
| FR-5 | Epoxy | Continuous filament woven glass fabric |

[a] Total inorganic filler content equal to 45 percent maximum by weight.

[b] Total halogen content equal to 900 ppm maximum Bromine or Chlorine and 1500 ppm combined Bromine and Chlorine tested in accordance with 8.12.

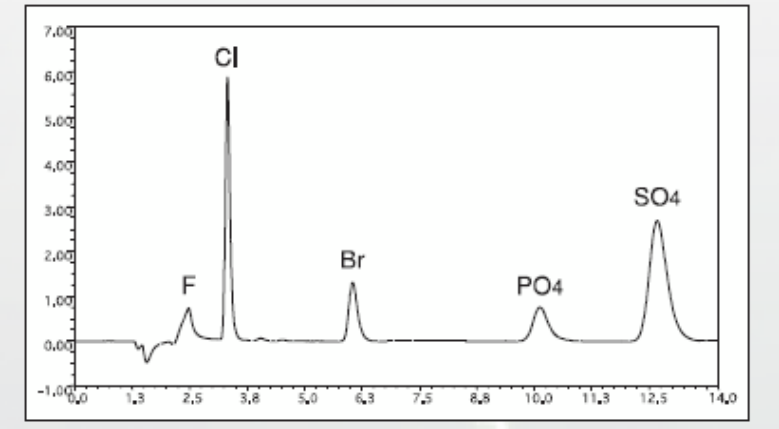
7.7.1 FR-4.0 and FR-4.1 grades must contain 50 percent epoxide resin minimum excluding inorganic fillers. The total inorganic filler content by weight is 45 percent maximum. This shall be determined from constituent components provided by the supplier when submitting products for evaluation. IR reference scans may be used to verify the presence of indicated compounds. IR scans that do not match existing profiles in the suppliers file will indicate the need for LTTA per variations allowed in 7.7.

Added 7.7.1 effective June 30, 2014

# UL 746E Non-Halogen Testing / Requirements

- IPC-TM-650, 2.3.41
  - Test Method for Total Halogen Content in Base Materials

- Compliance Criteria in paragraph 8.12:
  < 900ppm Chlorine
  < 900ppm Bromine
  < 1500ppm Total Chlorine + Bromine



# Impact to Laminate, Solder Resist and PWB Manufacturers

# UL 746E Impact (Published Standard)

- New FR-4 grouping requirements
  - Published date: May 13, 2013
  - Announcement Letter date: to be sent June, 2013
  - Mailing to QMTS2, QMJU2, ZPMV2, ZPXK2 manufacturers
  - Effective date: June 30, 2014

| **Requirement Before 2001** | **FR-4** | | | |
|---|---|---|---|---|
| **2013 Published Requirements (effective in 2014)** | **FR-4.0** (~80%) | | **FR-4.1** (~20%) | |
| **Primary Resin** | Epoxy > 50% by weight | | | |
| **Flame Retardant** | Brominated | | Non-Halogen (Phosphorus, etc.) | |
| **Filler** | None | Inorganic Max 45% by wt | None | Inorganic Max 45% by wt |

# Impact to Laminate Manufacturers

- File Review for Recognized FR-4 laminates
  - Group into FR-4.0 or FR-4.1
  - No new grade designation needed
  - Brominated FR-4s change to FR-4.0
    - No testing - existing materials already tested per UL746E
    - File and Listing Card change from FR-4 to FR-4.0
  - Non-Halogen FR-4s change to FR-4.1
    - Verification and testing for Halogen Content required per new paragraph 8.12, UL746E
      - Outside data accepted from DAP participants: Chemitox and Microtek
    - No additional testing – existing materials already tested per UL746E
    - Samples are same as flame coupons
    - Sample requirements to be sent by August 2013
    - Samples must be submitted by February 27, 2014

# Laminate New Work Requests

- Follow published UL 746E standard
  - FR-4.0 – no changes to test requirements
    - Traditional FR-4s option for abbreviated testing
    - Modified FR-4s require Full testing
  - FR-4.1 – tests same as FR-4.0 plus Halogen Content testing
  - Abbreviated testing, Section 8
  - IR, TGA, Flame, Ash, Flexural Strength properties must comply with UL746E
  - Material must compare to UL/ANSI IR reference spectra
  - Brominated Epoxy with Dicy or Phenolic curing agent (Traditional FR-4s only)
  - Full testing, Section 9
  - LTTA and short term performance testing
  - Modified FR-4s
    - Additives: Fillers, Secondary Resins, Curing Agents, Alternate Flame Retardants

# Impact to Solder Resist Manufacturers

- File review for Recognized Solder Resists
  - No new grade designation needed
  - No testing for Recognized solder resists with FR-4
    - Recognition changed to FR-4.0
    - Based on testing with traditional FR-4s only

- New work requests
  - Follow published UL 746E standard
  - No changes to test requirements
  - Testing required for each ANSI requested

# Impact to PWB Manufacturers

- Recognized PWBs using FR-4 material
  - No new PWB type designation needed
  - No testing for Recognized PWBs
  - Effective date: Start file update after completion of Laminate and Solder Resist file reviews

- New work requests for PWBs using FR-4.0 or FR-4.1
  - CCIL/MCIL and Coatings program ok
    - Applies to majority of FR-4.0 and FR-4.1
  - New requests for blended resin FR-4s
    - UL796 states material shall be generically similar per section 16.2
    - Very small group of materials
    - Testing requirements do not change
      - Bond/Delam and Flame
    - New type designation required

# PWB Impact Example

PWB type A new work request:

(See following slides)

30 laminates and 30 solder resists

- 2 halogen free FR-4
- 1 halogen free filled FR-4
- 5 filled FR-4
- 1 epoxy blend FR-4
- 20 traditional FR-4

# Impact Example for New PWB Type A

| Current | Generic Material Type |
|---|---|
| All 30 FR-4 | Hal Free FR-4 |
| | Hal Free FR-4 |
| | Hal Free Filled FR-4 |
| | Blend FR-4 |
| | Filled FR-4 |
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| | Traditional FR-4 |
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| | Traditional FR-4 |

| Test Increase | 200+ | |
|---|---|---|
| 2001 Standard Requirement | Test | With Solder Resist |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| Non-ANSI | Test Each | All |
| FR-4 | Test 1 | 1 |
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| Test Increase | 3 | |
|---|---|---|
| 2013 Standard Requirement | Test | With Solder Resist |
| FR-4.1 | Test 1 | 1 |
| FR-4.1 | | |
| FR-4.1 | | |
| FR-4.0 | Test 1 | All |
| FR-4.0 | Test 1 | 1 |
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# Testing Impact

| Standard Revision | Test Increase |
|---|---|
| 2001 Standard Required Testing | More than 100x |
| | |
| 2013 Standard Required Testing | 3 |

# THANK YOU.