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# **PWB Thermal Management and UL Pre-Selection Programs**

Presented by  
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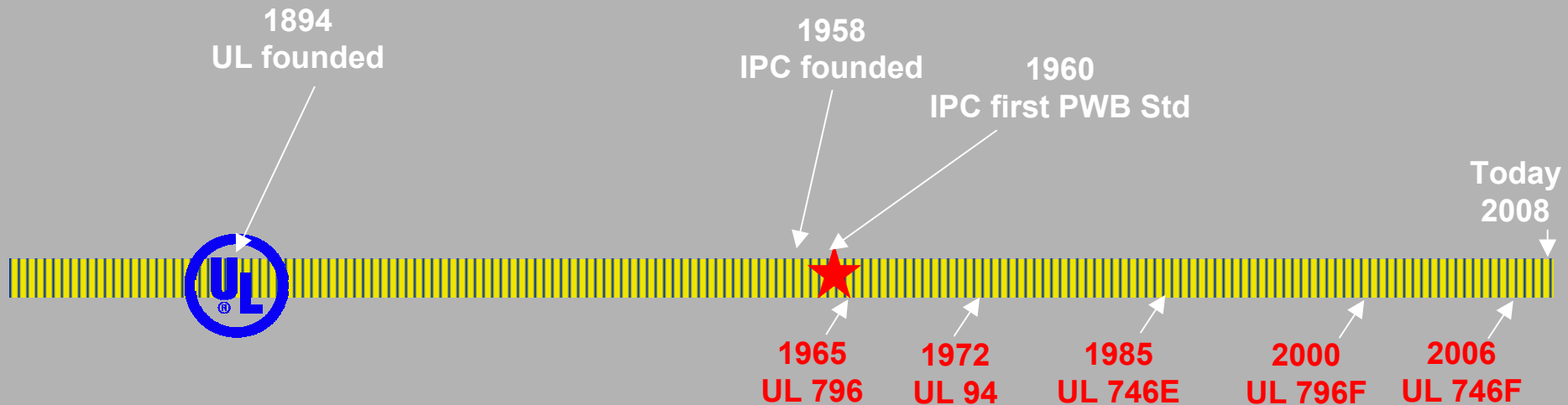
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# Who is UL?

Underwriters Laboratories Inc (UL) is an independent, not-for-profit safety testing and certification organization.

Founded in 1894, UL has earned a reputation as a global leader in product safety standards development, testing and certification.





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# **Background on UL's Certification Program for PWBs and Laminates**

# Printed Board Terminology

**Many terms are used for circuit boards in the electronics industry**

- Printed Boards (PBs)
- Printed Circuit Boards (PCBs)
- Printed Wiring Boards (PWBs)

**Official IPC term is currently “Printed Boards”**

**In order to reduce confusion with other components and end products tested within UL, we continue to use the term PWBs which will be used through-out this presentation for PBs.**



# Demand Driver – for UL Certification

## End Product Safety Issues for PWB

- Intended location
- Environmental issues – RoHS requirements
- Maximum operating temperature
- Flammability
- Material characteristics
- Conductor Adhesion
- Delamination



# Pre-selection

The process of assessing and choosing insulating materials for electrical products.



# Advantages of Pre-selection

- Aides in material selection during the design stage
- Compare and evaluate material performance levels
- Eliminate testing each material in specific part configurations
- Faster qualification of alternate materials
- Pre-selection successfully used as a material performance specification in product standards for decades
- Faster time to market

# PWB Property Characterization

## PWB Parameters

- Solder Limits
- Maximum Operating Temperature (MOT)
  - Conductor Adhesion (Bond Strength)
  - Delamination
- Flammability Classification
- Direct Support (DSR)
- Comparative Tracking Index (CTI)

# PWB Solder Limits

## **Solder limits represent assembly process**

- Maximum surface temperature
- Cumulative exposure time

## **Simulated on PWB samples with thermal shock (thermal stress) test.**

- Designed to evaluate the physical fatigue of boards exposed to the anticipated assembly soldering temperatures (Solder Limits)

## **Test with maximum temperature or multiple solder limit**

- Specified by PWB mfr

# Multiple Solder Limits

## Assembly processes now use Surface Mount Technology (SMT)

- Traditional solder float test does not represent industry practices
- PWBs exposed to at least 3 cycles of reflow process
  - #1 cycle for single sided, #2 cycles for double sided, #3 cycle for rework
- Multiple solder limits are used to represent the temperature profile during the soldering operation

# Maximum Operating Temperature (MOT)

## **MOT represents PWB maximum continuous use temperature**

- End product exposure under normal operating conditions
- Minimum acceptable MOT specified by end product requirements
- Can not exceed dielectric material mechanical or electrical RTI

## **Simulated on PWBs with short term thermal conditioning**

- Exposure temperature based on PWB mfr request
- MOT determined by analysis of PWB physical properties
  - Conductor adhesion and board delamination

# Relative Thermal Index (RTI)

## **A temperature assigned to the dielectric material**

- Does not unacceptably degrade the material
- Electrical and Mechanical properties
  - Electrical – Dielectric Strength
  - Mechanical – Flexural Strength and Tensile Strength

**Determined by a benchmark comparison of temperature, time, and critical property degradation after long-term thermal aging**

# PWB Flammability Classification

**Classification represents small scale sample evaluation and burn time**

- Flame Ratings - V-0, V-1, HB, VTM-0, VTM-1, VTM-2

**Determined by performing UL94 burning tests on the board**

- With and without coatings based on finished board
- After thermal shock (thermal stress) exposure

**Minimum acceptable flame class is specified by end product requirements**



# Direct Support Requirements (DSR)

Direct Support Requirements (DSR) represent performance characteristics for Recognized laminates in direct contact with current carrying parts at 120V or less.



# DSR Performance Tests

## Comparative Tracking Index (CTI)

- determine spacing requirements with addition of wet contaminant;

## Dielectric Strength (DS)

- establish insulation resistance baseline at 5000V or 6.89 kV/mm;

## High Current Arc Ignition (HAI)

- simulate loose connections and broken leads;

## Hot Wire Ignition (HWI)

- determine ignition properties when adjacent to or supporting an insulated or uninsulated wire;

## Volume Resistivity (VR)

- determine if material is an insulator or a semi-conductive material;

## Heat deflection

- identify and restrict the use of low temperature polymeric materials
- not required for thermoset or film materials



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# How lead-free affects thermal management of the PWB

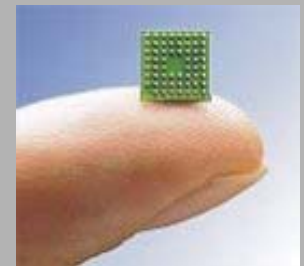
# Global Electronics Movement

Boards required to be

- Smaller
- Cheaper
- Lead-free

OEMs turning to

- Unique Rigid PWB constructions
- Flexible PWBs



# Communication is Key

Communication needed up/down the supply chain

Switching to lead-free involves the OEM, EMS, Assembler and PWB Fabricator,

- determine if lead-free is appropriate direction for end product

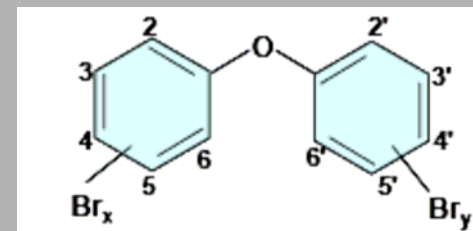
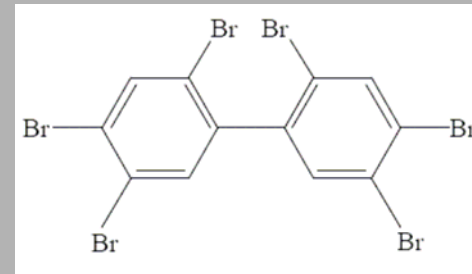


# RoHS Directive

## Restricted Substances

- Cadmium
- Hexavalent Chromium
- Lead
- Mercury
- Brominated Flame Retardants
  - Polybrominated Biphenyl (PBB)
  - Polybrominated Diphenyl Ether (PBDE)
- Exempt Tetrabromobisphenol A (TBBPA)

I	II	IIIb	IVb	Vb	VIb	VIIb	VIIIb	VIIIb	IXb	Xb	XIb	XIIb	III	IV	V	VI	VII	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
H																		He
Li	Be												B	C	N	O	F	Ne
Na	Mg												Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac**	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuq	Uub	Uuc	Uud	Uue	Uuh			
Lanthanides *			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
Actinides **			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		



# Electronic Equipment Affected by RoHS

**Appliances**

**Tools**

**IT Equipment**

**Telecommunications Equipment**

**Lighting**

**Toys**

**Sports equipment**

**Currently RoHS exempt**

- Medical Devices
- Monitoring and Control Instruments

**Household  
Appliances**



**IT and  
Telecommunication  
Equipment**



**Lighting  
Equipment**



# Lead-free Processing Challenge

**Lead-free materials require 30°C to 45°C higher melting temperatures when compared to tin-lead solder.**

Soldering Material Melting Points and Associated Solder Pot Temperatures

Material	Melting Range (°C)	Solder Pot Temperature (°C)
<b>Sn-Pb</b>	<b>183 – 188</b>	<b>250</b>
Sn-Cu (99.3Sn/0.7Cu)	227	270 – 280
Sn-Ag-Bi	206 – 213	260
<b>Sn-Ag-Cu</b>	<b>217</b>	<b>260 – 270</b>
Sn-Ag (96.5Sn/2.5Ag)	221	265 – 275

# Lead-free Processing Challenge

## **Lead-free temperatures reduce the process tolerance**

- Tin/Lead reflow 225°C
- Lead-free reflow 245°C+
- Component max temp 260°C

## **Tolerance reduced by more than 50%**

- 15°C for lead-free instead of 35°C for tin/lead

## **Affects both PWB mfrs and Assemblers**



# Higher Temperatures

## **Potential problems in the PWB**

- Delamination and warping
- Thermal shock induced cracks
- Damage to the components, such as
  - Plastic connectors, relays, LEDs, electrolytic and ceramic capacitors, etc.

## **Modifications required in process to**

- Prevent damage from higher temperatures
- Wetting and solder joint formation problems
- Overheating the assembly and components

# Potential Solutions to Lead-free Challenges

## Pre-selection of materials and PWBs

- Select alternate materials with higher temperature ratings for soldering process
- Select PWBs proven to be Lead-free compatible





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# How to Reduce Time to Market When Selecting Alternate Materials

The screenshot shows a Microsoft Internet Explorer browser window with the address bar displaying <http://iq1.ul.com/pwb/>. The page features the UL logo and the title "UL iQ for Printed Wiring Boards". A navigation bar includes "Home" and "Contact Us" links, along with a search bar and filters for "Type", "File Number", "Tradename", "Company", and "Parametric".

## Welcome to UL's iQ for Printed Wiring Boards Database

UL's iQ for Printed Wiring Boards includes materials covered under the following categories

- Printed Wiring Boards**  
**Component - Printed Wiring Boards - (ZPMV2)**  
This category covers printed wiring boards for use as components in devices or appliances. The boards may use organic or inorganic base materials in a single or multilayer, rigid or flexible form. Circuitry construction may include etched, die stamped, precut, flush press, additive, and plated conductor techniques. Printed-component parts may be used.
- Laminates**  
**Component - Laminates - (QMTS2)**  
This category covers materials that have been tested in accordance with established methods to define their properties in order to facilitate investigation of their use in end-product applications. These materials may consist of filament-wound tubing, industrial laminates, vulcanized fibre, and other materials for use in fabricating Recognized printed wiring boards.
- FMIC Flex PWB's**  
**Component - Flexible Printed Wiring Boards - (ZPXK2)**  
This category covers printed wiring construction incorporating flexible materials for use as components in devices or appliances. Flexible materials are defined as films or materials exhibiting flexible properties. The constructions may use flexible materials in a single or multilayer build-up and in combination with additional flexible or rigid materials. Flexible material constructions may employ etched, die stamped, precut, flush-press, additive plated conductors, polymer thick film, dual access, cast and adhesiveless techniques. Printed-component parts may be used.
- PWB Coatings**  
**Component - Coatings for use on Printed Wiring Boards - (QMJU2)**  
This category covers permanent coatings for use on Recognized printed wiring boards. These coatings may consist of solder resists (solder masks) or conformal coatings.

The materials covered in this database are incomplete in certain constructional features or restricted in performance capabilities and are intended for use as components of complete equipment submitted for investigation rather than for direct separate installation in the field. THE FINAL ACCEPTANCE OF THE COMPONENT IS DEPENDENT UPON ITS INSTALLATION AND USE IN COMPLETE PRODUCTS SUBMITTED TO UNDERWRITERS LABORATORIES INC.

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# UL iQ - PWB Parametric Search

UL iQ for Printed Wiring Boards - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Refresh Mail Print Print Preview

Address http://iq1.ul.com/pwb/default.aspx Go Links

 Underwriters Laboratories

## UL iQ™ for Printed Wiring Boards

Home Contact Us

SEARCH: **Type** File Number Tradename Company **Parametric**

Search for: **Printed Wiring Boards**

Construction Type: n/a	Company Name: <input type="text"/>	Conductor Attributes		
Flame Class <input type="radio"/> equal to <input checked="" type="radio"/> ≥ n/a	<input type="radio"/> single sided <input checked="" type="radio"/> double or single sided	Min Width	Min Edge	Max Area Diam
Max Operating Temperature (C): n/a	Max Solder Temp (C): <input type="text"/>	<input type="text"/> mm	<input type="text"/> mm	<input type="text"/> mm
Comparative Tracking Index (CTI): n/a	Solder Time (sec): <input type="text"/>	Min Ext Thk	Max Int Thk	Max Ext Thk
Meets UL796 DSR* n/a	<input type="checkbox"/> show multiple solder limit types only	<input type="text"/> mic	<input type="text"/> mic	<input type="text"/> mic
<input type="checkbox"/> additionally certified in accordance with Canadian National requirements				

\*A triangle symbol is marked on those products within a given type designation that comply with direct support of current-carrying parts performance level requirements of UL 796. "All" is used to indicate that all base materials under that type designation comply with direct support of current-carrying parts performance level requirements of UL 796.

Local intranet



# UL iQ - PWB Parametric Search



## UL iQ™ for Printed Wiring Boards

Wiring, Printed - Component

E41363

### CMK CORP

1106 FUJIKUBO, MIYOSHI-MACHI, IRUMA-GUN SAITAMA-KEN 354-8580 JP

### CA10

#### Multilayer printed wiring boards

Cond Width Min (mm)	Cond Width Edge (mm)	Cond Thk Min (mic)	Cond Thk Max Int (mic)	Cond Thk Max Ext (mic)	SS/ DS	Max Area Diam (mm)	Solder Limits Temp (C)	Solder Limits Time (sec)	Max Oper Temp (C)	Flame Class	Meets UL796 DSR	CTI
0.03	0.03	9	35	102	DS	25.4	180	900	130	V-0	All	2
							200	360				
							230	360				
							260	60				
							288	20				

Report Date: 1991-01-03  
Last Revised: 2006-06-20

Underwriters Laboratories Inc®



# PWB Material Pre-selection Programs

Two pre-selection programs for materials

- Metal Clad Industrial Laminate (MCIL or CCIL)
- Permanent Coatings Program

Allow generically similar materials to be characterized as suitable for cross substitution without re-evaluation in the PWB.



# UL iQ - Laminate Parametric Search

The screenshot shows a Microsoft Internet Explorer browser window displaying the UL iQ for Printed Wiring Boards website. The address bar shows the URL: <http://plastics.ul.com/pwb/Default.aspx>. The website header includes the UL logo and the text "Underwriters Laboratories" and "UL iQ for Printed Wiring Boards". A navigation menu contains links for "Home", "Introduction", "Help", and "Contact Us". Below the navigation menu is a search bar with the text "SEARCH:" and several tabs: "Company", "Parametric", "Type Dsg", "Tradename", and "File Number". The "Parametric" tab is selected, and the search criteria is set to "Laminates".

The search form is titled "Laminate category: Unclad material ratings" and includes the following fields and options:

- Laminate category:** Unclad material ratings (dropdown)
- Company Name:** (text input)
- Type:** Industrial Laminates (dropdown)
- ANSI Type:** n/a (dropdown)
- Minimum Build up (mm):** (text input)
- Flame Class:** equal to   $\geq$   n/a (dropdown)
- Meets UL796 Direct Support Req
- Electrical RTI (C):** n/a (dropdown)
- Hot Wire Ignition (HWI):** n/a (dropdown)
- High Voltage Tracking (HVTR):** n/a (dropdown)
- Mechanical RTI (C):** n/a (dropdown)
- High Arc Ignition (HAI):** n/a (dropdown)
- Comparative Tracking Index (CTI):** n/a (dropdown)

Below these fields are sections for "Board Attributes", "Solder Limits", and "Conductor Attributes":

- Board Attributes:** Max Operating Temp (C): n/a (dropdown), Type: n/a (dropdown),  single\_sided  double\_or\_single\_sided
- Solder Limits:** Max Temp (C): (text input), Time (sec): (text input),  show multiple solder limit types only
- Conductor Attributes:** Max Area Diameter (mm): (text input), Min External Thk (mic): (text input), Max External Thk (mic): (text input), Max Internal Thk (mic): (text input)

At the bottom of the form is a checkbox:  additionally certified in accordance with Canadian National requirements. A "Search" button is located below the form.

# UL iQ - Laminate Parametric Search

The screenshot shows a Microsoft Internet Explorer browser window displaying the UL iQ for Printed Wiring Boards website. The address bar shows the URL: <http://iq1.ul.com/pwb/default.aspx>. The website header includes the UL Underwriters Laboratories logo and the title "UL iQ for Printed Wiring Boards". A navigation bar contains "Home" and "Contact Us" links. Below this is a search bar with tabs for "Type", "File Number", "Tradename", "Company", and "Parametric". The "Parametric" tab is selected, and the search term "Laminates" is entered in the search box.

The main search form is titled "Laminate category:" and includes the following fields and options:

- Laminate category:** A dropdown menu with "Unclad material ratings" selected. A list of options is visible: Unclad material ratings, Base film material ratings, Metal clad ratings, Bonding films - supported (Bondplys), Bonding films - unsupported (Freefilms), Covercoats, Coverlays, Stiffeners, Investigated flex package combinations, and Ultrathin buildups.
- Type:** Industrial Laminates
- Minimum Build up (mic):** n/a
- Electrical RTI (C):** n/a
- Mechanical RTI (C):** n/a
- Board type:** n/a
- Max Oper Temp (C):** n/a
- Company Name:** [Empty text box]
- ANSI Type:** n/a
- Meets UL796 Direct Support Req:**
- High Voltage Tracking (HVTR):** n/a
- Comparative Tracking Index (CTI):** n/a
- Min Ext Conductor Thk (mic):** [Empty text box]
- Max Ext Conductor Thk (mic):** [Empty text box]
- Max Int Conductor Thk (mic):** [Empty text box]
- Max Conductor Area Dia (mm):** [Empty text box]
- show multiple solder limit types only:**
- additionally certified in accordance with Canadian National requirements:**

A "Search" button is located below the form. The Windows taskbar at the bottom shows the Start button, several open applications (C:\data\13..., Microsoft P..., MSN.com, IQ for PWB's..., UL iQ for Pri...), a 100% system tray, and the time 5:24 AM.

# Pre-selection Criteria for MCIL Addition of Alternate Laminates

Laminate Parameter		Certification Requirement
(1)	UL category code (CCN)	Recognized QMTS2 industrial laminate
(2)	UL/ANSI laminate type	Recognized with the same UL/ANSI type (FR-4, CEM-1, and CEM-3 are considered equivalent; all other UL/ANSI types are distinct.)
(3)	Minimum laminate thickness	Recognized with the same or thinner thickness (Ultrathin laminate and prepreg materials for use in multilayer PCBs require a minimum of delamination testing.)
(4)	Minimum cladding thickness (copper weight)	Recognized with the same or thinner thickness copper (MCIL program does not apply to unclad laminates.)
(5)	Maximum cladding thickness (copper weight)	Recognized with the same or greater thickness copper
(6)	Number of sides clad	Double sided constructions represent single sided constructions for rigid PCBs

Continued on next slide



# Pre-selection Criteria (cont'd) for MCIL Addition of Alternate Laminates

<b>Laminate Parameter</b>		<b>Certification Requirement</b>
(7)	Maximum area diameter unpierced (MAD)	Recognized with a minimum 50.8mm which represents larger areas
(8)	Solder limits	Recognized with a) the same or greater temperature and b) the same or longer dwell time
(9)	Maximum operating temperature (MOT)	Recognized with the same or greater temperature
(10)	Flammability rating	Recognized with the same or better flame rating
(11)	Meets Direct Support (DSR)	Yes, if required by the end product
(12)	Comparative tracking index (CTI)	Recognized with appropriate performance level (PLC) if required by the end product

# UL iQ - Coatings Parametric Search

The screenshot shows a Microsoft Internet Explorer browser window displaying the UL iQ for Printed Wiring Boards website. The address bar shows the URL <http://plastics.ul.com/pwb/Default.aspx>. The website header includes the UL logo and the text "Underwriters Laboratories" and "UL iQ for Printed Wiring Boards". A navigation bar contains links for "Home", "Introduction", "Help", and "Contact Us". Below this is a search bar with tabs for "Company", "Parametric", "Type Dsg", "Tradename", and "File Number". The "Parametric" tab is selected, and the search criteria is set to "Coatings for Printed Wiring Boards".

The search form includes the following fields and options:

- Coating Type: Resist (dropdown menu)
- Flame Class: n/a (dropdown menu)
- Min Laminate: (input field)
- ANSI Type: n/a (dropdown menu)
- Company Name: (input field)
- Max Solder Temp (C): (input field)
- Solder Time (sec): (input field)
- Min Coating Thick (mic): (input field)
- Max Coating Thick (mic): (input field)
- Max. Electrical Temp. Index (C): (input field)
- Env. Cond: indoor only (radio button), indoor and outdoor (radio button)
- Min. Spacing (mm): (input field)
- show only coatings with multiple solder limits

A "Search" button is located below the form. A note at the bottom of the form states: "\* Coatings Recognized for use with FR-4 ANSI materials are considered suitable for use with CEM-1 and CEM-3 materials."

# Advantages of UL Recognition

## **Materials included in iQ database are covered under UL's Component Recognition Program**

- Type Testing
  - Provides user with confidence that the component initially complies with requirements
- On-going compliance (FUS – Follow-up Service)
  - Audit Surveillance of materials and PWBs during production
  - Provides user with confidence that the component continues to meet these requirements moving forward



# Summary

- ✓ Lead-free requires higher temperatures
- ✓ iQ database enables users to locate suitable materials/PWBs for higher temp applications
- ✓ Pre-selection programs eliminate the need to test each material in each specific part configuration
- ✓ Faster qualification of alternate materials
- ✓ Confidence that the materials continue to meet requirements (type testing and on-going verification)
- ✓ Faster time to market





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**Thank You**

**Questions?**