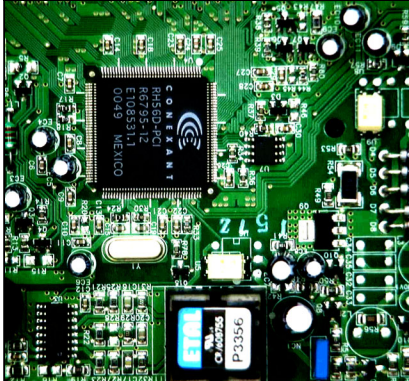


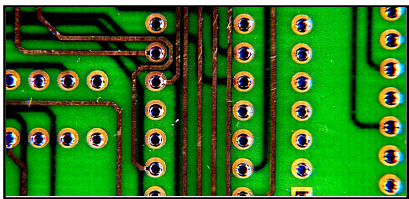
**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS**



**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS**

The printed wiring board (PWB) is an essential part of a total electronic circuit packaging system. The design requirements of the PWB must accommodate the various components required to achieve product functionality, while meeting packaging and other product design requirements.

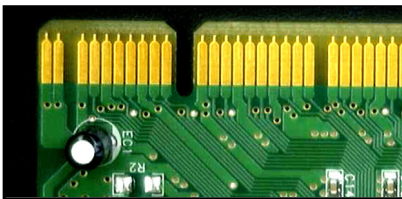
Boards shall be clean and damage-free, with sharply defined conductive patterns. Plating and solder mask shall be of uniform color and finish, holes properly located, markings sharply defined and aligned, and electrical / solder termination areas bright and shiny.



**GENERAL REQUIREMENTS**

The printed wiring board is clean and damage-free, with sharply defined conductive patterns. Plated-through holes (PTH) and vias are properly located, are clean and unfilled, and exhibit smooth and uniform plating. Electrical termination areas are bright and shiny. Solder mask exhibits proper registration.

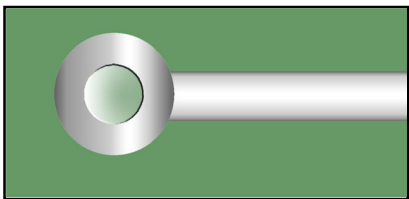
[Best Workmanship Practice](#)



**PREFERRED  
GOLD / PRECIOUS METAL CONTACTS**

Contact surfaces are clean and bright, with a uniform and smooth finish.

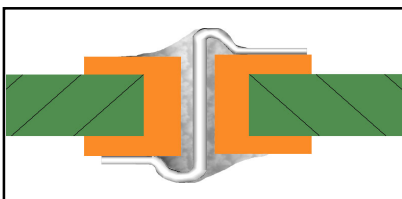
[Best Workmanship Practice](#)



**PREFERRED  
HOLE LOCATION / REGISTRATION**

Holes (supported / un-supported) shall be centered in the lands and located per engineering documentation. Annular ring shall be concentric to the pad.

[Best Workmanship Practice](#)




**PREFERRED  
INTERFACIAL CONNECTIONS (VIAS)  
DOUBLE-SIDED PWBs**

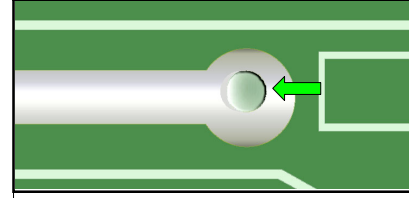
VIAs in double-sided PWBs require the use of filler wire (Z-wire) for support if the PWB coupon has not been evaluated by construction analysis (micro-section).

[NASA-STD-8739.3 \[ 11.2.4.a \]](#)

**NASA WORKMANSHIP STANDARDS**

	<b>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION</b>	Released: 04.05.2002	Revision:	Revision Date:
	<b>JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</b>	Book: 5	Section: 5.01	Page: 1

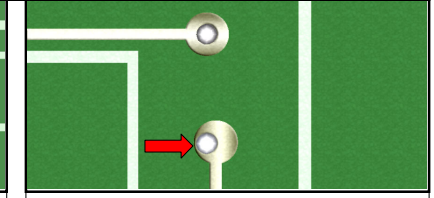
**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)**



**ACCEPTABLE  
ANNULAR RING**

The hole is not centered in the land, however it is acceptable providing the minimum annular ring requirement is not violated.

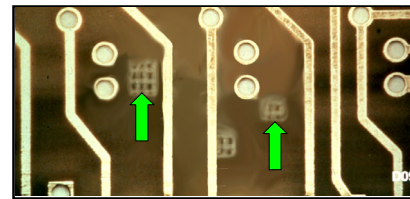
[Best Workmanship Practice](#)



**UNACCEPTABLE  
INSUFFICIENT ANNULAR RING**

The lower hole is improperly located, causing the annular ring dimension to be less than minimum requirements.

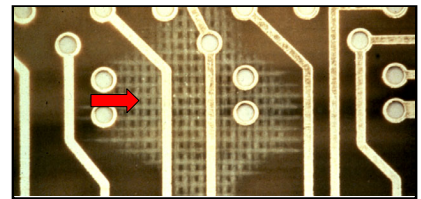
[Best Workmanship Practice](#)



**ACCEPTABLE  
CRAZING**

Crazing (whitish, discrete spots or crosses below the laminate surface) which does not bridge uncommon conductors is acceptable.

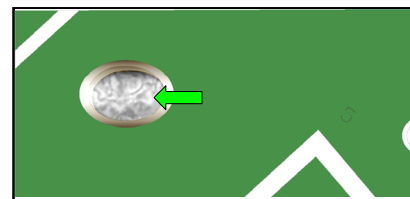
[NASA-STD-8739.2 \[ 12.8.2.c.3 \]](#)



**UNACCEPTABLE  
CRAZING**

Crazing which bridges uncommon conductors is unacceptable.

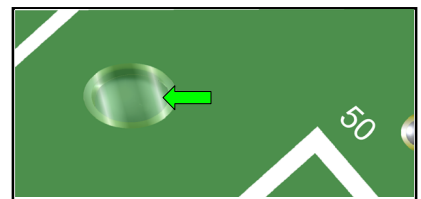
[NASA-STD-8739.2 \[ 12.8.2.c.3 \]](#)



**ACCEPTABLE  
EPOXY / SOLDER FILLED VIAS / PTH**

VIAs and plated-through holes, not intended for lead insertion, may be plugged by epoxy resin or solder, if documented on the engineering drawings.

[Best Workmanship Practice](#)




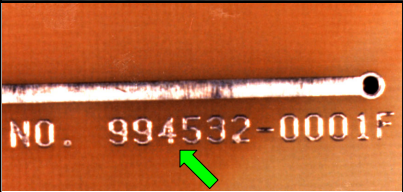
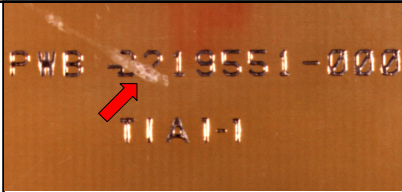
**ACCEPTABLE  
TENTED VIAS / PTH**

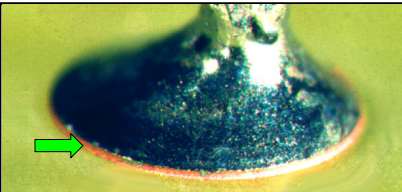
VIAs and plated-through holes not intended for lead insertion may be tented by solder mask, if documented on the engineering documentation.

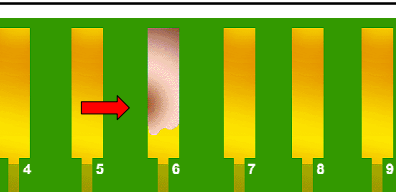
[Best Workmanship Practice](#)

**NASA WORKMANSHIP STANDARDS**

	<b>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION</b>	Released: 04.05.2002	Revision:	Revision Date:
	<b>JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</b>	Book: 5	Section: 5.01	Page: 3


PRINTED WIRING BOARD (PWB) GENERAL REQUIREMENTS (cont.)	
	
<p><b>ACCEPTABLE ETCHED LEGENDS / MARKINGS</b></p> <p>Legends / markings may exhibit slightly irregular definition, broken letters / lines, size or density, provided they are legible and/or their intent is clear.</p> <p><a href="#">Best Workmanship Practice</a></p>	<p><b>UNACCEPTABLE ETCHED MARKINGS / LEGENDS</b></p> <p>Poor definition, improper alignment / polarity, missing characters, smudged, smeared, multiple-imaged, touch or cross over solderable surfaces, exposed copper, delamination, violate electrical spacing requirements.</p> <p><a href="#">Best Workmanship Practice</a></p>

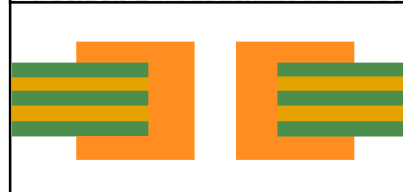
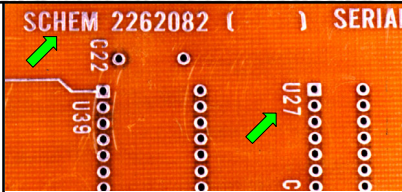

<p><b>ACCEPTABLE EXPOSED BASE METAL</b></p> <p>Exposed base metal on the vertical edge of printed wiring conductors, lands, and pads is acceptable.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.5 ]</a> <a href="#">NASA-STD-8739.3 [ 13.6.2.c.5 ]</a></p>

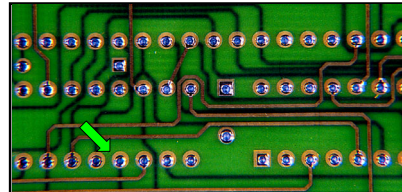

<p><b>UNACCEPTABLE EXPOSED BASE METAL</b></p> <p>Defects or damage (cuts, nicks, gouges, scrapes, etc.) that result in exposed base metal (except for the vertical edges of circuit traces, lands, and pads) shall be rejectable.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.5 ]</a> <a href="#">NASA-STD-8739.3 [ 13.6.2.c.5 ]</a></p>

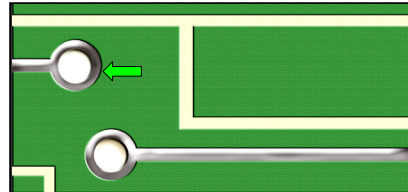

<p><b>ACCEPTABLE LABELS</b></p> <p>Labels shall exhibit a flat, smooth profile, legible graphics, proper placement, and adhesion. Labels shall be non-conductive, and shall not be placed over components, exposed circuit traces, vias, or solder terminations.</p> <p><a href="#">Best Workmanship Practice</a></p>

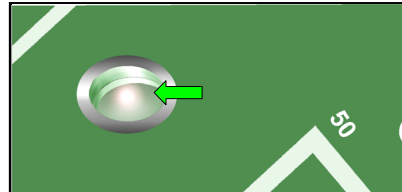

<p><b>UNACCEPTABLE LABELS</b></p> <p>Labels which exhibit damage, improper placement, improper adhesion, are conductive, and/or are placed over components, exposed circuit traces, vias, or solder terminations etc. shall be rejectable.</p> <p><a href="#">Best Workmanship Practice</a></p>

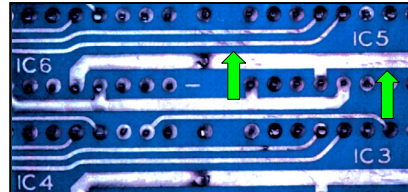
NASA WORKMANSHIP STANDARDS			
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Released: 04.05.2002	Revision: Revision Date:
	JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058	Book: 5	Section: 5.01 Page: 4


PRINTED WIRING BOARD (PWB) GENERAL REQUIREMENTS (cont.)	
	
<p><b>PREFERRED INTERFACIAL CONNECTIONS (VIAS) MULTI-LAYER PWBs</b></p> <p>Vias in multi-layer PWBs do not require the use of filler wire (Z-wire), nor shall they be solder-filled. No dedicated effort shall be made to remove solder in unused holes.</p> <p><a href="#">NASA-STD-8739.3 [ 11.2.4.b ]</a></p>	<p><b>PREFERRED ETCHED LEGENDS / MARKINGS</b></p> <p>Legends / markings are sharply defined, of uniform size and density, correct alignment and polarity, and meet minimum electrical spacing requirements. Markings do not touch or cross over solderable surfaces.</p> <p><a href="#">Best Workmanship Practice</a></p>


<p><b>PREFERRED SOLDER MASK / RESIST COATING</b></p> <p>Coating is uniform in color and finish. Registration is correct. No blisters, scratches, voids, waves, ripples, wrinkling, bubbles, haziness, tackiness, or entrapped particles.</p> <p><a href="#">Best Workmanship Practice</a></p>

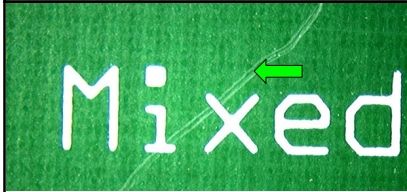

<p><b>PREFERRED SUPPORTED HOLES</b></p> <p>Supported / plated-through holes (PTH) designated for lead insertion exhibit a smooth / even bore and plating, proper diameter, are free of resist, and have symmetrical annular rings.</p> <p><a href="#">Best Workmanship Practice</a></p>


<p><b>PREFERRED UNSUPPORTED HOLES</b></p> <p>Unsupported / non-plated-through holes (NPTH) exhibit smooth / even walls, proper diameter, are free of plating, and have symmetrical annular rings.</p> <p><a href="#">Best Workmanship Practice</a></p>


<p><b>ACCEPTABLE DISCOLORED CONDUCTORS</b></p> <p>Slight dulling of clean metallic surfaces is acceptable, provided the surface conductivity or solderability is not affected.</p> <p><a href="#">Best Workmanship Practice</a></p>

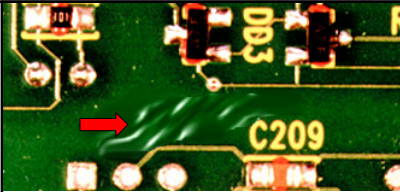
NASA WORKMANSHIP STANDARDS			
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Released: 04.05.2002	Revision: Revision Date:
	JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058	Book: 5	Section: 5.01 Page: 2

**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)**



**ACCEPTABLE  
LAMINATE SCRATCHES**

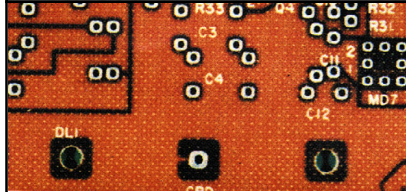
Scratches, scrapes, gouges, nicks, and / or cuts to the laminate that do not expose glass fiber or reduce electrical spacing are acceptable.  
[NASA-STD-8739.2 \[ 8.7.4.c \]](#), [ 12.8.2.c.6 ]



**UNACCEPTABLE  
LAMINATE SCRATCHES**

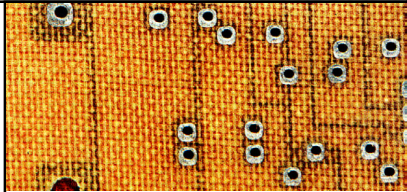
Scratches that expose glass fiber are an indication of improper process control and/or handling.  
[NASA-STD-8739.2 \[ 8.7.4.c \]](#), [ 12.8.2.c.6 ]

**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)**



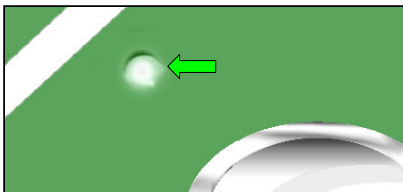
**ACCEPTABLE  
WEAVE TEXTURE**

Weave texture is a visual condition in which a weave pattern is apparent, but where the glass cloth is completely covered by resin and not exposed.  
[Best Workmanship Practice](#)



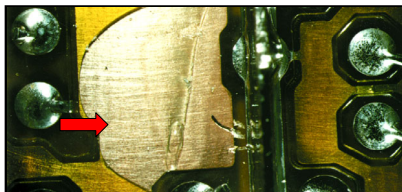
**UNACCEPTABLE  
EXPOSED WEAVE**

Weave exposure reduces the dielectric properties between conductive patterns to less than the minimum electrical clearance.  
[NASA-STD-8739.2 \[ 12.8.2.c.3 \]](#)



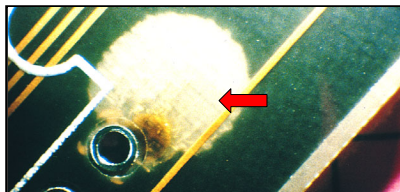
**ACCEPTABLE  
LAMINATE VOIDS**

Laminate voids located a minimum of 0.003 inch (0.080 mm) from the periphery of a plated-through hole, and sized less than 0.003 inch (0.080 mm) in any dimension, are allowable.  
[Best Workmanship Practice](#)



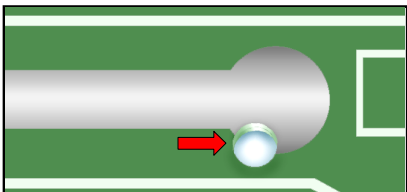
**UNACCEPTABLE  
LAMINATE VOIDS**

Laminate voids located less than 0.003 inch (0.080 mm) from the periphery of a plated-through hole, and sized greater than 0.003 inch (0.080 mm) in any dimension, are not allowed.  
[Best Workmanship Practice](#)



**UNACCEPTABLE  
BLISTERS**

Blistering between any of the laminate layers, or between the laminate and the metallization, is not allowed.  
[NASA-STD-8739.2 \[ 12.8.2.c.10 \]](#)  
[NASA-STD-8739.3 \[ 13.6.2.c.10 \]](#)



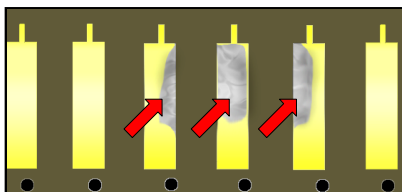
**UNACCEPTABLE  
BREAK-OUT**

Break-out of the annular ring is caused by misregistration during the drilling process.  
[Best Workmanship Practice](#)



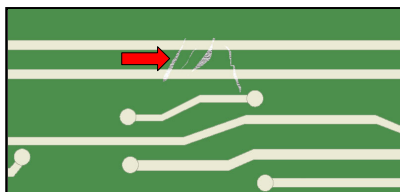
**ACCEPTABLE  
PLATING**

Plating is uniform and smooth. Luster may vary from bright to slightly dull. Minor scratches, scuffing, and solder on non-contact areas of fingers are allowable.  
[Best Workmanship Practice](#)



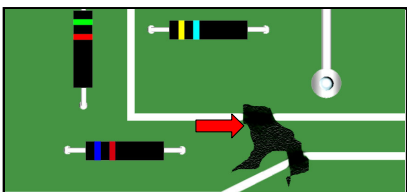
**UNACCEPTABLE  
IRREGULAR PLATING**

Irregular or skipped plating is an indicator of improper process control, and/or contamination.  
[Best Workmanship Practice](#)



**UNACCEPTABLE  
BRIDGING**


Bridging of conductive surfaces is an indication of improper process control.  
[NASA-STD-8739.2 \[ 12.8.2.c.4 \]](#)  
[NASA-STD-8739.3 \[ 13.6.2.c.4 \]](#)




**UNACCEPTABLE  
CONTAMINATION**

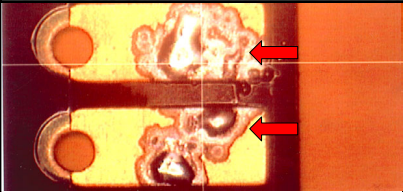
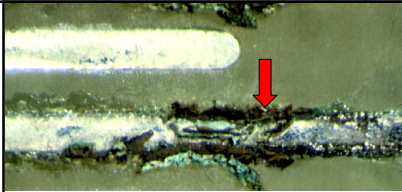
Contamination is a reliability concern.  
[NASA-STD-8739.2 \[ 12.8.2.b.9 \]](#)

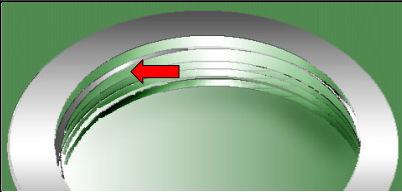
**NASA WORKMANSHIP STANDARDS**

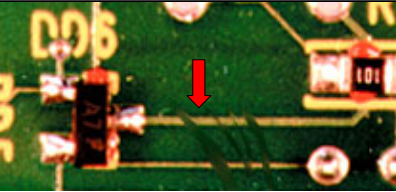
	<b>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION</b>	Released: 04.05.2002	Revision:	Revision Date:
	<b>JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</b>	Book: 5	Section: 5.01	Page: 5

**NASA WORKMANSHIP STANDARDS**

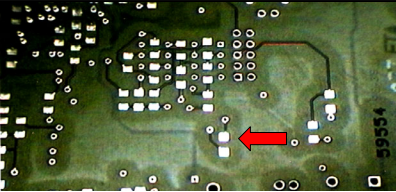
	<b>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION</b>	Released: 04.05.2002	Revision:	Revision Date:
	<b>JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</b>	Book: 5	Section: 5.01	Page: 7


PRINTED WIRING BOARD (PWB) GENERAL REQUIREMENTS (cont.)	
	
<p><b>UNACCEPTABLE CONTAMINATED PLATING</b></p> <p>Plating is not uniform, smooth, bright, and/or shiny. Solder or other contamination on the contact area shall be cause for rejection.</p> <p><a href="#">Best Workmanship Practice</a></p>	<p><b>UNACCEPTABLE CORROSION</b></p> <p>Corrosion is a reliability concern.</p> <p><a href="#">NASA-STD-8739.2 [ 7.4.1.d ]</a></p>

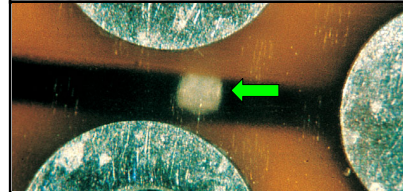
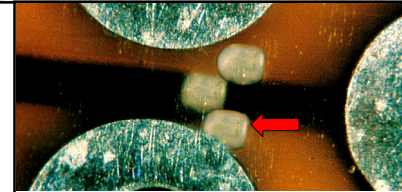

<p><b>UNACCEPTABLE CRACKED / RINGED BARREL</b></p> <p>Cracks or ringing in the barrel are cause for rejection.</p> <p><a href="#">Best Workmanship Practice</a></p>

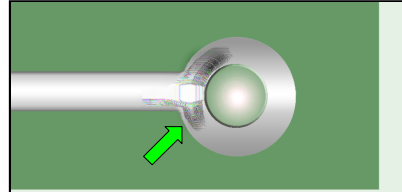

<p><b>UNACCEPTABLE CUT / DAMAGED PATTERN</b></p> <p>Repaired or damaged printed wiring conductor pattern shall be cause for rejection.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.9 ]</a> <a href="#">NASA-STD-8739.3 [13.6.2.c.9 ]</a></p>

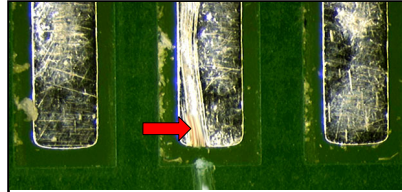

<p><b>UNACCEPTABLE DEMETALLIZATION / LEACHING</b></p> <p>Boards exhibiting leaching or loss of metallization shall be rejected.</p> <p><a href="#">Best Workmanship Practice</a></p>

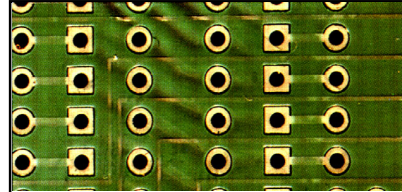

<p><b>UNACCEPTABLE DISCOLORATION</b></p> <p>Contamination or improper drying typically causes discoloration of the laminate or solder mask in the patterns depicted. Re-cleaning / demoisturizing may correct this problem, provided no other damage is apparent.</p> <p><a href="#">Best Workmanship Practice</a></p>

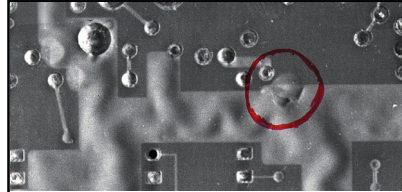
NASA WORKMANSHIP STANDARDS			
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Released: 04.05.2002	Revision:      Revision Date:
	JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058	Book: 5	Section: 5.01      Page: 8


PRINTED WIRING BOARD (PWB) GENERAL REQUIREMENTS (cont.)	
	
<p><b>ACCEPTABLE MEASLING</b></p> <p>Measling (whitish, discrete spots or crosses) below the laminate surface that do not bridge uncommon conductors is acceptable.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.3 ]</a></p>	<p><b>UNACCEPTABLE MEASLING</b></p> <p>Measling (whitish, discrete spots or crosses) which bridges uncommon conductors is unacceptable.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.3 ]</a></p>


<p><b>ACCEPTABLE SMOOTH TOOL IMPRESSION MARKS</b></p> <p>Scratches, scrapes, gouges, nicks, and / or cuts to the printed wiring pattern that do not expose base metal or reduce cross-sectional area are acceptable.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.5 ]</a></p>


<p><b>UNACCEPTABLE SCRATCHES (PRINTED WIRING)</b></p> <p>Scratches that expose base metal are an indication of improper process control and/or handling.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.5 ]</a></p>


<p><b>ACCEPTABLE SOLDER MASK</b></p> <p>Minor waves, ripples, or wrinkling which do not reduce the coating below minimum thickness requirements. Isolated bubbles or voids, which do not bridge conductive patterns or reduce electrical spacing requirements.</p> <p><a href="#">Best Workmanship Practice</a></p>


<p><b>UNACCEPTABLE SOLDER MASK DEFECTS</b></p> <p>Solder mask tackiness, cracking, flaking, or separation from the substrate or conductors.</p> <p><a href="#">NASA-STD-8739.2 [ 12.8.2.c.8 ]</a> <a href="#">NASA-STD-8739.3 [ 13.6.2.c.8 ]</a></p>

NASA WORKMANSHIP STANDARDS			
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Released: 04.05.2002	Revision:      Revision Date:
	JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058	Book: 5	Section: 5.01      Page: 6

**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)**

<p style="text-align: center;"><b>UNACCEPTABLE EDGE DELAMINATION</b></p> <p>Edge delamination is an indicator of improper tooling, process control, or handling. <a href="#">NASA-STD-8739.2 [ 12.8.2.c.7 ]</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE EDGE PROJECTIONS</b></p> <p>Edge projections that reduce electrical separation below minimum requirements are rejectable. <a href="#">Best Workmanship Practice</a></p>

**PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)**

<p style="text-align: center;"><b>UNACCEPTABLE REDUCED CROSS-SECTIONAL AREA</b></p> <p>Conductors that exhibit reductions in cross-sectional area are incapable of carrying the designed current load, and are susceptible to reduced reliability. <a href="#">Best Workmanship Practice</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE REPAIRED CONDUCTOR PATTERN</b></p> <p>Repairs to damaged printed wiring conductor pattern shall only be made after authorization, and by approved process. <a href="#">NASA-STD-8739.2 [ 12.8.2.c.9 ]</a> <a href="#">NASA-STD-8739.3 [13.6.2.c.9 ]</a></p>


<p style="text-align: center;"><b>UNACCEPTABLE EXCESSIVE BOW / TWIST</b></p> <p>Excessive bow or twist may inhibit proper mounting and may result in mechanical interference or shorting to adjacent assemblies or chassis. <a href="#">Best Workmanship Practice</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE EXPOSED / PROTRUDING GLASS FIBERS</b></p> <p>Exposed glass fiber in the laminate indicates a process control problem and is a long-term reliability concern. <a href="#">NASA-STD-8739.2 [ 12.8.2.c.6 ]</a></p>

<p style="text-align: center;"><b>UNACCEPTABLE ROUGH / UNEVEN EDGES (LAMINATE)</b></p> <p>Edges which are rough or uneven present a handling, or sharp edge / protrusion hazard. Additionally, the presence of a rough or uneven edge may increase the potential for delamination of multi-layer boards. <a href="#">Best Workmanship Practice</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE SOLDER MASK MISREGISTRATION</b></p> <p>Solder mask misregistration violating minimum annular ring requirements. Presence of mask material in plated-through holes designated to be soldered. <a href="#">Best Workmanship Practices</a></p>


<p style="text-align: center;"><b>UNACCEPTABLE HALO EFFECT</b></p> <p>A lightened area around a hole or via, typically induced by mechanical stress. Haloing which bridges uncommon conductors is unacceptable. <a href="#">NASA-STD-8739.2 [ 12.8.2.c.3 ]</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE IMPROPER HOLE LOCATION</b></p> <p>The improper location of holes (i.e.: component lead, via, mounting, etc.) is caused by misregistration during the drilling process. <a href="#">Best Workmanship Practice</a></p>

<p style="text-align: center;"><b>UNACCEPTABLE SOLDER SPLATTER / WEBBING</b></p> <p>Solder splatter and webbing is typically caused by moisture contamination or improper laminate bake-out, and is a reliability and short-circuit concern. <a href="#">NASA-STD-8739.2 [ 12.8.2.c.4 ]</a></p>	<p style="text-align: center;"><b>UNACCEPTABLE UNDER-ETCH</b></p> <p>Under-etch is an indicator of improper process control / improper chemistry during etching. Under-etch can result in bridging between traces, resulting in short circuits. <a href="#">Best Workmanship Practice</a></p>

**NASA WORKMANSHIP STANDARDS**

 <p>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</p>	Released: 04.05.2002	Revision:	Revision Date:
	Book: 5	Section: 5.01	Page: 9

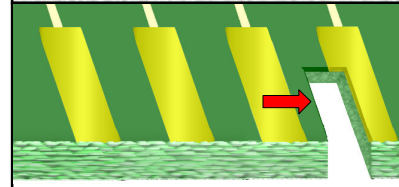
**NASA WORKMANSHIP STANDARDS**

 <p>NATIONAL AERONAUTICS AND SPACE ADMINISTRATION JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77058</p>	Released: 04.05.2002	Revision:	Revision Date:
	Book: 5	Section: 5.01	Page: 11

PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)

THIS PAGE IS  
INTENTIONALLY BLANK.

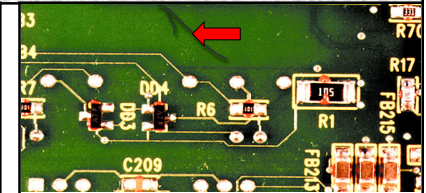
PRINTED WIRING BOARD (PWB)  
GENERAL REQUIREMENTS (cont.)



**UNACCEPTABLE  
IMPROPER PUNCH-OUT / NOTCH / ROUTING**

The improper location of punch-out, notching, or routing is caused by misregistration or improper process control.

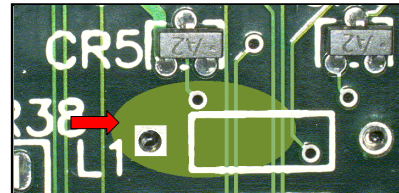
[Best Workmanship Practice](#)



**UNACCEPTABLE  
LAMINATE CRACKS**

Cracks in the laminate are cause for rejection.

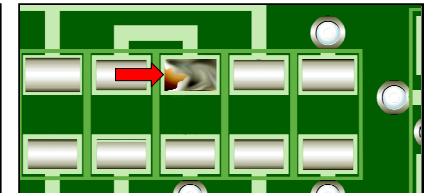
[NASA-STD-8739.2 \[ 12.8.2.c.6 \]](#)



**UNACCEPTABLE  
LAYER DELAMINATION**

Delamination between any of the laminate layers, or between the laminate and the metallization, is not allowed.

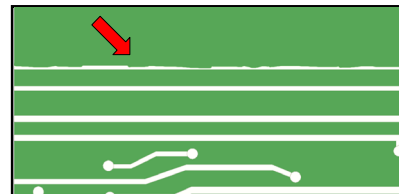
[NASA-STD-8739.2 \[ 12.8.2.c.7 \]](#)



**UNACCEPTABLE  
NON-WETTING**

Tin, tin/lead reflowed or solder coated surfaces, exhibiting non-wetting on any conductive surface where a solder connection will be required shall be rejected.

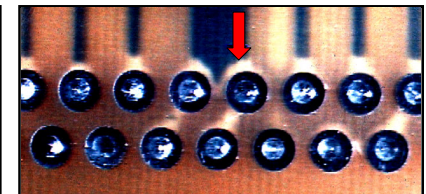
[Best Workmanship Practice](#)



**UNACCEPTABLE  
OVER-ETCH**

Conductors that are over-etched are incapable of carrying the designed current load, and are susceptible to reduced reliability.

[Best Workmanship Practice](#)



**UNACCEPTABLE  
PINK RING**

Pink ring is caused by a thinning of the oxide coating on the copper layer in the through-hole / inner-layer interface zone, and is considered an indicator of a process control problem.

[Best Workmanship Practice](#)

**NASA WORKMANSHIP STANDARDS**



NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION  
  
JOHNSON SPACE CENTER  
HOUSTON, TEXAS USA 77058

Released: 04.05.2002	Revision: 5.01	Revision Date:
Book: 5	Section: 5.01	Page: 12

**NASA WORKMANSHIP STANDARDS**



NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION  
  
JOHNSON SPACE CENTER  
HOUSTON, TEXAS USA 77058

Released: 04.05.2002	Revision: 5.5	Revision Date:
Book: 5	Section: 5.5	Page: 10