From The Lab

By Bob Neves

Do You Have Your Decoder Ring?

I recently had a customer call me and ask for an explanation of the MIL-S-13949 Material Designation system. You know, those three-letter acronyms (TLAs) followed by numbers and letters which are supposed to "accurately and thoroughly" describe laminate and prepreg. I decided to put my secret "MIL SPEC" decoder ring on, in an attempt to decipher the Code. Don't tell anybody, or the NSA might come looking for me.

The laminate material code found in MIL-S-13949 is broken up into six groups of letter/number descriptions: 1) Base material, 2) Base material thickness, 3) Type and weight of metallic foil, 4) Grade of pits and dents, 5) Class of thickness tolerance, and 6) Class of bow and twist. Prepreg material rates even higher than laminate, weighing in with an astounding eight description groups. They cheated a little as the first three prepreg groups are the same as the first laminate group except that the letter *P* precedes the group to let you know that the designation is for *P*repreg and not laminate. Typically/fortunately, we seldom see more than the first part of the designator on a specification or print. Unfortunately, this part of the full designator is the one that causes the most confusion. To prevent me from boring you to tears, I am only going to focus this column on the first designation group which consists of three letters (prepreg adds a *P* in front). Groups 2–6 are reasonably self explanatory, and do not present much confusion, so if you really want to know the "full" code you will have to pull out that dusty specification of yours and use your own decoder ring. For those of you that are itching to follow along (ha), I have included the appropriate text directly from MIL-S-13949 for your reading enjoyment.

MIL-S-13949

1.2.1.1.1 Base material. The base material is identified by three letters. The first letter shall represent the reinforcement material (see 1.2.1.1.1.1), the second the resin system (see 1.2.1.1.1.2) and the third letter representing special consideration (see 1.2.1.1.1.3). If the third letter is not *N* or *P*, then the second and third letter must represent the same resin system (see 1.2.1.1.1.3). Unless otherwise specified (see 6.2), all base materials shall be the natural color of the resin system.

1.2.1.1.1.1 Reinforcement material. The reinforcement material shall be identified as follows:

A—Aramid, woven.
B—Aramid, non-woven.
G—E-glass, woven.
N—E-glass, non-woven.
C—Polyester, non-woven.
Q—Quartz, woven.

1.2.1.1.1.2 Resin system. Unless otherwise specified, the resin system shall be identified as follows:

E—Epoxy, non-flame retardant.
B—Epoxy, non-flame resistant, hot strength retention.
C—Cyanate ester, flame resistant.
F and M—Epoxy, flame resistant.
I—Polyimide, high temperature.
H—Epoxy, flame resistant, hot strength retention.
P and T—Polytetraflouroethylene, flame resistant.
R, X, and Y—Polytetraflouroethylene, flame resistant, for microwave applications.

1.2.1.1.1.3 Special consideration. Unless otherwise specified, the special consideration shall be as follows:

N—For natural color of resin system.
P—For coloring agent or opacifier added to resin system.
K—For natural color of resin system *F* with a glass transition temperature between 110°C and 150°C and which is formulated entirely of epoxy resin(s) unmodified for general purpose or modified for chemical resistance.
L—For natural color of resin system *I* with a glass transition temperature greater than 250°C.
M—For coloring agent or opacifier added to resin system *F* with a glass transition temperature between 110°C and 150°C and which is formulated entirely of epoxy resin(s) unmodified for general purpose or modified for chemical resistance.
G—For natural color of resin system *F* with a glass transition temperature between 150°C and 200°C and which is formulated entirely of epoxy resin(s)

Bob Neves has spent the last ten years as the director of technical services for Microtek Laboratories, an independent test facility. Prior to his tenure at Microtek, Bob worked in quality management and engineering in PWB manufacturing. He currently serves as the IPC's Rigid Board General Committee chairman, Rigid Board Test Method Task Group chairman, Laboratory Qualifications (IPC-QL-653) Committee chairman, member of DESC's Tiger Team for MIL-P-RRRRR (MIL-PRF-31032), member of Blue Ribbon Committee for MIL-S-XXXXX (MIL-PRF-5X) and convenor of IEC TC52 Working Group 10 Printed Wiring Test Methods. You can reach him by e-mail at BobNeves@thetestlab.com or at the company web site: http://www.thetestlab.com.

either modified or unmodified for high temperature integrity and wide operational latitude.

T—For natural color of resin system *F* with a glass transition temperature between 170°C and 220°C and which is formulated of epoxy resin(s) blended with non-epoxy resin(s) for high temperature integrity and wide operational latitude.

J—For natural resin system *I* with a glass transition temperature between 200°C and 250°C and which is formulated of polyimide resin(s) unmodified, modified or blended with non-polyimide resin(s) for wide operational latitude.

As you can see (if you didn't read it, trust me), the first letter in Group 1 is the designator for the reinforcement material within the laminate/prepreg (again, I'm ignoring the *P* for prepreg). You have six reinforcement material choices here of which *G* (E-glass, woven) reinforcement is by far the most popular. Other interesting, up and coming (or old and resurfacing) reinforcement materials are aramid, quartz and polyester.

The second letter in Group 1 is the designator for the resin system in the laminate/prepreg. Here is where it starts to get interesting! Here you have choices between epoxy, polyimide, cyanate ester, and PTFE which is more commonly known as "T?fl?n" (The vowels have been removed for security purposes). You also have the choice of burning (for you pyros) or self-extinguishing resin systems. The reasonably clear cut appearance of this resin system designator is deceiving as these seemingly generic systems come in a plethora of blends and mixes which range widely in both material and processing characteristics.

To classify the differences in resin system properties/blends, the third letter in Group 1 (special consideration) was born. In the early days the only special consideration was given to material color (natural N or unnatural P). How many of you remember the red, blue and black material that used to be so popular? There still are a couple of people who make colorful laminates today, and I can tell you that these materials never (appear to) have problems with sub-surface defects. Yes, you can solve your measly problems with black laminate!

As time went on, and the laminate manufacturers began to tinker with their formulas, other special considerations were developed. The designators *N, K, M, G,* and *T* were an attempt to classify and categorize differences in epoxy-based resin systems, while the designators *N, J* and *L* were an attempt to classify the differences between polyimide-based resin systems. In composing these special consideration designators, the intent was to categorize the resin systems by specific combinations and properties. Unfortunately this special consideration system is not non-exclusive in its categorization. In fact, many of today's resin systems fall into two of the special designator categories. Below is a breakdown of the special considerations category for both epoxy- and polyimide-based resin systems.

Special Considerations For Epoxy

The *N* designator's only descriptor is "natural color". There is NO glass transition temperature (Tg) stipulation for this type of material, and just about every epoxy-based resin system material can fall into this category. This designator applies to both flame retardant and non-flame retardant epoxy resin systems.

The *K* designator applies to both pure and/or modified epoxy resin systems that are flame retardant, and are "natural" in color with a Tg between 110°C and 150°C.

The *M* designator has the same as the K designator (Tg between 110°C and 150°C) with the exception that an "unnatural" coloring agent or opacifier was added to resin system.

The *G* designator is for pure or modified epoxy resin systems. The system must be flame retardant F with natural color and a Tg between 150°C and 200°C.

The *T* designator is for flame retardant *F* resin systems formulated of epoxy resin(s) blended with non-epoxy resin(s) for "high temperature integrity and wide operational latitude" having a Tg between 170°C and 220°C.

Special Considerations for Polyimide

As with the epoxy systems above, the *N* designator again uses the catch all wording "natural color". There is NO Tg stipulation for this type of material, and just about every polyimide material falls into this category.

The *J* designator applies specifically to polyimide resin systems which have a Tg between 200°C and 250°C. This resin system can be pure or modified polyimide, a blend of polyimide resins, a blend between any polyimide resin(s) and "another" resin system. This is a catch all for all types of polyimide-based resin systems that fall within the referenced Tg range.

The *L* designator uses the wording "natural color" to describe the characteristics of the material. The other stipulation for this *L* type is that the Tg of the resin system is greater than 250°C.

The unfortunate part about all this duplicity is the affect it has on the PWB manufacturer.

What Does It All Mean To You?

Wake up and shake that comatose look out of your eyes. I'm just getting to the interesting part! Now that the message has been decoded, let me give you some examples of situations where a material(s) can fit into more than one designation.

Epoxy Materials

A blend of three slightly different flame retardant, natural colored epoxy resin systems with a Tg of 140°C would fit into both the *GFN* and *GFK* designations. A blend of flame retardant epoxy and non-epoxy resin systems with a Tg of 180°C would fit into both the *GFN* and *GFT* designators.

Polyimide Materials

A blend of two polyimide and epoxy resins with a Tg of 210°C would fit both into the *GIJ* and *GIN* categories. A single pure polyimide with a Tg of 260°C would fit into both the *GIL* and *GIN* categories.

The unfortunate part about all this duplicity is the affect it has on the PWB manufacturer. Each of these different formulations have different processing characteristics; unfortunately, the material buyer is not assured of what he is getting by this designation system. When you order a *GFN* material, you could get a pure epoxy with a Tg of 130°C or a blend of epoxy and non-epoxy systems with a Tg of 210°C. When ordering *GIN* material, you could get a resin system with a 180°C or 260°C Tg. When you order *GIJ* material, you could get a pure polyimide, a modified polyimide, or an polyimide/??? mix of resins. The scenario where "high grade" materials would be sold in the *N* special consideration category is unlikely—but possible.

To look on the bright side, most manufacturers only have a limited number of resin systems that they conjure up and have internal policies governing which resin systems they can ship as *GFN, GIN* or *GIJ* material. To avoid manufacturing and performance problems, I would suggest to any material buyer that he make himself aware of the "decoder ring" policies of his supplier so that satisfaction—and not surprise—is delivered to his back door.