

# SMT Adhesives

## Evaluating the Material's Critical Parameters

By Steven J. Beckman, Rick Labbe and Suzette Cowan of  
Lockheed Martin Commercial Electronics

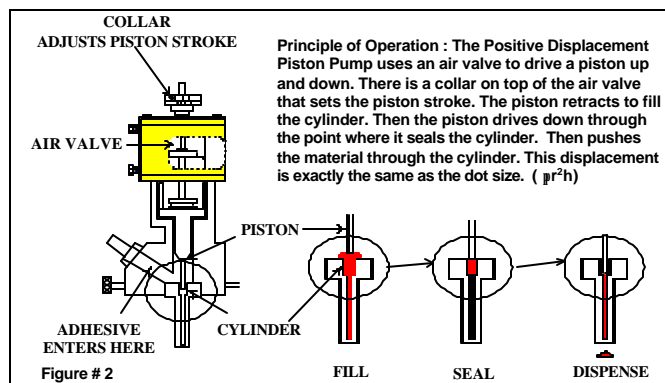
And

By Frank Murch, Doug Dixon and Steve Marongelli of  
Universal Instruments Corporation

The use of adhesives in the SMT process is often overlooked. Adhesives are largely viewed as a temporary process to hold components on the board until the solder joint is formed. The yield improvements that can be made in dispensing and through the correct selection of adhesives can be dramatic. When Lockheed identified adhesives and dispensing as a key area for process improvement the methods for evaluation and the critical parameters were largely undocumented and poorly understood. Lockheed evaluated the information and resources available in the industry and identified Universal Instrument's process abilities and laboratory as a key resource. Universal Instruments and Lockheed jointly studied the process as a whole and the effects of



various process and material parameters at Universal Instrument's facilities in New York and Lockheed's facility in New Hampshire. This report describes the test regimen we used to evaluate commercial adhesives and make selections from a basis of sound engineering principles. The two companies studied three broad categories of SMT epoxy performance: dispense capability, mechanical strength and environmental robustness. Each of these areas produced results that improved overall yield and process stability.



**DISPENSE CAPABILITY**

The trend within the industry is toward smaller components such as 0805s and 0603s. IPC Class 3 requires that adhesive material does not come into contact with the solder pad lands. To satisfy this requirement on 0805 and smaller sized chip components, tight control over dispensed dot diameter, by correlation volume, is a necessity. Undersize dots will not provide adequate tack or bond strength to mechanically secure the SMT parts, whereas oversize dots will lead to workmanship violations and, in the extreme, potential for reduced solder joint integrity. Lockheed uses Piston Positive Displacement Pump technology as the basis for adhesive dispense. Figure # 2 shows this pump’s concept of operation and Figure # 1 shows the actual head configuration with 4 pumps.

**Fineness of Grind**

Fillers in the adhesive systems are particles that can significantly affect the material’s ability to flow. If the fillers are large relative to the inside diameter of the nozzle tip (i.e. generally a minimum 1:7 ratio should be maintained) then the material will behave much more like an aggregate as opposed to a uniform mono-structural fluid. Particle size was examined using the fineness of grind block. This is a common method found in the materials industry, reference ASTM # D-1210. Figure # 3 clearly shows the relationship between particle size and the nozzle opening. The results, as displayed in graph # 1 indicates a wide variation among the candidate epoxies. The nozzle to produce the smallest nominal dots (e.g. 14 mil) has approximately an 7 mil inside diameter, epoxies with maximum particle size below 1 mil or 25 microns are preferred.

**Dot Diameter Variation**

Each candidate epoxy was dispensed onto a test board, after pump parameters were tuned, to deliver single 14, 18 and 30 mil nominal dots. Fifty dots of each size were measured by a vision-driven coordinate measuring machine; dot diameter mean and standard deviation, and Cpk were calculated. Graph # 2 represents typical results. Notable observations include the tendency for some adhesives to perform better at the small diameter as compared to the larger diameters, and others vice versa. Best epoxy results are interpreted as those that are centered on the nominal target dimension, and have relatively small variation over the range of target diameters.

**Shape Score - Speed Test**

After tuning each pump for optimum performance at delivering four nominal single dot diameters (i.e. 14 mils to 50 mils), a series of 5000 dots each were dispensed. These were visually inspected, and all occurrences of

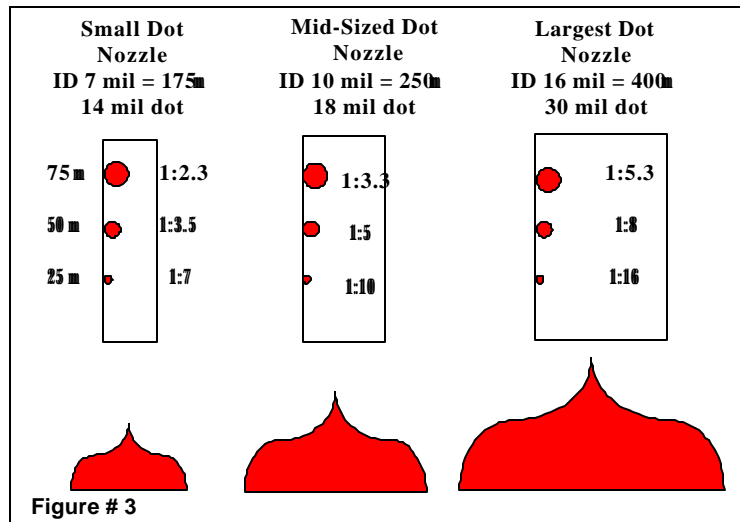
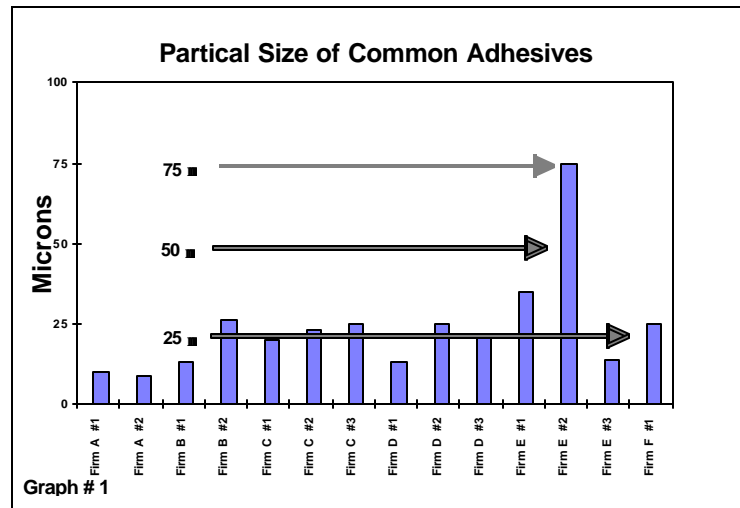


Figure # 3



Graph # 1

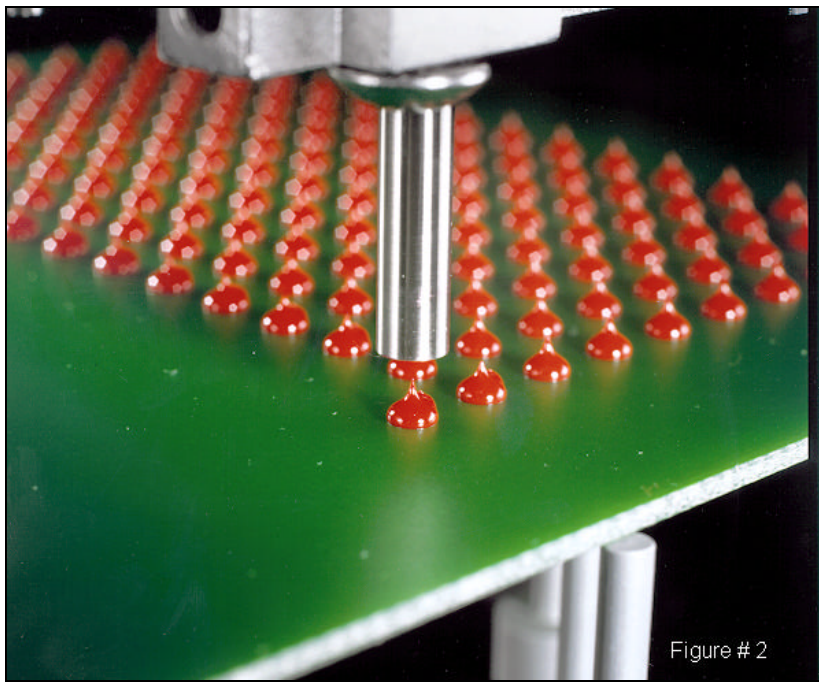
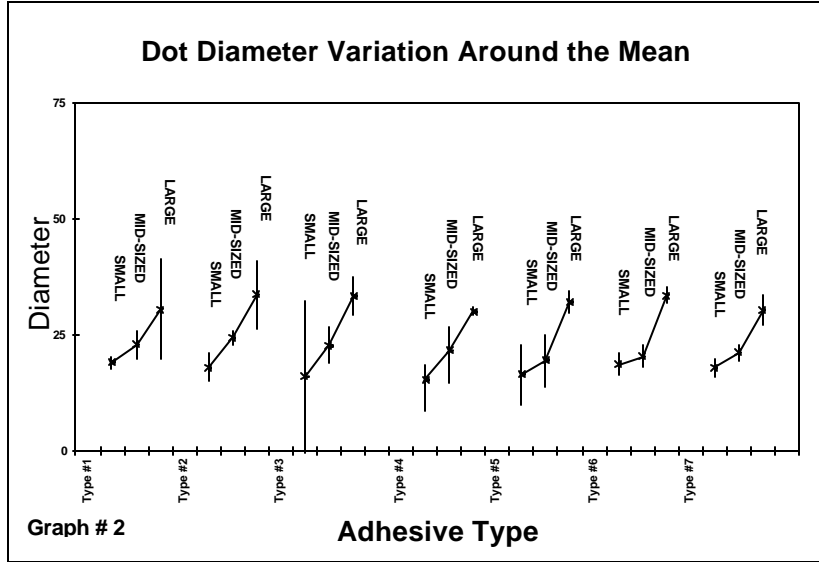
anomalous spreading, slumping, bleeding, skipping, and stringing were recorded. These deviations (i.e. from an ideal hemispherical deposition) were counted and plotted as “percentage defects” by glue dot size and epoxy type. The expose that exhibit lower overall total defects are clearly preferred.

**MECHANICAL HOLDING**

**Potential: Green and Cured Strength**

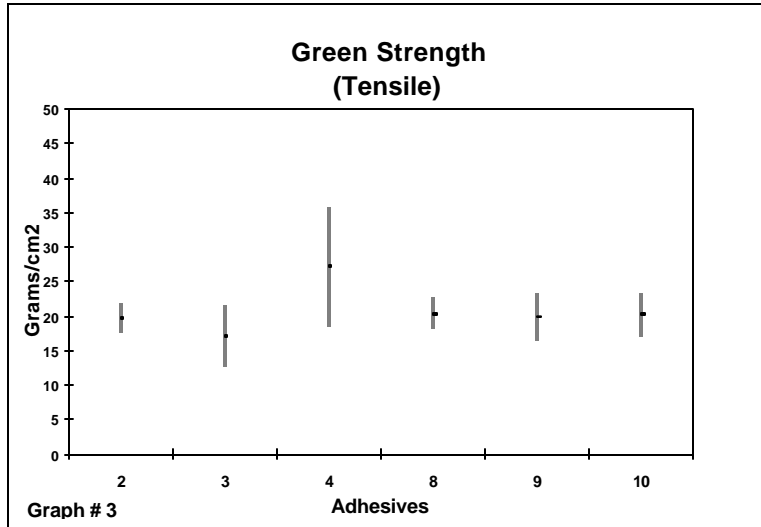
The primary functional role of an SMT adhesive is to mechanically hold the part to the PWB until soldering occurs. In an un-cured state, the adhesive must have sufficient tack to hold the placed parts in proper alignment while the board is accelerated and decelerated through the remainder of the placement cycle. Adhesive should be inherently stable in the ambient conditions of the manufacturing floor, e.g. epoxies should not lose tack if moderate delays occur between the Dispense and

Place or between the Place and Cure process steps -- these are inevitable. After curing, and before soldering, the adhesive must have adequate bond strength to secure the device through all subsequent material handling operations, e.g. PWBs are flipped, PTH parts are manually inserted, and spot mask applied in preparation for wave soldering. The epoxy bond must remain strong throughout its exposure to liquid flux, pre-heat temperatures, and chip plus laminar wave exposures.

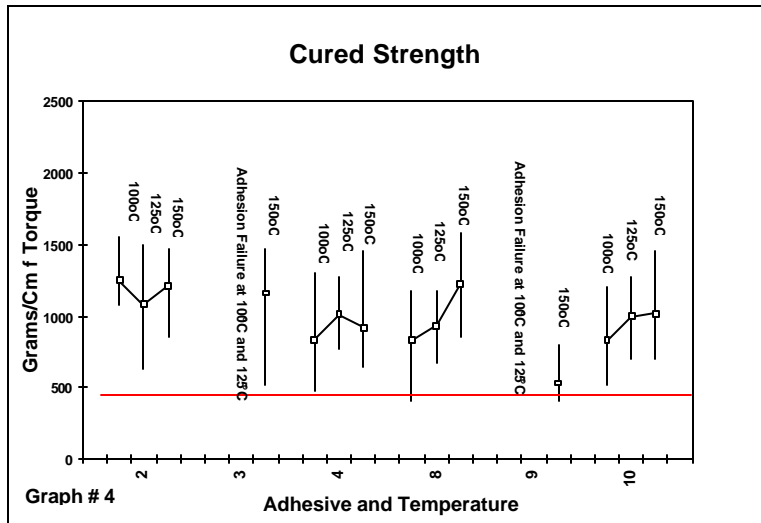


### Green Strength

Both tensile and shear green strength were evaluated; the first quantitatively, the second qualitatively. The test method for tensile green strength was: screen print a 40 mil diameter by 10 mil thick deposition of adhesive onto a test plate; orthogonally lower an extension rod into the un-cured adhesive; use a load cell apparatus to record load levels during controlled extension rod removal. Graph # 3 represents typical results. Adhesives with high tensile green strength and small variations about the mean are preferred.



Shear green strength was evaluated pragmatically by placing parts into corresponding 0603, 0805, 1206, and TANT D sized epoxy depositions and subjecting the material to the full force of high-speed chip-shooter table motion. This test enabled, for a consistent set of nominal dot diameters, a comparative study of the un-cured epoxies' ability to hold parts under shear loading.



### Cured Strength

Torque and lap shear testing were performed to measure the SMT adhesives' cured-state load bearing properties. Torque and shear loading are relevant as material handling imposed stresses will have constituent elements of both. In addition we wanted to assess the effect of profile of cured adhesion strength. Three profiles were developed: 1) 100°C for 10 minutes, 2) 125°C for 3.5 minutes and 3.) 150°C for 1.5 minutes dwell time. The results are shown in Graph # 4. As can be seen, various adhesives require a minimum temperature to have acceptable adhesion and others show differing amounts of adhesion with increased temperature. Knowing the characteristics of the adhesive can increase yields by allowing the optimum profile to be used. Graph # 4 shows adhesive #8 and 10 increase adhesion with increased temperature. Adhesives with high torque and lap shear strengths and small variations about the means are again preferred.

Interestingly, despite that fact that multiple PWB substrate material types were tested (i.e. multifunctional FR-4 with LPI solder mask, multifunctional FR-4 without solder mask, and tetrafunctional FR-4 without solder mask) there were no consistent significant differences among the board materials relative to cured strength.

## ENVIRONMENTAL ROBUSTNESS

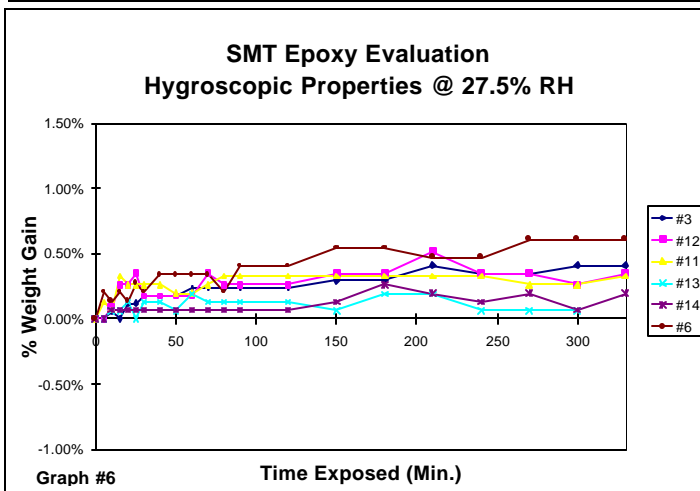
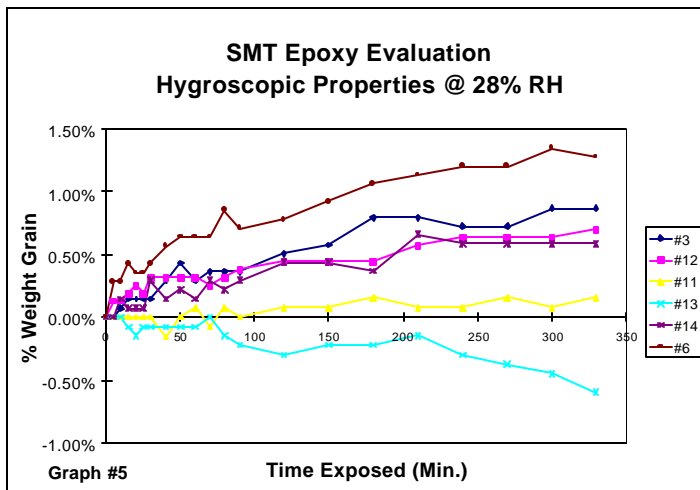
SMT adhesives must be robust in the face of normal manufacturing floor ambient conditions. Temperature is often controlled to +/- 5 F and humidity to +/- 15% RH. Certainly within these bounds, and preferably over significantly greater ranges, the epoxy dispense and mechanical strength properties should not vary. Depending on the operational policy, it may not be unusual for epoxy PWBs to sit up to one hour before having SMT parts placed: e.g. due to breaks, feeder-outs, meetings. During this interval, the epoxy should not absorb ambient moisture, release volatiles or skin over (i.e. partially cure). All of these factors will affect the epoxy's tendency to form solid, high-strength mechanical bond.

### Hygroscopic Properties

Hydroscopy is the tendency for a material to absorb moisture from the ambient environment. It should be noted three types of voids are possible: 1) A weight loss is an indication of a solvent loss. 2.) Voiding with no weight loss or gain is normally air entrapment

(although out gassing is also a possibility) and 3.) Hydroscopy, moisture absorption is the dominate problem and is seen as a weight gain. By accurately weighing samples of un-cured epoxy over time comparisons can be made. It is possible with this test to determine the relative tendencies to take-on moisture. For the purpose of developing a response surface, tests were run, all at room temperature (68F), in

three % RH ambient environments: 28, 50 and 80. 28% and 50% RH results are shown here. Graphs # 5 and # 6 depict the net weight gains (or loss) over time of several materials tested in 28% and 50% RH respectively. Noteworthy are dramatic hygroscopic tendencies among several of the epoxies -- absorbing relatively large amounts of moisture. This effect is most pronounced when comparing the 28% and 50% RH data concurrently



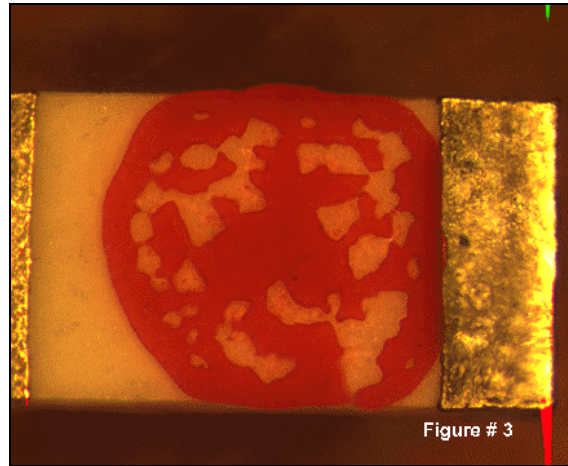
Preferred epoxies are those that show little or no weight gain or loss during these tests. These epoxies have the greatest process tolerances with respect to potential delays for Dispense to Place as well as Place to Cure process steps. Most concerning are the epoxies which show a tendency for large weight changes when exposed to various ambient conditions - even over time frames as short as 1 hour. The impact of absorbed moisture is the force of the next test. "Cured Appearance".

### Cured Appearance

For this test, each epoxy material was dispensed onto glass slides in a series of 14, 18 and 30 mil diameter dots. Thirty minutes elapsed between the Dispense and Place operation; another thirty minutes was allowed to elapse between the Place and Cure operations. Ambient temperature and humidity were controlled to 68 +/- F and 30 +/- 5% RH respectively.

After cure, each of the epoxy / dot-size groupings were inspected through the glass with the aid of a microscope. Figure # 3 represent gross voiding found in one sample. These results correlate well with the degree of absorption for the respective epoxies in the Hygroscopic testing described previously. Absorbed moisture is trapped in pockets within the bulk of the adhesive during cure.

Adhesives cure in different ways. Notably some cure from the outside in and “skin” holding the moisture in. Others cure at temperatures above 100°C and seem to be able to lose the moisture more gracefully and show remarkable low levels of voiding even with high levels of moisture absorption. No voiding is clearly preferred. Risk increases with degree of voiding. Voids directly effect adhesion and the distribution of adhesion values. Significant voiding represents a serious potential for flux and/or solder entrapment -- either of which can lead to yield and reliability problems.



### Conclusions

Dispensing is a poorly understood technology. It is the norm for users to accept the adhesive with no or minimal testing. Even manufacturer's of dispensing equipment often have a surprising lack of knowledge about the effects of the material in the process. As the demands for world class performance increase and the component size ( and density) increase this is increasingly becoming an area where improvements are being sought. There are three broad categories of SMT epoxy performance tested: dispense capability, mechanical strength and environmental robustness. Within each category, tests to evaluate the adhesive materials were described and typical results presented. A synopsis of the findings follows:

- 1) Epoxy dots dispense capabilities should be tested over the full range of application diameters/volumes.
- 2) Prior to full-scale implementations, a 5000 - 10,000 dot experiment can be used to assess a materials propensity to have undesirable dispense characteristics, e.g. spread, skip, slump, string.
- 3) Green and Cured strength tests verify the epoxy's ability to mechanically secure the part during and through the process until solder connections are formed.
- 4) Hygroscopic property test results (i.e. the rate of moisture absorption) correlate well to subsequent formation of voids in cured epoxy dots.

Through the use of good engineering practices and studies such as these, performance improvements can be realized. As the industry moves to smaller components such testing will become more common.

There are additional areas of interest specific to adhesives that have not been discussed: rheology, shelf life and machine life, extractable ionic and surface insulation resistance. In addition the effect of the dispensing pump technology, proper dot size selection and positional accuracy are key parameters as well. For further information the authors can be contacted at:

Lockheed Martin Commercial Electronics, care of Steven J. Beckman, Director, Operations Engineering, 603-885-2550 or [BECKMAN\\_SJ@pcsmtp.lcec.lockheed.com](mailto:BECKMAN_SJ@pcsmtp.lcec.lockheed.com)

Universal Instruments care of the GDM product team, 607-779-1134 or [murch@uic.com](mailto:murch@uic.com)

