# empfasis

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The EMPF is a U.S. Navy-sponsored National Center of Excellence focused on the development, application and transfer of new electronics manufacturing technology by partnering with industry, academia and government centers and laboratories in the U.S.


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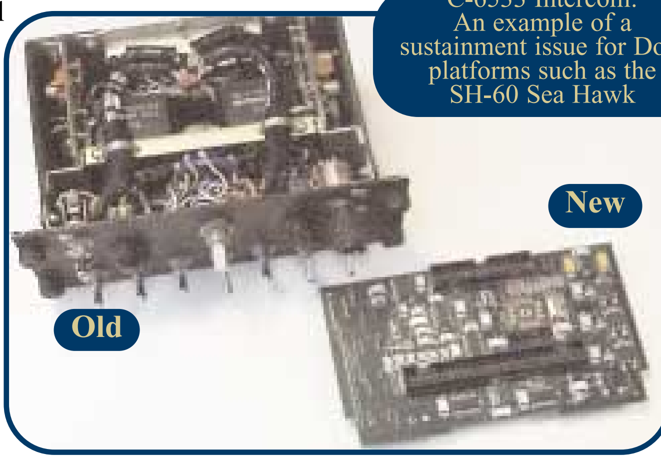
## Sustainment Strategies for Military Electronics

Aging military electronic systems found in avionics, land, and weapon system platforms are in constant need of upgrade and maintenance. Factors affecting sustainment of such systems include declining defense funding, escalating Operations and Support (O&S) costs, and the expansion of platform life cycles. Weapon systems that continue beyond their projected lifetime are at greatest risk with respect to component level obsolescence and diminished manufacturing source issues.

Solutions to sustainment challenges can employ several strategies that can offset O&S costs and support increased life cycles. The lack of military grade electronic component parts can be compensated with the use of commercially available parts. These commercial off the shelf (COTS) components are currently being tested and refined to determine their suitability for military use. Factors that should be considered prior to the insertion of COTS components include both environmental and material compatibility characteristics. Component reliability considerations related to operating environments such as temperature, humidity, and vibration, as well as material compatibility characteristics such as coefficient of thermal expansion, assembly processing chemistries, and post assembly coatings should all be considered. In cases where data for reliability does not exist, it may be necessary to perform studies that replicate the operational environment. Additionally, it should be noted that since many COTS components are not available in legacy package equivalents, it might be necessary to perform a more extensive redesign to accommodate newer package styles.

Since not all COTS components are specifically tailored to military requirements, it may be necessary to evaluate functional equivalency and determine if any design compensation is required. Such compensation could necessitate additional circuitry or firmware. If design compensation is considered prohibitive, services are available to design and manufacture exact reproductions of current obsolete parts in identical packages. These services are typically costly and may not meet cost objectives in limited quantities but can provide a solution without extensive redesigns.




C-6533 Intercom: An example of a sustainment issue for DoD platforms such as the SH-60 Sea Hawk

In most cases, comprehensive redesigns are warranted to offset current O&S cost projections. When possible, it is preferred to maintain all form, fit, and functional characteristics in order to meet performance expectations, minimize integration costs, and gain user acceptance. The redesign methodology may employ integration

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# Failure Analysis of Electronics

The phone rings at your desk, on the other end is a frantic customer. One of the assemblies you have been shipping for six months has suddenly started failing in the field. After doing a little research you discover that:

1. The assemblies that fail cross several date codes of bare boards.
2. All the process control indications on the production line were well within specifications.
3. The assemblies did not see any unusual conditions in the field.

While tracking this information, you start to perform a failure analysis of the assembly, which, at this point in time, is the only way to discover (and fix) the problem.

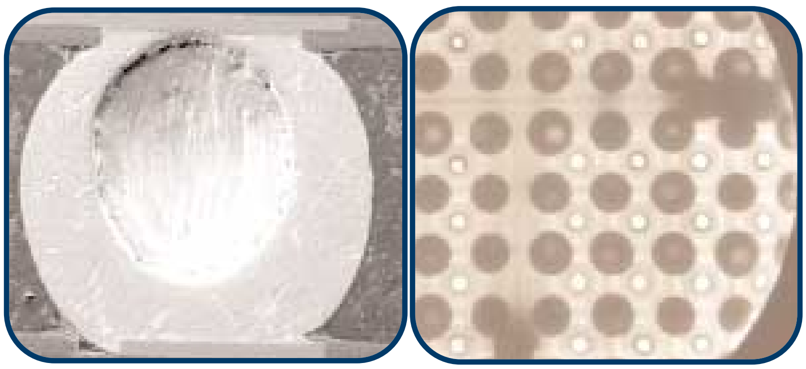

**Figure 1. Voids in a BGA bump viewed on an SEM after microsectioning (left) & transmission X-ray imaging (right)**

Unfortunately, at one time or another, most manufacturers have to deal with a failure analysis of an assembly or device. Having experienced failure analysis experts with the proper tools at their disposal is invaluable in determining root failure causes.

Performing failure analysis is like being a detective or an investigative reporter. The key to a rapid and thorough investigation is asking the right questions. The first stage to any failure analysis investigation is to take the time to gather as much information as possible without disturbing the sample. Questions to ask before starting laboratory work should include:

- What is the suspected failure?
- What are the symptoms?
- Where is the failure located?
- What is in the area of the failure (next to and on the opposite side)?
- Are there other failures like this one? If there are others, look for a common thread such as: same product lots, same operators, same manufacturing site, change in process, change in materials, change in vendor, change by vendor, etc...
- What was happening when the failure occurred?
- Was the device under power?
- Was it undergoing any stress testing (heat, cycling, vibration, etc...)?
- Had it worked prior to assembly or prior to shipping?
- What is the history of the device?
- What environmental conditions had it seen?
- How many hours of service had it seen?
- What is the typical lifetime of a similar device?
- How many devices like this have functioned properly?
- How old/new is the design, process, and materials being used?

The answers to these questions will help to create a story that can help you focus your efforts before performing a test. After determining the background story, the next step should always be a detailed visual inspection. This should include examining the device under magnification as well as with the naked eye. Often times anomalies that can aid in the failure analysis can be observed under inspection. Items to look for include:

- Solder joint wetting angle
- Amount of solder
- Cracks in solder joints or components
- Bubbles or blisters in the solder mask, component body, or conformal coating
- Debris
- Discoloration
- Charring
- Popcorning
- Pitting
- Device placement accuracy
- Missing components
- Residues
- Component markings

Failure analysis of electronic devices plays a critical role in product development and quality assurance. Taking a systematic approach, understanding the techniques available, and communicating results effectively are all key to performing failure analysis.

After interviewing the customer, it was determined that the board design, components, and materials for assembly have all been the same for 18 months with no failures, but they have recently starting using a new board vendor and a new surface finish. The boards passed a functional test after assembly, but then failed after thermal cycling. The location of the failure is always a quad flat pack (QFP), but it is random among the four QFPs on the assembly. They are currently experiencing a 25 percent failure rate of devices and have stopped production. Visual inspection of an assembly shows excessive solder wicking up the lead, but little solder on the pads. At this point, a preliminary conclusion can be drawn: there may be a solderability problem with the bare board, hence the solder preferentially wicking up the lead rather than on the solder pad. Now, a test plan can be drawn up.

In testing an assembly or device, a wide range of analytical methods and techniques can be used to investigate a failure (see box on p. 10). Each instrument and technique provides different information; a shotgun approach is usually not the most effective means of analysis. From the information gathered earlier, a test plan can be developed. For example, the test plan for this example should include:

1. Visual inspection of the assembly to a workmanship standard such as IPC-A-610.
2. Measurement of the HASL thickness on a bare board using X-ray fluorescence or cross-section.

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# Prototyping and Pre-Production

The prototyping and pre-production phase of a project is defined as the period of time between the completion of the design engineering work, culminated by the engineering design review, and the release of the product for a full production run. Many important tasks must be accomplished during this phase in order to verify the product and ensure a successful launch of the company's new endeavor.

Unfortunately, time constraints during this period often accelerate the critical path of the project schedule in order to meet the mandatory completion date. The prototyping and pre-production phases are often compromised in various manners due to these constraints. This article provides suggestions on how to minimize the detrimental effects to your organization when you are caught between the proverbial "rock and a hard place."

A typical project development cycle consists of the following:

- Marketing Requirement Statement
- Conceptual Design
- Engineering Specification
- Senior Management Review
- Engineering Design
- Engineering Breadboard
- Engineering Design Review
- Production/Engineering Prototype
- Critical Design Review
- Production Pilot Run
- Manufacturing Design Release
- Full Production

## Control

During the initial phases of this development cycle, the design-engineering group usually maintains project responsibility. However, after the engineering design review phase, the production team should become increasingly involved to ensure that the new design can be manufactured in production quantities. Accordingly, engineering and production personnel should work as a team to ensure that all requisite design guidelines are met, while conceiving a product that has a minimal level of producibility issues.

## Communication

Is everyone speaking the same language? Poor communication across departments is often the source of problems during the critical stages, such as debugging, testing, and documenting the new product. For example, it is important for everyone on the team to understand the definition of the "prototype." Is it defined as the engineer's breadboard? Or, is it the first layout or "cut" of the printed circuit board (PCB) that defined the basic form, fit and function of the design? The prototype could also be defined as the qualification unit or the first unit delivered to the customer for approval. Or, finally, the prototype could be defined as the first unit delivered off the manufacturing production floor. Be clear that everyone understands exactly what is meant when using ambiguous terms.

Weekly status review meetings, and even daily informal get togethers, where everyone has a chance to raise issues and set priorities, help to eliminate communication problems and build a smooth transition from engineering to manufacturing.

## Documentation

During the prototyping and pre-production phases, there are two important concepts to follow concerning documentation:

1. Always start with a "baseline" documentation package.

2. Always build the prototypes to the documentation package making corrections by "redlining" the prints, as changes are required. Next, revise the documentation, so that the prototype hardware always matches the documentation revision level.

The pre-production team must have the discipline not to fall into the trap of building the hardware first, and then trying to catch up with the documentation later. This action will not produce the desired end result of a thoroughly checked out documentation package.

As part of the engineering design review, there must be a documentation release (engineering drawing release). This is the point where the transfer of knowledge occurs from the design engineers out to the rest of the organization. It is this "baseline" documentation package that the production group starts with as they add in the manufacturing procedures, processes, and testing documentation.

## Testing

In order to guarantee that the design satisfies the customer's requirements, it is necessary to subject the prototypes / production units to a series of tests. These usually fall into two types:

1. Production functional tests

2. Qualification tests

Production functional testing is performed on 100 percent of the units to assure proper operation of each unit. Often parametric data is taken and monitored during these tests for statistical process control (SPC) information.

Qualification testing often requires subjecting the product design to extreme limits of temperature, humidity, voltage range, vibration, thermal shock cycles, electrical static discharge (ESD), and electrical magnetic interference (EMI), while monitoring relevant performance characteristics. Specialized test chambers and data acquisition instrumentation are required for these tests. The tests are generally performed on only a limited number of prototype units, as well as

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# Prototyping and Pre-Production

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an occasional sampling of the production run units for periodic re-qualification.

Another area of testing that is often eliminated at pre-production due to budget or time restraints is that of diagnostic troubleshooting tests. Whether it is for the production floor technician trying to repair line failures, or the field engineer trying to service the product at the customer's site, diagnostic test software routines, and even the simple placement of test points on a circuit board, are desirable features worth reviewing early in the design phase.

### Components

During the construction of the prototypes, and during the early engineering development phases, the components selection is often revised. This is an area where careful control is needed. Since the inventory of parts is not yet under formal engineering change notice (ECN) control, the tracking of revisions, and disposition of the old revisions of components in stock, becomes vital.

### Costing

Maintaining a top-down bill of material breakdown (with the parts and labor costs matched up with the target unit cost), must be well understood at the beginning of the project. Costing decisions and / or tradeoffs are often made during pre-production and are based on accurate material and labor cost estimates. Each component, subassembly, assembly, and final unit should have a current cost (actual purchased price), and a standard cost (accounting tracking) associated with it in order to make the correct decisions for material control and disposition.

Low volume or high volume quantities will dictate machining vs. tooling for molds, or application specific integrated circuit (ASIC) chip versus standard circuit. Overall life -- or total ownership -- cost of the product is also useful information to have developed during this prototype phase.

### Design for Manufacturability

Assembly processes, procedures, fixture design, and production tooling are some of the issues that the manufacturing engineer deals with as part of his producability review. Cost reductions, diagnostic testing and vertical integration or outsourcing (cable harnesses for instance) decisions must also be made by the manufacturing team.

The resources, facilities, capital equipment, and specialized work force talents, as well as the training of each individual company will greatly impact how the pilot production run is set up.

### Formal Manufacturing Design Review & Production Documentation Signoff

Presented to senior management for approval and release to production, this final phase includes the reports of all qualification testing, prototype performance, and results of the production pilot run. It is the final opportunity for everyone to either bestow their approval or to raise an objection. The documentation package is now considered complete and placed under formal configuration control.

### Summary

The following suggestions may be useful during your next prototyping and pre-production experience:

- Have the production group become an integral part of the team during the prototype pre-production phase.
- Maintain good communication with weekly/daily quick status meetings.
- Always start with a baseline documentation package.
- Build to the documentation package.
- Hold an engineering design review with an engineering drawing release.
- Subject the prototypes to both functional and qualification testing.
- Use SPC on parametric data.
- Include diagnostics and testability features in the design.
- Apply tight material control over prototype components.
- Establish accurate costs for all material and labor.

The EMPF is available to assist you with your most difficult problems; whether they be prototype stress testing, technical training of associates, component evaluation, cost reduction, design for manufacture, documentation, material failure analysis, or design / research consultation.

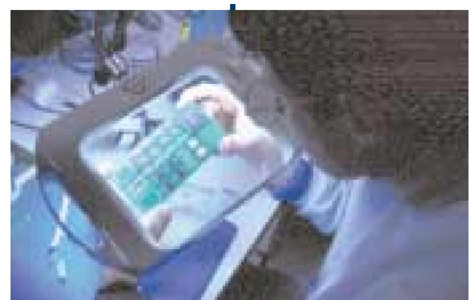
Pitfalls are avoided when input from qualified, experienced engineers, along with consultation of industry experts, are used to develop checklists for validation of designs and processes. Contact the EMPF Helpline during your next prototype / pre-production project phase in an effort to ensure the efficient operation of your production lines.

**Call the FREE EMPF Helpline at (610) 362-1320**

# Cleanliness Testing

Many printed wiring assembly (PWA) failures that occur in the field can be attributed to manufacturing residues that were not properly removed. It is essential that the cleaning process be monitored to ensure proper removal of contaminants that lead to high defect rates when exposed to time, temperature, and humidity. The EMPF has the ability to perform standard ionic cleanliness testing on your PWAs.

Ionic cleanliness testing will measure residues that are conductive and potentially corrosive. Bulk ionic testing can be performed using our Ionograph 500 M SMDII. This instrument, often used as a process control tool, can determine bulk ionic contamination in terms of NaCl equivalents.



The EMPF also has the ability to perform Ion Chromatography. Ion Chromatography is a powerful tool that is able to separate and identify each ionic residue on a PWA. Identifying the residues allows process engineers to identify the source of the residue and determine the best remedy.

The EMPF can also work with you on all your other electronics needs including Scanning Electron Microscopy (SEM), Element Detection & Analysis (EDS), Failure Analysis, Photo Micrographs, Solder Joint Analysis, Solder Joint Structures, Board Fab Issues, Environmental Stress Screening, Thermal Shock: Liquid to Liquid and High Speed Transfer Rate (2 sec.) -65°C to +150°C, Thermal Cycling, Automotive and Military Environment Humidity Cycling (Soak 85°C and 85 percent RH), Bias Capability, and Highly Accelerated Stress Testing (HAST).

**For More Information**

**Contact the EMPF Helpline at:**
**phone: (610) 362-1320**
**website: *www.empf.org***

# Combining Basic Surface Mount Soldering with IPC-A-610C Certification

While the manufacturing sector has been leading the U.S. economic slow down, many companies in the electronics industry continue to have difficulty hiring skilled assemblers and inspectors. At the same time, demands for knowledge and skills are increasingly important. Components are smaller and Printed Wiring Assemblies (PWAs) are more densely populated and expensive. Waste cannot be tolerated. Original Equipment Manufacturers (OEMs), Electronic Manufacturing Service (EMS), and employment agencies have identified problems finding workers that can satisfy the demands of the industry and customer requirements.

Engineers and instructors at the EMPF have recently identified an effective training sequence; combining basic surface mount hand soldering with industry recognized certification training. In less than two weeks, this sequence can provide workers with skills and knowledge that the electronics manufacturing environment demands. The EMPF Learning Center supports operator and inspector candidates with experience and knowledge, giving candidates an opportunity with the latest in Surface Mount Technology (SMT) hand soldering techniques. The Learning Center provides students with an understanding of workmanship requirements as well. This sequence is ideal for companies that need to bring unskilled operators or inspectors up to speed quickly and it can also beneficial to companies that need to have their operators and inspectors cross-trained.

This training sequence includes two steps: hands-on skills and certification training. During the first five-day course, students will develop the basic SMT soldering techniques necessary for the workplace. Demonstrations cover the most popular SMT package styles. Students will demonstrate proficiency in installing, removing and replacing chip capacitors and resistors, leadless chip carriers, a variety of gull wing leaded packages, and J-leaded components.

Every student will have access to the latest in soldering and rework equipment from manufacturers such as Pace, APE and Metcal. Students receive instruction and hands-on lab time on techniques for solder extraction, vacuum assisted hot bar, heated hot gas for localized reflow, and heated tweezers hand tools. The program provides instruction in the proper care and use of the variety of tips and tools used to optimize hand soldering and removal of SMT components.

Every student will be given ample time to practice techniques and perfect their skills. The final step in this portion of the sequence is demonstration of proficiency. Operator and instructor candidates will demonstrate proficiency by assembling a test board that meets IPC-A-610C Class 3 requirements.

The second step in the sequence provides three days of inspection training. This program provides novice workers with an opportunity to achieve certification from the IPC. During this portion, students will be taught the acceptability of electronic assemblies. They will be tested on their ability to correctly apply the acceptance criteria of IPC-A-610C. Students will also be introduced to related documents such as IPC-J-STDs, which provide specifications for process control, solder, flux, and paste, as well as other related materials, tools, equipment, and test methods.

An emphasis is placed on performance of the soldering process and component installation requirements for through hole and surface mount assemblies, but the program covers the entire IPC-A-610C document. It also provides information on how to properly handle electronic components and assemblies using electrostatic discharge (ESD) control, as well as different tools and devices that are currently used in the industry to minimize the hazards of ESD. Other topics that are covered in the course include mechanical assembly, marking acceptability, and conformal and solder resist coating acceptability. Cleanliness of electronic assemblies and various test methods are also introduced. Students who successfully complete a written test based on this instruction will receive certification from IPC, which is recognized throughout the electronics manufacturing industry.

These training sessions give companies the opportunity to have their employees trained quickly and thoroughly. They will become IPC certified, proficient in the necessary techniques and familiar with the current trends of the industry under the guidance of expert instructors. Operators will gain practical experience in hand soldering of surface mount components and will have a thorough understanding of acceptance criteria for surface mount and through hole soldering.

The EMPF Learning Center is the answer for companies that cannot afford to tie up valuable resources, personnel, and equipment needed to train new or existing employees in-house. The Learning Center offers a learning environment where classrooms are equipped with the best equipment, tools, and materials and has a full staff of expert instructors that provide new insight and knowledge for students to take home and share with their company experts.

**For information about the Learning Center, contact the Registrar at 610-362-1295**



NAVY MANTECH manufacturing technology program

" Cut here and save!!

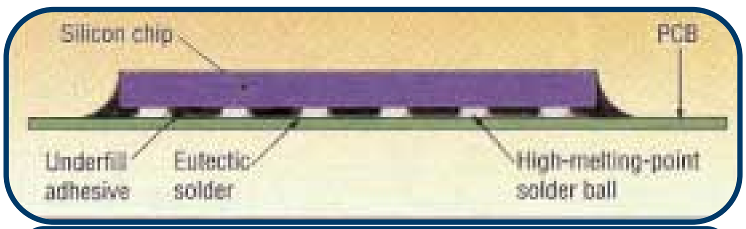
Electronics Manufacturing Productivity Facility

TECH TIPS...

# Flip Chip Underfill Processing part I

With today's advancements in component packaging, dispensing has become more of a critical part of the electronics manufacturing line. For example, increasing popularity of such processes as Flip Chip underfilling has led to complications in the industry. It has become an additional process step in the assembly line that involves strict attention to accuracy and effectiveness. Although the process of underfilling Flip Chips has become a manufacturing variable, many of the leading dispense equipment manufacturers have developed precision machines that have greatly improved underfilling processes, while maintaining productivity throughout the assembly line. Improvements in various types of underfills that are now offered have also minimized many of the common process control issues.

This month's Tech Tips, which is the first part of a two part series, focuses on key variables and requirements for Flip Chip underfilling as well as the necessary hardware, dispensing parameters, heating styles, types of underfills, and cost effective throughput recommendations.




An example of a Flip Chip that has been underfilled

## 1. Overview of the Underfill Process

- The Flip Chip is conveyed in-line or hand loaded into the dispensing equipment.
- The die is then heated to temperature or is heated during dispensing to provide good underfill flow.
- The Flip Chip is located either mechanically by fixture or by an automated vision alignment system.
- The fluid is dispensed on one or more sides of the Flip Chip, sometimes in multiple dispense passes.
- The underfill fluid flows via capillary action under the Flip Chip.
- Depending on the pattern chosen, a fillet pass may be required to provide an even fillet around the perimeter of the Flip Chip.
- The die is then cured at the underfill manufacturer's recommended temperature.

## 2. Heating the Flip Chip to Underfill

Packages are typically heated prior to the dispensing of underfill adhesives. This allows the fluid to reach the recommended specified temperature just before it reaches the substrate. The underfill fluid is then heat-induced using what is known as capillary action to draw the fluid under the die. The temperature at which this occurs typically is between $60^0$ C and $90^0$ C.

Heating sometimes occurs at the dispense station creating a gate in the assembly process because of the time it takes for the die to heat up. Generally, there are three types of underfill heating methods; contact heating, infrared heating, and convection heating.

**Contact Heating**: When substrates are brought into contact with a heated platen or surface and then brought up to temperature by conduction, it is considered to be contact heating. The platen control is used in a closed-loop method causing the substrate temperature to be controlled passively. Temperature can be held evenly with this method, however, it is time consuming to ramp up. This system will only work on a single sided substrate.

**Convective Heating:** Convective heating uses hot air blown on parts causing them to heat up. This can be done in either an open or closed-loop system. While this is an effective method, it can produce unnecessary heat inside a dispensing machine, reducing the pot life of some underfills.

**Infrared Heating:** This system uses bulbs that radiate heat to the substrate, making it easier to accurately measure the no-contact temperature of the board itself. Infrared heating also allows for better ramp rate control of the temperature by heating a substrate in a minimum amount of time without exceeding the maximum temperature. Unlike that of contact heating and convective heating, infrared heating can also provide more concentration of heat in a particular area with the use of moveable IR units. The only disadvantage to a system like this is that it may not work with certain fiducial image recognition systems because of its flashing bulbs. Infrared heating is the system of choice because it is the most consistent and can be easily controlled.

## 3. Vision and Mechanical Alignment

**Vision**: Typically, vision alignment occurs when two fiducial marks on opposite corners are optically recognized (shape and size) aligning the programmed

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NAVY MANTECH manufacturing technology program

# Flip Chip Underfill Processing
(Continued from p. 7)

dispense pattern with the Flip Chip. This is usually done automatically based on the location of the programmed fiducial marks. If fiducials are not present, the corner of a substrate or Flip Chip may be used.

**Mechanical:** Mechanical alignment is usually done through the use of a custom fixture for the substrate or Flip Chip device. Tooling pins that are predrilled in the substrate during the bare board fabrication process are also sometimes used.

### 4. Dispensing Methods

Choosing the right dispensing method is imperative to properly underfilling a Flip Chip. The following are the three most commonly used dispensing systems in the industry with a brief description of how each system works along with their underfilling advantages and disadvantages.

**Time and Pressure:** Time and pressure is a controlled, pressurized system with a nozzle valve that is used on such applications as chip bonding, conductive adhesion, and solder pasting. It is rarely ever used for underfilling because of consistency and material handling.

**Auger Pump:** An auger pump works using a pump with a lead screw rotating in a body adding energy to the adhesive path within the body. This is done by turning on and off the screw's electric motor pumping measured amounts of adhesive through the body. This system is primarily used for underfilling and encapsulating because of its accuracy and flexibility. However, it is not a good system to use for high production volumes due to its inconsistency at higher speeds which ranges from 5ml/sec to <250ml/sec.

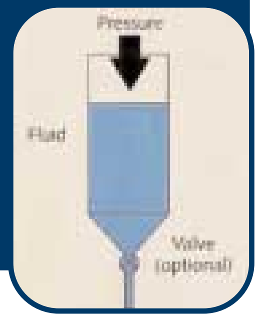
**Positive Displacement Pump:** Also known as a piston pump, a positive displacement system operates by the movement of a piston in a closed chamber. Much like the time and pressure pump, the piston pump works best with materials such as chip bonding fluid, conductive adhesives, solder pastes, and underfill. This system proves to have better accuracy with underfill at higher speeds in a production environment. The disadvantages are the complexity of cleaning and its sensitivity to air bubbles in the fluid.

To briefly sum up, choosing the right system is based on the quantity of product. For example, a prototype environment will likely use an auger pump where the production or OEM facility will likely use a positive displacement pump.

Next month, Tech Tips will review types of underfills, dispensing patterns, dispensing accuracy, choosing the right needle, curing the underfill, and increasing Flip Chip processing throughput.

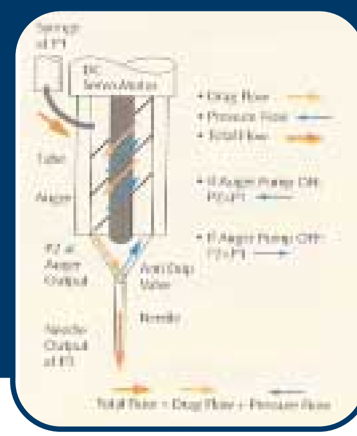
#### Time and Pressure

**Speed**: Viscosity, pressure and needle dependent. Typically <25ml/sec.
**Repeatability**: Typically > +/-10 percent.
**Advantages**: Simple and inexpensive
**Disadvantages**: Flow rate change is directly proportional to changes in viscosity, often requiring recalibration. Often requires shutoff valve to prevent dripping.



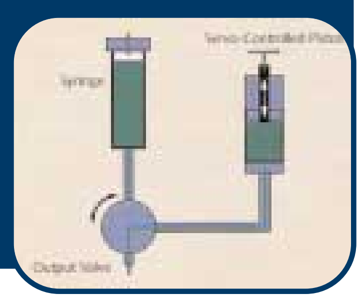

#### Auger Pump

**Speed**: Viscosity, pressure and needle dependent. Typically <50 ml/sec.
**Repeatability**: Typically +/-4 to +/-10 percent short term (<30 minutes).
**Advantages**: Less viscosity sensitive and more accurate than Time and Pressure.
**Disadvantages**: Flow rate changes with changes in viscosity, often requiring recalibration to hold accuracy tolerance. Often requires shutoff valve to prevent dripping since pump is not positive displacement.



#### Positive Displacement Pump

**Speed**: 5 ml/sec to >250 ml/sec.
**Repeatability**: < +/- 1 percent except for very small dispense volumes (<30 ml).
**Advantages**:Fast, accurate and less damaging to encapsulant fillers than auger pumps. Dispense volume proportional to piston travel, so one time calibration establishes accuracy for long production runs. Cost is about the same as auger pump, but has lower cost of ownership.
**Disadvantages**: Requires periodic cleaning with limited pot life materials. More expensive than Time and Pressure dispensing.



# Manufacturer's Corner

## Metcal BGA/CSP Rework Station

To meet the demand for smaller footprints, improved electrical performance and/or higher I/O in a given space, manufacturers are investigating advanced packaging technologies. Rework for advanced packages present challenging issues. Removal, solder paste dispensing, thermal profiling, and placement are all key elements that need to be considered when reworking components.

Defined are some common advanced packages:

Ball Grid Array (BGA) indicates an array of solder balls underneath the component used to connect it to the circuit board, instead of peripheral leads as used with a Quad Flat Pack (QFP) or Plastic Leaded Chip Carrier (PLCC).

Chip Scale Package (CSP) has been described as "a component whose overall size is no greater than 1.2 times the size of the silicon die inside the component." CSP's are generally smaller than BGAs and have a typical ball pitch of between 0.5 and 1mm.

Flip Chips are bare silicon die that have solder bumps attached and are assembled face down onto a substrate. This package offers the smallest possible component size, with the fastest possible operating speeds.

To address rework needs, the EMPF is using Metcal's BGA/CSP Rework Station. The changeable nozzles, precision stencils, and simple thermal profiling software makes the Metcal BGA/CSP Rework Station easy to use and a valuable tool. This unit becomes especially critical for the EMPF training courses. During training, students have the opportunity to work directly with this unit by removing, pasting, and reflowing PWB's and components.

The EMPF also uses the rework station to place larger or expensive components that normally would not be run on an automated component placement machine. Below are key features of the Metcal Rework Station:

**Vision System:** The Metcal BGA/CSP Rework Station offers an integral vision system for accurate component and stencil alignment. The vision system utilizes a prism that allows the user to look simultaneously at the topside of the printed circuit board (PCB), and a superimposed image of the underside of the component.

Metcal BGA & CSP Rework Station

Using micrometer adjustment, the images can be accurately aligned on the X, Y & Theta axis, prior to placement. The vision systems include facilities for either solder paste or flux application to the rework area - without the need to remove the board from the machine. Consistent solder paste deposits can be printed using the vision-mounted stencils that allow accurate alignment and co-planarity adjustment.

**Dip Transfer:** This process involves dipping the component into a known depth of gel flux, depositing an exact amount onto each solder ball. The process is quick, consistent, clean and negates the need for cleaning after reflow. Both processes have proven successful, even on fine pitch CSP. With EMPF testing different flux chemistries, the flexibility and precision of the dip transfer allows for accurate and repeatable flux application.

**Reflow Profiling:** As with production reflow oven technology, Metcal Rework Systems use low airflow forced convection heating. The patented Micro Oven Reflow Head delivers temperature uniformity, assuring safe and simultaneous reflow of the component being removed - without disruption to adjacent parts.

The systems are fitted with an underboard heater. The convection heaters (depending on the model) are suitable for smaller PCBs and thermally demanding multi-layer boards. This eliminates problems associated with warped boards.

BGA's, CSP's, and Flip Chips are all array packages. The rework of an array package requires process control and repeatability, to replicate the original assembly thermal process. When reworking BGA, a greater level of process control is required to reduce the risk of a defect and to ensure the perfect result.

**Windows Based Software**: This interactive software precisely controls both heaters, making profile set up simple. Using closed loop feedback monitoring, the software controls the four stages of the reflow profile: preheat, soak, reflow and cooling. The board temperature can be monitored using the integrated thermocouple, and real time adjustments can be made to the times and temperatures during operation.

**Nozzles**: There is a wide range of standard reflow nozzles available for most common array packages. Nozzles are also available for QFP packages. In addition, custom manufactured nozzles for unusual or odd shaped components, such as EMI shields and plastic surface mount connectors are available.

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# Sustainment Strategies for Military Electronics

(continued from p. 1)

of COTS components or programmable devices to reduce obsolescence and or miniaturization techniques to increase functionality and reduce cost. Redesign efforts can be initiated using legacy design documentation when available. If however, the documentation is incomplete or unavailable, reverse engineering techniques may be required.

The EMPF provides a variety of engineering resources to solve electronics manufacturing problems including those related to sustainment of electronics. Engineers from a variety of disciplines work together to provide technical solutions including reverse engineering, re-engineering, design for manufacturing, circuit redesign due to obsolescence and modern packaging technology integration. The EMPF is well positioned to supply total on-site solutions from design through prototype. Some of the in-house tools used for this capability include computer aided drafting (CAD), a printed circuit artwork scan-to-file creation system, and a full complement of state of the art electronics manufacturing processing equipment. The EMPF has a proven track record of providing engineered solutions for electronics and is well positioned to assist in solving sustainment problems.

# Failure Analysis of Electronics

(continued from p. 2)

3. Sequential Electrochemical Reduction Analysis (SERA) of a bare board to look for tin or tin-copper oxides.

4. Cross sectioning and analysis of solder joints (analysis includes optical microscopy and scanning electron microscopy to look for solder joint integrity).

Simply performing the analysis and gathering the data is not enough; the results must be interpreted and communicated effectively. The most common way to do this is with a written report. The report should contain results and conclusions. Ideally it should also contain recommendations and/or a recovery plan. Well-labeled images or graphs are excellent ways of presenting results and supporting conclusions. Also, having background and procedure/test method sections will enhance the report and allow future readers to better understand the "why" and the "how" of the effort and help the customer in making sure the failure does not re-occur. The EMPF can re-create failures on the factory floor to demonstrate the processes and the solutions.

**Scanning Electron Microscopy**
**Element Detection and Analysis**
**Micro-Section & Metallographic Analysis**
**Differential Scanning Calorimetry**
**Thermo-gravimetric Analysis**
**Fourier Transform Infrared Spectroscopy**
**Bulk Ionic Testing (Ionograph)**
**Ion Chromatography**
**UV-Vis Spectroscopy**
**SERA Solderability Testing**
**Wetting Balance Testing**
**ROSA Solderability Restoration**
**X-ray Inspection**

**Analytical tools available at the EMPF**

Failure analysis of electronic devices plays a critical role in product development and quality assurance. Taking a systematic approach, understanding the techniques available, and communicating results effectively are all key to performing failure analysis. The EMPF can help. Call our Helpline to speak to a failure analysis expert who will help you ask the right questions and determine the proper tests, or ask for an sample test report. The EMPF has analytical laboratories on site to aid our customers in failure analysis and, the EMPF offers a course in Failure Analysis of Electronic Devices (next offering is May 22-24). This course covers the instruments used in failure analysis and failure analysis methodologies. The lecture portion of the course will also be offered at the SMTA International Conference in Chicago in October 2001.

# Metcal BGA/CSP Rework Station

(continued from p. 9)

**Stencils**: The unique vision stencil-printing feature allows the user to perform accurate stencil alignment and co-planarity adjustments under high magnification, removing the variables out of single component solder-paste printing. The vision system can also be used for solder-paste print inspection. Wide ranges of standard and custom stencils to suit most ball & lead patterns are available. The EMPF has found great success with paste-on-part processing. Paste-on-part allows for accurate paste dispensing and minimizes errors.

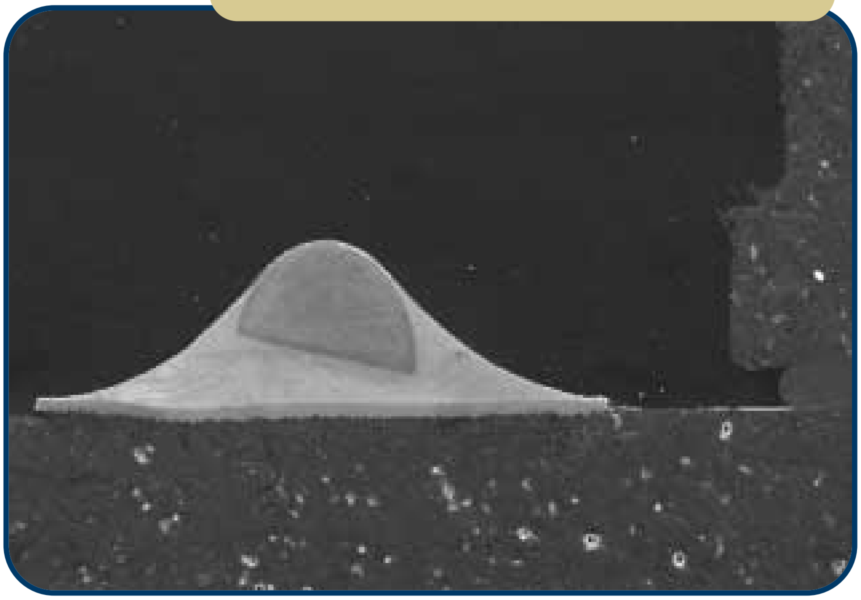
The EMPF recently used the Metcal Rework Station for BGA solderability testing. The standard method of testing BGA solderability would be to place the component on a ceramic coupon and run it through the in-line reflow oven process. The EMPF duplicated this process with a ceramic or glass pyrex slide and a BGA component. Doing the study on the Metcal Rework Station provided two advantages: 1. there was no need to take the reflow oven off line during a production build and, 2. with the glass slide, a mirror could be used to observe the wetting of the ball as it occurred. Ultimately, this station helps to answer the following questions: 1. Does the component stick to the coupon? 2. What is the ball symmetry and consistency? For more information on the Metcal BGA & CSP Rework Station, call the EMPF Helpline at (610) 362-1320.

# Ask the EMPF Helpline!

The EMPF Helpline receives many calls each week. The Helpline team of scientists, engineers, and technicians try to answer questions and solve problems as quickly as possible. This is accomplished at no cost or obligation to the caller.

Recently, the Helpline was faced with a particularly difficult task. A very experienced manufacturer of aerospace electronics required an expert third party analysis of the solder joints on their connector devices. The EMPF scientists are experienced in evaluations of solder joints, boards, components, and other devices, but this manufacturer had some particular requirements that posed a challenge. This customer laser-solders gold plated connectors with lead-free solder paste and required the evaluation to satisfy the requirements of a potential customer.

SEM Cross-section of Connector Solder Joint



The customer's concern was a small discoloration line that began to appear on the exterior of the solder joint. The caller required a complete analysis and report. He also needed to be present for the evaluation to gain a better understanding of the internal workings of the solder joint and the process. Additionally, the customer required that it all be completed in less than four days.

After assisting with travel plans and scheduling the customers immediate visit to the EMPF facility in Philadelphia, the customer began preparing samples to bring with them for evaluation. Research on lead-free solder microstructure was reviewed and the most up to date lead-free soldering resources were tapped.

When the customer arrived with the samples, the solder joints were evaluated using polarized light microscopy, scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). Using information acquired from previous EMPF research into the behavior and microstructure of tin-silver solder joints, a two percent Nital etch was applied to the customer's prepared cross-sections of the joint. Key areas of the evaluation included wetting, intermetallic measurement, contamination identification, microstructure identification, and elemental composition qualification. The customer was familiarized with sample preparation and investigation techniques and assisted in evaluating wetting and joint appearance using stereo and metallographic microscopes. The customer sat alongside the EMPF scientists at the SEM and examined the tin-silver and tin-copper intermetallics that form in the bulk solder and at the interfaces. While waiting for the generation of color X-ray images, the customer discussed some of their processing concerns with experienced EMPF processing engineers.

After a complete analysis, the discoloration line was attributed to anomalies from the laser reflow process that would not effect the overall joint reliability. A small summary report with a clean bill of health was generated for the customer just before their flight back that same day. The customers returned to their engineering plant not only with an accurate and timely evaluation of their high reliability application solder joint, but also with an understanding of how their non-traditional process affects solder microstructure. Upon receiving the full report a few days later, the customer requested additional analysis on other solder joints.

**If you have an electronics manufacturing problem, call the free EMPF Helpline at (610) 362-1320**

# American Competitiveness Institute - 2001 EMLC Courses

## Electronics Manufacturing

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**Electronics Manufacturing BOOT CAMP B**
Week 2 Jun. 25-29 Oct. 1-5

## Skills

**SMT Manufacturing**
Jul. 9-13

**SMT Rework**
Aug. 27-31

**BGA Manufacturing, Inspection & Rework**
Jun. 4-5 Oct. 11-12

**Advanced Packaging Techniques**
Jun. 6-8 Nov. 14-16

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Oct. 22-26

**IPC-A-610 Instructor Recertification**
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**IPC-A-600 Instructor Certification**
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## Continuing Professional Advancement

**Failure Analysis and Reliability Testing in Electronics Manufacturing**
May 22-24

**Characteristic Properties of Materials in Electronics Manufacturing**
Jun. 12-14

**For more information, please call the EMPF registrar at (610) 362-1295 or e-mail: registrar@empf.org**

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