Challenges & Considerations in Electronics Production Processes

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With the demand for printed circuit board manufacturers to build smaller boards with increased capability, coupled with challenges facing SMT such as the shortage in surface mount devices, it is no surprise that everyone is feeling the pressure to ensure their quality is second-to-none. Decreasing aperture size to accommodate smaller, fine pitch components requires greater accuracy, and the high demand for some electronic components means it’s critical that waste is kept to a minimum.

Focusing on some of the key challenges during the production of the printed circuit board, including the screen printing process, we explore how to overcome some key obstacles and how to introduce best practice into your processes to ensure you benefit from continual improvement.

**Contact between the PCB and stencil**

It sounds obvious, but it’s surprising how many issues there are ensuring there is good contact between the PCB and the stencil. There are a few variables which can have an effect on the contact, including the aperture size and shape, cleanliness and maintenance of equipment, as well as the thickness of the aluminium frames.

- **Aperture variables** - Some apertures have a narrow pitch and this can often lead to the solder paste spilling out of the aperture, causing a blur from one aperture to the next.

  Equally, in minute apertures, adhesion can often be problematic because the lack of solder doesn’t reach the pad.
• Cleaning and maintenance - ensuring daily cleaning and maintenance is carried out can be critical to alignment. Over time, the stencil plate and the PCB can become misaligned where they are no longer parallel to one another.

• Aluminium stencil box frames - available in different wall thickness from 1.5mm to 3.5mm. It can be tempting to keep the costs down and purchase the thinner walled frames, because it impacts the price. However, using thinner frames can also affect contact because they can distort with use. Although purchasing thinner walled frames can be tempting, in reality it's a false economy.

It's worth noting that ASM have designed a VectorGuard system, to help counterbalance the issues noted earlier. The DEK VectorGuard utilises a solid, high tension frame for fine pitch applications. Designed with compressed air, the VectorGuard clamping increases tension by up to 45%, providing a much greater transfer efficiency.

• Stencil vacuuming functionality - despite all of the potential variables that can affect the contact, there are functions that can help overcome some of the issues, such as stencil vacuuming. Even if the plate is showing signs of distortion, utilising the vacuuming functionality on the conveyor holds the stencil down, which stabilises the printing. It also helps to prevent any movement caused by the squeegee during the printing process.

Not all systems offer stencil vacuum functionality and if they do, it is often an optional extra. One of the solutions that does offer vacuum functionality as standard, is the Yamaha YCP10 Stencil Printer.

Filling the apertures with solder paste
Filling apertures with solder paste can be a challenge. Ensuring apertures are filled adequately i.e. not over filled or under filled, requires quite a few considerations. These can range from the quality of the solder paste, to factors such as the pressure, speed and angle the paste leaves the squeegee. Below are some of the considerations required to ensure apertures are adequately filled.

It’s easy to assume that following the data from the Gerber File should lead to a perfectly printed board. However, there are quite a few variables between the beginning and the end of the process, that can cause a range of imperfections to occur. Temperature and consistency of the paste, ambient temperature and humidity, squeegee pressure, and the separation speed can all affect the quality of the paste and overall alignment.
The screen printing process

- Temperature - As paste is thixotropic and can therefore change its viscosity under stress (such as a change in temperature) it is essential that the temperature is kept constant, ensuring the viscosity remains stable. The viscosity of the paste will dictate the pressure and speed required to create the board. If this changes, and the pressure and speed is kept the same, some imperfections will occur such as misalignment issues.

- Pressure - It’s important to get the squeegee pressure right, to prevent stencil deformation patterns. Most pastes work well with a pressure of 0.45 – 0.57 kg/in force, but if you prefer to be cautious, then set the squeegee initially low and start testing until you get a clean wipe.

- Speed - As the squeegee speed decreases and slows, the printing volume gradually increases, improving the fill of apertures. However, reducing the attack angle can also have significant advantages. As the attack angle is key to the volume, reducing the angle to 65 degrees (depending on aperture size), can increase the volume of solder in the aperture.

However, adjusting the angle of attack isn’t always that easy to achieve. This is because there are only a few solutions that provide the capability for engineers to adjust the angle of attack. One of the solutions that allows such adjustment is the Yamaha YCP10 Stencil Printer.

Optimising adhesion through design

Ensuring the solder paste is touching the lands is critical in the design phase. Stencil aperture size should typically be reduced by 10%. This is particularly the case where apertures may prove problematic (size or shape). Etching conditions also need to be considered and in some cases it might be wise to test incremental reduction in percentage until ideal adhesion occurs. If there isn’t enough land size in relation to the aperture, especially on minute apertures, then there will be a high probability that some detachment defects will occur. Other variables that need to be considered in the design process include:

- Stencil thickness - The ratio of the stencil thickness (or lateral area) in relation to the bottom area, increases the chance of detachment occurring. Although there are ‘ideal’ ratios between the two area dimensions, the shape of the aperture can also affect this ratio value.

- The shape of the apertures - The ‘ideal’ ratio for a circle, is no more than 1:7, and less than 2:0 for square. The corner of the squares can be problematic and so ensuring the ratios are correct and the speed is right, should minimise friction.

However, if these ratios are any larger, the stencil thickness should be re-evaluated. Most solder paste suppliers suggest - fast and constant is best to achieve good detachment.

- Surface characteristics - Is another variable of the stencil that can have an affect on detachment. Both the texture of the aperture wall surface (rough or smooth), or its repellency can change the effectiveness of detachment. For example, the additive process tends to provide a smoother wall finish and lasered tends to leave a rough or textured finish.

The smoother finish often provides better detachment, but using the additive process is usually more costly compared with laser, so it depends on what you are trying to achieve.
Although features of the aperture (such as the shape and surface characteristics) can cause issues with adhesion, there are features available with some systems that can encourage the solder into the aperture. The vibrating squeegee available with the E by DEK Stencil Printer is a feature that helps to manipulate the solder into the aperture. The Paste Height Monitor is also another feature of the E printer, which can ensure the optimum quantity of solder, by measuring the solder height utilising a calibrated laser.

This in turn will change your approach to everything discussed above. For this reason, all of the material you are working with and all of the tools you’re using needs to be considered holistically, to enable you to achieve the best results.

**Best practice**

Taking everything above into consideration, we have listed the main considerations below, which can be utilised as a checklist. There is no winning formula, because every aspect from the design (including aperture size and shape) to the thickness of the aluminium frame needs to be considered. Some factors can be counterbalanced with tools and functions on your equipment, such as the stencil vacuuming function, helping you to achieve the best results.

- Ensure cleaning and maintenance is carried out regularly.

- Invest in aluminium stencil frames with a good wall thickness.

- Utilise vacuum functionality to counterbalance any potential distortions.

- Test the speed, pressure and angle of the solder from the squeegee to obtain the right configuration for your design.

- Ensure the stencil aperture to land size is reduced by 10% as a starting point.

- The stencil thickness needs to be 1:7 ratio for circle apertures and less than 2:0 for square apertures.

- Consider the characteristics of the stencil including its texture and repellency.
The component placement process

The mounting process often utilises pick-and-place systems, which is still the most efficient way to mount components onto boards, but as components get smaller, this process becomes a constant battle to ensure the components are mounted accurately.

Focusing on some of the key challenges during the production of the printed circuit board, including the mounting process, we explore how to overcome some of the pain points, as well as potential difficulties that may occur in the future. Utilising this document to implement a proactive approach, may help you to minimise some of these potential problems before they occur.

Miniaturisation of holes

As we discussed in the previous article: ‘The Screen Printing Process - Challenges & Considerations 101’, components are constantly decreasing in size, sometimes requiring an aperture size of 0.1mm. When producing boards requiring apertures of 0.1mm to accommodate the 0201 chip, it introduces challenges that need to be addressed from the outset such as increasing routine cleaning and inspection.

Cleaning - Needless to say, additional requirement to increase these mandatory processes costs valuable time. To minimise wasted production time, some manufacturers have introduced systems that are designed to provide a quick release nozzle, using a jig. It can then be replaced with a clean nozzle, while the current part is cleaned in an ultrasonic cleaning system. This process can help to
minimise downtime, while ensuring your system is kept clean from debris.

Nozzle health check - Checking the health of the nozzle is critical and this can be categorised into two parts - a visual check and a performance check.

• Visual check - This can prevent a build up of debris before it occurs. Any debris on the nozzle, particularly at the tip can impact the recognition of the components and potentially lead to mounting failure. Typically, if you maintain a good clean nozzle, it will ensure you maintain a good recognition rate. A visual check will also ensure the nozzle stays aligned. Any deviation can result in a decrease in pick-up-rate, but potentially an increase in mounting failures too.

Performance check - includes the vacuum functionality and the spring action of the nozzle. Both of these actions are critical in maintaining good pick-up-rate and mounting consistency, as well as accuracy. If there are any inhibiting factors preventing the nozzle from performing its full spring action, it can also lead to component breakage.

However, nozzles that are manufactured from ceramics with bespoke ESD coatings, improve the stability and durability of the nozzle. This will also help prevent deformation from premature wear, which could lead to the nozzle sticking. The ESD coating will also ensure that the movement of the nozzle does not create a build up of electrostatic discharge.

Performing both visual and performance checks are imperative, especially with 0201 components, which require high precision throughout. This is especially the case during the pick-up process where the components are micro size.

Maintaining high precision pick-up

Maintaining high precision pick-up requires constant evaluation of several factors including pick-up position and height, as well as the vacuum level and the build-up of static charge from the tape.

• Pick-up position - Position of the pickup needs to be accurate, but there are a few aspects that can cause pick-up to become displaced. These include elements such as the accuracy of the tape alignment, nozzle distortion, feeder plate positioning, as well as the actual alignment of the feeding by the feeder.

• Pick-up height - Clearly this has to be setup correctly at the start of the process, but there are other variables which can affect the accuracy of the pick-up height including the tolerance of the feeder head, and the spring action of the nozzle itself. Any abnormality
The component placement process

in the spring action that inhibits a fluid motion can cause issues with the pick-up height.

Ensuring accuracy and working out any issues with a process of elimination can become tedious and very time consuming. Some systems have been developed with functionality that enables engineers to teach the machine to maintain both pick-up height and positioning. This is achieved by ‘teaching’ the system to pick-up at the centre of the nozzle every time, by recognising the image of the nozzle tip. It then automatically corrects any deviation off the centre.

Pick-up height can be taught by measuring the pick-up position and the height of the tape by contact tip with the nozzle. Comparison between the current setting can provide a different value. This can be input back into the system for increased accuracy, simultaneously minimising damage to component parts.

Optimum mounting onto the board

Assuming the pick-up height and the pick-up positioning are set correctly, the focus moves onto ensuring the components are mounted correctly onto the board.

One of the main considerations is mask thickness in relation to the component part size. For example, if you are intending to mount 0201 or 03015 components onto the board, you need to ensure you have set the mask thickness to between 40 - 60 microns.

However, as the component’s size increases, they require a thicker mask, so if the 0201 components are integrated onto the board with larger components (1005), it will require different levels of mask thickness to account for the variation in the size of the components.

Another solution is to consider utilising solder paste in chip form. Recognising the increasing complexity of board designs, some suppliers now offer the paste in chip form so it can be placed on or next to the pads, where an increase in the amount of solder is required i.e. for the larger components on mixed boards.

Root cause failure analysis (RCFA)

Unfortunately, even if you ensure best practice has been implemented and you have done everything you can to ensure production of a good quality PCB, you could still end up experiencing unexpected faults.

Cameras and vacuum sensors can inform you of issues such as tombstoning, or if the components aren’t released onto the board, but don’t provide any information as to why these issues have occurred.

Utilising a light high resolution camera with a wide field-of-view, along with analysis software could provide rapid analysis feedback, minimising downtime.

The software can analyse each image to detect inaccuracies during the pick and place steps. However, it is essential that the system is configured accurately and synchronised to firstly capture the image and analyse it at the exact point of picking and placing.

Multi-Accuracy Compensation System (MACS)

The MACS system which has been introduced onto some of the Yamaha YS Series Mounters, provides engineers with real-time machine vision. Utilising side-view and upward-looking cameras, the system can identify the centre of the component and by capturing its position with the centre of the nozzle, it can automatically correct any deviation that occurs in real-time.
Utilising the MACS system feature on the Yamaha YS series could reduce positional error from around 30 microns to less than 10. Find out more information on the Yamaha YS on the last two pages.

**Checklist**

Taking everything above into consideration, we have listed the main considerations below, which can be utilised as a checklist. There is no winning formula, because every aspect from the design (including the mixture of component size) to the cleanliness of the nozzle needs to be considered.

Some factors can be counterbalanced with tools and functions on your equipment, such as the ‘teach’ mechanism, helping you to achieve the best results.

- Investing in an ultrasonic cleaner and a spare nozzle to maintain accuracy and efficiency.

- Conduct both a visual check and a performance check on the nozzle regularly.

- Invest in a quality nozzle with an ESD coating to prevent sticking and electrostatic discharge.

- Follow the steps to ensure both the pick-up -- position and the pick-up height are accurately calculated and maintained.

- Utilise ‘teach’ functionality to ensure accuracy and consistency.

- Investigate solder paste in chip form. This can be utilised by your pick and place machine, for boards designed with a range of component sizes.

- Minimise downtime by installing and configuring analysis software to provide feedback on why a failure has occurred.

- Consider upgrading your system to one of the Yamaha YS Series Mounters and benefit from MACS system functionality, reducing positional error to less than 10 microns.
The last step in the PCB production process, following the screen printing and component placement, is reflow. Like we have discussed in the previous two articles, each process comes with its own set of challenges and the reflow stage is no exception.

The reflow process has taken on a life of its own with the evolution of changes in technology, impacted by environmental factors and the demand for greater accuracy with tighter tolerances.

Two of the main technologies deployed on the shop floor are either based on convection or vapour phase technology. In this article we look at both technologies and compare the advantages and disadvantages, with the aim of helping you to make an informed decision, if you are looking to invest in a solution.

One consideration is the minimisation of voids. For some engineers, filling the void and ensuring there is sufficient solder around the solder joint becomes a balancing act of several factors. These consist of variables such as the type of solder utilised i.e. no clean and water soluble lead-free solder, the manufacturer of the solder paste, stencil design, as well as the reflow process used - convection and vapour phase reflow.

Reflow: convection oven method

Typically, the convection method consists of four heat phases: preheat, thermal soak, reflow and cooling. These phases are depicted as zones within the convection oven, where the PCB passes through on a conveyor belt. However, some convection ovens consist of additional reflow zones and one
advantage of additional heating zones is it gives you greater process control.

As the convection process is ‘in-line’ with the rest of the assembly process, greater throughput can be achieved because it integrates with the other SMT systems, automating the entire process. The conveyor belt is key to driving the boards through the system, and adjusting the speed of the belt can help to refine the reflow process without having to manipulate the temperature of the different zones. If you start adjusting the temperature of one of the zones, it will adjust the other zones to compensate which could lead to undesirable consequences.

One of the potential consequences can be the insufficient wetting of the boards. Ensuring the boards achieve sufficient wetting, especially when they are densely populated, can be a challenge. Often with a diverse range of components sizes, ranging from anywhere between 0201 to 2920 chips sizes, all with a different thermal mass. Irrelevant of the chip range and size you are utilising on the board, you may still find that the board consists of voiding in some of the solder joints. According to findings from T. Lentz & G. Smith (2016), two out of three solder pastes in their investigation gave higher levels of voiding in the vapour phase reflow without vacuum, compared to RTS convection reflow. The solder includes both water soluble and no clean lead-free paste.

Reflow: vapour phase method

Ultimately, whichever solder paste is utilised, both the reflow solution and the paste needs to be configured to minimise both voiding and insufficient wetting. Therefore it’s important to consider the process holistically, rather than each element of the process separately.

Vapour phase solutions often require more investment than convection ovens, both from the initial investment of the system, but also from the operational perspective i.e., Galden® PFPE - Perfluropolyether Fluorinated Fluids. With its high thermal stability and wide operating temperature range, makes it ideal for the reflow of PCBs.

The perfluropolyether is heated to create vapour which provides the temperatures to create the wetting required for reflow of the board. It provides efficient energy transfer and is a relatively safe process meeting the FM approved 6930 standard.
The vapour phase method is ideal for PCBs mounted with a range of chip sizes, because there are minor temperature fluctuations between components differing in thermal mass.

In addition to vapour phase providing the inert gas atmosphere, resulting in temperature consistency for efficient wetting, the potential of overheating the PCB is eradicated because the temperature is restricted to the maximum temperature of the vapour, which is around 230°C for lead free.

However, vapour phase tends to be more of a manual process and is usually associated with batch production, which impacts the potential throughput. Although there are vapour phase systems that do cater for large volume production, they come at a significant cost compared to most convection solutions.

Equally, convection solutions don’t lend themselves well to organisations that have space restrictions, because they tend to be considerably larger than vapour phase ovens.

Interestingly, T. Lentz & G. Smith (2016) found that both water soluble and no clean pastes demonstrated a statistical significance with voiding levels, with the no clean solder showing a mean level of voiding a low 1.4% in the RTS (convection) method, compared with a much larger 14.1% with the vapour phase method. However, they did document that vapour phase with vacuum did reduce levels of voiding.

### Making an informed decision

Ultimately, the reflow method that is right for your business will depend on a range of factors including:

- **Design** - The design of the board and the range of components including the size of the chips, can have a bearing on what method is utilised. I.e. if the board is densely populated you might want to consider the vapour phase option, where you benefit from inert gas atmosphere.

- **Volume** - If you require high volume, then you need to consider that some vapour phase solutions can be provide only a batch reflow process. Convection ovens have been designed to automate with the rest of the SMT line and typically provide higher throughput. However, some vapour phase systems have been developed to offer increased automation, delivering greater throughput, but the technology comes with a requirement for significant investment. It should be noted that throughput volume depends on the solder profile.

- **Range** - When you manufacture a range of boards, there are additional factors that need to be considered such as how many different boards you need to process through the system. Typically, you’d need to allow for the zones to reset if you were utilising convection ovens which could impact turnaround times.

- **Application** - If the PCBs are critical and are utilised in applications such as aerospace, defence, or medical, the vapour phase solution provides the benefit of PFPE which eradicates the possibility of overheating and provides greater consistency, even with components with greater thermal mass. However, vapour phase requires significant investment, which is not going to pay dividends if the boards are going to end up in consumables of low value.
Voiding

Aspandiar, R. (2019) suggests that the size of the void is less critical than the location because if the void is located on the solder joint, it is more likely to impact the reliability than a larger void situated away from the joints. However, with some methods showing that voiding can be present with a mean value of 14%, with some solders using vapour phase methods, it begs the question how many of those voids are situated on the solder joints themselves.

Quality control and continual improvement

Whether you decide to invest in vapour phase or convection technology, ensuring the systems are configured to meet the correct specifications to accurately reflow your boards is essential. After all, you could have the latest oven on the market with all of the technology, but if you don’t configure it properly and setup the profiles correctly, inevitably you’ll end up with insufficient wetting, voids or even overheated boards.

Therefore, its imperative that engineers utilise the tools they have at their disposal to configure the ovens (particularly the convection systems) to optimise their performance. Tools such as Thermal Profilers should be utilised proactively, rather than just as a trouble shooting aid. Utilised with the AutoSeeker Profile Optimiser software negates the need for balancing the zones, with the aim of achieving the gold standard for every profile.

Thermal Profilers

Thermal profiler systems such as the PRO thermal profiler from SolderStar include insulated micro dataloggers which can be utilised with a range of accessories, capturing comprehensive data for profiling the oven to optimise the reflow process. The AutoSeeker Profile Optimiser, unique to SolderStar can be added to the system where it searches through millions of combinations of oven set points, to provide suggested settings for both temperature and speed. This solution is not restricted to convection ovens, it can be utilised with wave and vapour phase reflow methods.


Electronic Production Equipment

At Hawker Richardson, we pride ourselves at partnering with our customers to supply solutions that endeavour to fulfil long term goals. Our suppliers share this ethos and help us to provide solutions that deliver on these principles of quality, flexibility and longevity. Here are some of the solutions documented in the articles on the previous pages.

Stencil Solutions: E by DEK Stencil Printer

E by DEK, an innovative platform with high-quality components, sophisticated construction, and modular design that guarantees a stable and reliable printing process.

- 8 seconds core cycle time.
- Sophisticated construction.
- Modular design.

Stencil Solutions: Yamaha YCP10 Compact Stencil Printer

The YCP10 utilises Yamaha’s 3S adjustable angle print head system and a high rigidity base frame to maintain accuracy. A vacuum stencil clamping system ensures high accuracy.

- Compatible with large circuit boards and a wide variety of stencil frame sizes.
- A wide range of optional features.
- Easy-to-use with intuitive software.

Surface Mounters: Yamaha YSM20R Surface Mounter

With the ability to be both flexible and fast, operators worldwide are transforming their businesses with this compact but powerful surface mounter.

- Two types of beam variations.
- ‘Smart Recognition’ handles odd shapes quickly.
- Two newly-developed heads in a ‘One-head solution’.

Reflow Solutions: 1809MK5 Series Convection

The Heller 1809 Mark5 Series produces belt speeds up to 1.4m/min to accommodate the fastest pick and place systems and delivers the highest levels of repeatability.

- Heater module response of less than one second to temperature changes of less than 0.1ºC.
- Allows different boards to be run on a single profile.
- Store up to 500 temperature recipes and profile graphs.
About Hawker Richardson

Part of GCEM Group, Hawker Richardson is the leading supplier of industrial production and production machinery and tools in Australia and New Zealand. Established in 1923, Hawker Richardson originated as a machine assembler dealing in specialised metals.

Supporting a range of industries with a wealth of experience
As well as supplying best-in-class industrial production tools and solutions to general manufacturing, aviation, automotive and electronics industry customers, Hawker Richardson provides a wealth of product knowledge, industry experience and unsurpassed service support.

Helping you to achieve your long-term business goals
Working closely with clients of all sizes and budgets, Hawker Richardson offers customised product solutions that not only satisfy the customer’s requirements in the short-term, but equips them with the tools to reach their long-term business goals.

Operating above and beyond the product sell and supply
Hawker Richardson invests in long-term relationships with partners, customers and employees. Committed to supporting customers through and beyond the sales cycle, ensures customers benefit from aftersales care and technical support, transcending most comparative suppliers both in Australasia and around the world.

One of the strengths of Hawker Richardson is in their knowledge of their brands and their problem-solving abilities. They have always come through when we have needed help. Their support throughout equipment installation and their ongoing support has been second to none, and we will no doubt be continuing our relationship long into the future.

Ryan Burke, RØDE Microphones

Hawker Richardson has always been a good supporter of equipment. They have staff who are very knowledgeable in terms of the different sorts of equipment they provide and so if we have a problem, they’re very quick to respond. Anything which is urgent has always been addressed very quickly and they have always been available when we need them as well.

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