BREAKING THROUGH FLUX RESIDUES TO PROVIDE RELIABLE PROBING ON PCBAS- CONSISTENT CONNECTIONS ACROSS DIFFERENT NO-CLEAN SOLDERS, FLUXES AND LAND DESIGNS

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ABSTRACT

No-clean fluxes have been in use for many years, but there is a need for knowledge that allows the industry to better understand the robustness of probing methodologies across different wave and reflow processes. Can different fluxes be used reliably? What pressures and probes are required?

This paper discusses the variety of challenges presented by probing solder pads, including the use of different types of solder, fluxes and land designs.

In this study, concerns involving the reliability of probing different solder/flux compounds, the land configurations, the contact pressures and probe styles will be discussed in detail.

Study Details

Test Boards

A board was designed (Figures 3) to allow the connectivity of multiple solder chemistries to be measured and tested. Each board comprised 16,160 pads:

- 8080 35 mil lands with 54 mil spacing. (Figure 1)
- 8080 35 mil vias with 54 mil spacing.
- Solder Resist 50 mil diameters.

The design also provided source points so the resistance between those points and the measurement point would always match and enabled kelvin measurement technique to be used. (Figure 2)

Using both land and via pad styles allowed testing of the most common probing scenarios. With this design multiple probe tip styles from crown to spear styles could be used to test their effectiveness.

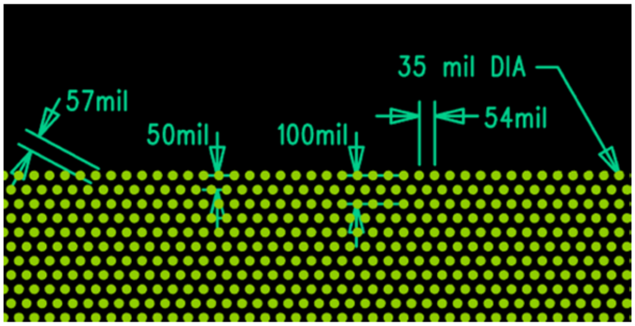


Figure 1: Board Dimentions

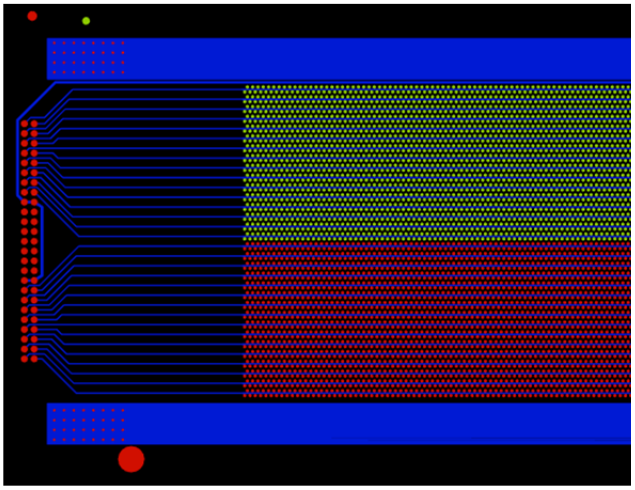


Figure 2: Measurement Points

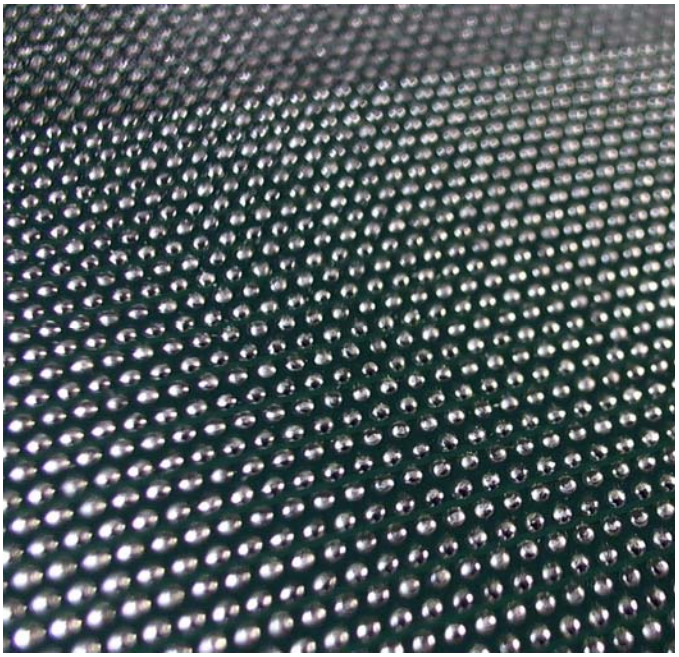


Figure 3: Test Board

Solder and Flux Chemistries

Various processes were employed, corresponding to the specific target applications for each of the tested compounds:

A – High Reliability Solder Paste: This paste was developed for high-reliability applications, where the final assemblies are operating in challenging environmental conditions (high-humidity, wide temperature ranges), and where a large process window (profile, atmosphere) is required by the assembly manufacturer. The paste patterns were deposited using a custom-made laser-cut 5 mil SS stencil. The process followed a standard reflow profile sheet as shown in figure 4. Two boards were used for programming and profiling before the paste was stencil-printed and reflowed in 7 zones convection reflow oven.

B – General Market Paste: This paste is intended for conventional SMT applications and presents robust printing and reflow characteristics. The board processing principles were similar as for paste A.

C – Wave Soldering Flux: This chemical flux was designed with an emphasis on high heat-resistance for the assembly of thick boards using a conventional wave process. The boards were processed on a wave solder machine using with the following profile: Flux deposition 1200 micrograms/in^2, preheat temperature 90C, A silver free alloy (solder pot at 270C) with a solder dwell time of 3s.

Recipe	Slope Between Temperature 35-100	Time Between Temperature 35-217°C	Slope Between Temperature 215-225	Maximum Temperature	Time Above Temperature: Total (+/-) 217°C	Slope Between Temperature 220-200	Maximum Positive Slope	Maximum Negative Slope
(Substrate)	°C/sec	sec	°C/sec	°C	sec	°C/sec	°C/sec	°C/sec
ICT NC-Paste Recipe (Mix16IN)	1.6	147.2	1.3	242.8	62.7	-2.0	2.0	-3.2

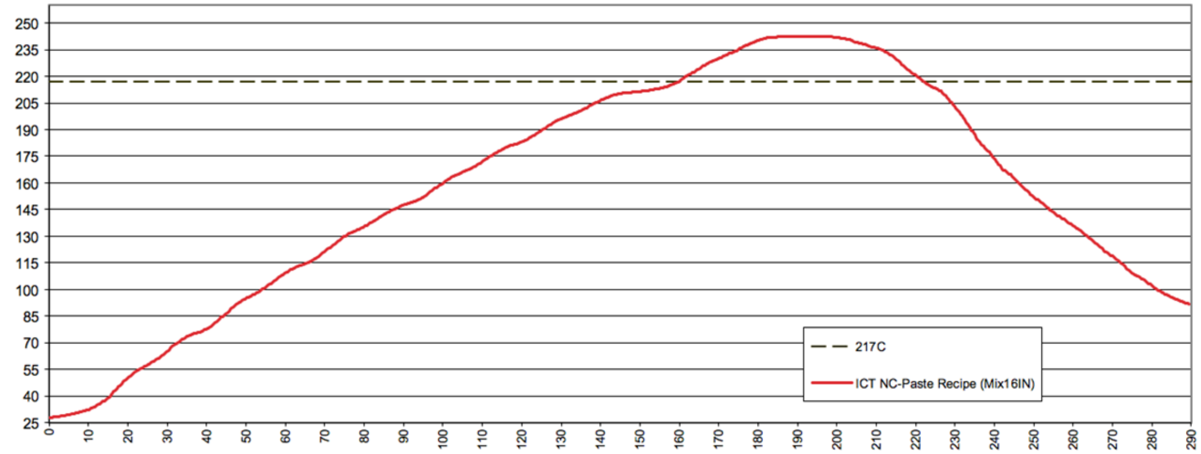


Figure 4: Reflow Profile

D – Selective Solder Flux: A chemical flux specifically designed for selective soldering applications, with an emphasis on dispensability (Drop-jet), limited spread, and high-reliability given the variable heat transfer experienced by the flux in this application. This formula was proven to be reliable from room temperature to liquidus, thus mitigating the risks associated with satellites/unheated or partially activated flux residues. The board preparation was executed on a selective soldering machine, using a drop jet fluxer system using the following process parameters: flux deposition of 3000micrograms/in^2, a board preheat of 90C, and a 3s solder dwell time, solder alloy SAC305, and a solder bath temperature of 290C.

Test Methodology Used

To test each board and Solder/Flux Chemistry, we use flying probe system. The measurement system was selected because it can provide the following capabilities for the study:

- Variable Probe Angle – the probe angle can be adjusted between 0 and 8 degrees, allowing for all probing scenarios to be tested.

- Measurement Capability – the system provided high accuracy 4-wire Kelvin measurements to 0.01 Ohms

- Calibrated probe height and pressure control – the system had to be able to adjust to the height of the board and be able to control the probe pressure between 0 and 3N.

- Accuracy to ensure the same probing positions on each pad. The Condor has a positional resolution of 0.625um.

For the tests we used a rotating pattern to minimize any issues from paste coverage. Each test sample was split into 33 rotating locations over each of the 64 rows. Each row was divided into 3 groups having a High, Low and Soft Landing contact speeds. These 3 groups where then divided into 11 final pressures. (Figure 5)

These speeds are:

1. High Speed = 1402mm/s (55.2 inch/sec)
2. Low Speed = 135mm/s (5.3 inch/sec)
3. Soft landing = 3.6mm/s (0.14 inch/sec)

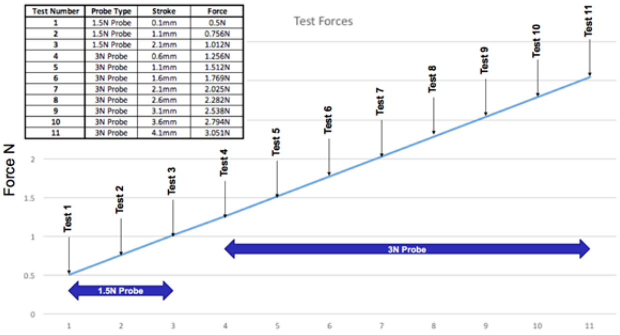
			GKS-112		GKS-100	
Test Number	**Speed**	**Probe Type**	**Stroke**	**Force**	**Stroke**	**Force**
1	**High**	1.5N Probe	0.1mm	0.5N	0.1mm	0.5N
2	**High**	1.5N Probe	1.1mm	0.756N	1.1mm	0.738N
3	**High**	1.5N Probe	2.1mm	1.012N	2.1mm	0.976N
4	**High**	3N Probe	0.6mm	1.256N	0.8mm	1.25N
5	**High**	3N Probe	1.1mm	1.512N	1.3mm	1.5N
6	**High**	3N Probe	1.6mm	1.769N	1.8mm	1.75N
7	**High**	3N Probe	2.1mm	2.025N	2.3mm	2N
8	**High**	3N Probe	2.6mm	2.282N	2.8mm	2.25N
9	**High**	3N Probe	3.1mm	2.538N	3.3mm	2.5N
10	**High**	3N Probe	3.6mm	2.794N	3.8mm	2.75N
11	**High**	3N Probe	4.1mm	3.051N	4.3mm	3N
12	**Low**	1.5N Probe	0.1mm	0.5N	0.1mm	0.5N
13	**Low**	1.5N Probe	1.1mm	0.756N	1.1mm	0.738N
14	**Low**	1.5N Probe	2.1mm	1.012N	2.1mm	0.976N
15	**Low**	3N Probe	0.6mm	1.256N	0.8mm	1.25N
16	**Low**	3N Probe	1.1mm	1.512N	1.3mm	1.5N
17	**Low**	3N Probe	1.6mm	1.769N	1.8mm	1.75N
18	**Low**	3N Probe	2.1mm	2.025N	2.3mm	2N
19	**Low**	3N Probe	2.6mm	2.282N	2.8mm	2.25N
20	**Low**	3N Probe	3.1mm	2.538N	3.3mm	2.5N
21	**Low**	3N Probe	3.6mm	2.794N	3.8mm	2.75N
22	**Low**	3N Probe	4.1mm	3.051N	4.3mm	3N
23	**Softlanding**	1.5N Probe	0.1mm	0.5N	0.1mm	0.5N
24	**Softlanding**	1.5N Probe	1.1mm	0.756N	1.1mm	0.738N
25	**Softlanding**	1.5N Probe	2.1mm	1.012N	2.1mm	0.976N
26	**Softlanding**	3N Probe	0.6mm	1.256N	0.8mm	1.25N
27	**Softlanding**	3N Probe	1.1mm	1.512N	1.3mm	1.5N
28	**Softlanding**	3N Probe	1.6mm	1.769N	1.8mm	1.75N
29	**Softlanding**	3N Probe	2.1mm	2.025N	2.3mm	2N
30	**Softlanding**	3N Probe	2.6mm	2.282N	2.8mm	2.25N
31	**Softlanding**	3N Probe	3.1mm	2.538N	3.3mm	2.5N
32	**Softlanding**	3N Probe	3.6mm	2.794N	3.8mm	2.75N
33	**Softlanding**	3N Probe	4.1mm	3.051N	4.3mm	3N

Figure 5: Test Plan

Across the 33 groups, 4 styles of probes were used: for the 0 degree angle a Spear style, a Pyramid style and Crown style; and for the 8 degree angle the Spear style probes was used. To provide a range of contact forces two styles of probes were used 1.5N and 3N.

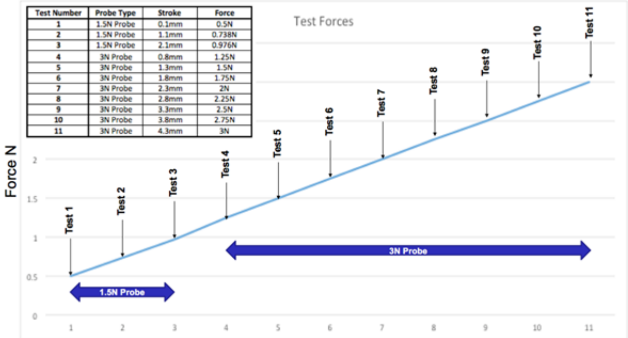
1- Spear head @ 8°
2- Spear head @ 0°
3- Pyramid head @ 0°
4- Crown head @ 0°

The graphs in Figures 6 and 7 show the relationship between force and distance for these probe types.



Test Number	Probe Type	Stroke	Force
1	1.5N Probe	0.1mm	0.5N
2	1.5N Probe	1.1mm	0.756N
3	1.5N Probe	2.1mm	1.012N
4	3N Probe	0.6mm	1.256N
5	3N Probe	1.1mm	1.512N
6	3N Probe	1.6mm	1.769N
7	3N Probe	2.1mm	2.025N
8	3N Probe	2.6mm	2.282N
9	3N Probe	3.1mm	2.538N
10	3N Probe	3.6mm	2.794N
11	3N Probe	4.1mm	3.051N

Figure 6: Forces by Test Number Spear Probes



Test Number	Probe Type	Stroke	Force
1	1.5N Probe	0.1mm	0.5N
2	1.5N Probe	1.1mm	0.738N
3	1.5N Probe	2.1mm	0.976N
4	3N Probe	0.8mm	1.25N
5	3N Probe	1.3mm	1.5N
6	3N Probe	1.8mm	1.75N
7	3N Probe	2.3mm	2N
8	3N Probe	2.8mm	2.25N
9	3N Probe	3.3mm	2.5N
10	3N Probe	3.8mm	2.75N
11	3N Probe	4.3mm	3N

Figure 7: Forces by Test Number pyramid and crown Probes

The test methodology uses a 4-wire kelvin measurement between the row end pads (figure 2) and the pad to be tested. Each of the 16,160 pads is only tested once to ensure the results are not contaminated by previous probing.

Measurements Methodology

As shown in Figure 8, heads 1 and 2 land on locations on the net that are connected to the via or test point being measured. They act as sense and force points and these probes do not move during the test of the 33 locations. Head 3 is equipped with the 1.5N nail for a specific probe shape, while head 4 is equipped with the 3N of the same probe shape. According to the pressure required, either head 3 or head 4 lands on the via or test point being measured.

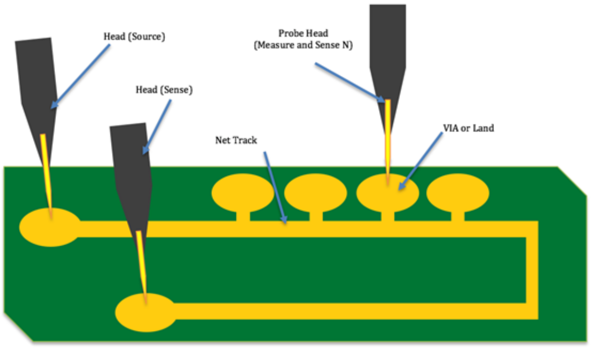


Figure 8: Kelvin Test Probing

The 4-wire, kelvin measurement is done so that force and sense of one side are heads 1 and 2, and the force and sense of the opposite side are wires of either head 3 or head 4.

To achieve the best repeatability a set of measurements are taken using the high limit of 0.1 ohms, an integration of 100ms and a delay of 100ms. If the test fails, another set of measurements are taken with a high limit of 5 ohms using same integration and delay. Each measurement is then recorded.

A measurement will be considered as unsuccessful if it measures over 10 ohms. If successful, it will be considered in the average taken for its group.

To ensure accurate pressure board warping is calculated and compensated for. In addition, solder height is also compensated for on the lands.

Landing of heads 1 and 2 is verified before head 3 or 4 land. To ensure we have no errors from previous probing actions, auto-correction is not allowed to be used on the pad being tested.

RESULTS

In all cases with the correct probe type all pads and Solder/Flux Chemistries could be probed. In all cases the crown heads had the least reliable performance in this study.

To compare the different nail head types, the graphs are re-grouped for easier analysis.

The results for these tests are shown in Appendix's A and B.

Appendix A - Via's

The pyramid head has the best contact success ratio and least resistance on average. Pressure of 1.5 Newton is enough to get almost 100% success rate with contact resistance around 0.05 Ohms for high speed.

With the exception of the General Market Paste the pyramid pins also give the best results for low speed and soft landing. The high speed is a good factor in penetrating General Market Paste.

The spear has a lower contact success ratio and an increased resistance. However, the smaller size of the spear probe, both head and body, provide capability for flying probe and smaller components to be able to access locations that are very close without touching.

It was also noted that for angled probing as pressure increased above 1.5-2.5N, the contact reliability is reduced because of the probe sliding from the via.

Appendix B - For Lands, Test Points and Soldered SMD Pads

For the soldered Land SMD test points, pyramid and crown head types in general are the best. For soft Landing on High Reliability Solder Paste material, the crown head style resulted in the lowest performance.

The study also showed that high speeds works better than low speed and soft landing for spear head types.

CONCLUSION

Overall, land patterns appear more probable than patterns configured with a via. It seems that the presence of vias result in the occurrence of a residue more difficult to penetrate on top of the solder joint.

This effect is apparent at all speeds and for all compounds, except for the wave flux. The vias induce a segregation phenomenon during the process, where the high-molecular weight / poorly probable components of the flux tend to concentrate at the surface, while the lighter/low viscosity components find an escape route in these channels. The wave flux formulations are too low on high-molecular weight components for this effect to be prevalent.

Looking at the results collected on the patterns with vias (e.g. the most discriminative ones), there are clear distinctions in the probability of the components tested in this study. The pastes are generally harder to probe than the selective flux, while the wave soldering formula is the most process-friendly compound. These differences can come from the process (wave soldering vs conventional reflow), but also the formulation strategies adopted for these different classes of compounds. Strong differences in heating profiles, especially in temperature ranges where the organic compounds start to decompose, and atmospheres, combined with the residue-washing effect of the wave can alone induce these significant distinctions in probability. Based on these fundamental processing differences, no-clean pastes will yield larger amount of residues on top of the solder joint. Also, Paste fluxes are generally much more active and prone to leaving hard-to-penetrate residues than wave soldering fluxes. In addition to being responsible for the cleaning of the soldered surfaces, these fluxes also have to interact with reactive (e.g. high-surface surface area) solder powders until consumed (e.g. during their shelf-life), which generally requires the use of larger amounts of activators.

Out of the two tested solder pastes, the High-reliability Paste seems more process-friendly than the General market paste. Significant formulation differences resulted in these distinct behaviors. The key aspect is the formulation of the polymer – rosin components, as well as the presence of high-boiling point solvents which present a plasticizing effect. The end-residue will therefore have different mechanical properties, as highlighted by these probing tests. In addition, it should be noted that the reflow process should have a very significant impact on probing results: both the reflow profile and the reflow atmosphere will affect the physicochemical characteristics of the residue, hence its probability. Therefore, a probing study should be integrated as an extra response to process optimization work. Looking at the other class of compounds, the relatively better probability of wave soldering fluxes compared to selective soldering fluxes can also be explained from a process and a formulation perspective. First, the wave soldering fluxes require relatively larger amounts of fluxes in the soldering area. Also, the silver free alloy used in combination with the wave soldering fluxes resulted in significantly higher bath temperatures than the SAC305 alloy employed for the selective process.

Finally, from a formulation perspective, the selective flux was designed to be more heat resistant, to cope with the longer preheating time associated with the selective process, but also to the use of thicker boards. To achieve these performance improvements, the amount of heat-resistant formulation components was significantly increased, resulting in larger amounts of residues. These residues were thoroughly tested for their electrochemical reliability (Electrochemical Migration, SIR, Corrosion, according to IPC-TM-650 standards) in a very large process window envelope (from room temperature to reflow). It is interesting to note that in all situations (pad configurations, class of compounds, process, formula specificities) there is always a robust probing technique available as long as one is willing to spend the time to execute studies described above.

Probing Guidance

The study clearly proved that all of these Solder and Flux Chemistries can be reliably probed.

For the reader of this study we can provide some guidance to the pressure and probe tip style to use with the different flux and pad styles. This guidance is based on the probes and compounds used in this study.

Note: Force noted is minimum force advised.

General

Vias:
Tip - Pyramid
Force - 2N
Contact Speed - High Speed Contact

Lands:
Tip - Crown
Force - 2N
Contact Speed - High Speed Contact

By Compound

General Market Paste on Vias:
Tip - Pyramid
Force - 1.5N
Contact Speed - High Speed Contact

High Reliability Paste on Vias:
Tip - Pyramid
Force - 1.5N
Contact Speed - High Speed Contact

Selective Solder Flux on Vias:
Tip - Pyramid
Force – 1.5N
Contact Speed - High Speed Contact

Wave Soldering Flux on Vias:
Tip - Pyramid
Force - 2N
Contact Speed - High Speed Contact

General Market Paste on Lands:
Tip - Crown
Force - 1.5N
Contact Speed - High Speed Contact

High Reliability Paste on Lands:
Tip - Pyramid
Force - 2N
Contact Speed - High Speed Contact

High Reliability Paste on Lands:
Tip - Crown
Force - 1.5N
Contact Speed - High Speed Contact

Selective Flux on Lands:
Tip – Crown
Force - 2N
Contact Speed - High Speed Contact

ACKNOWLEDGEMENTS

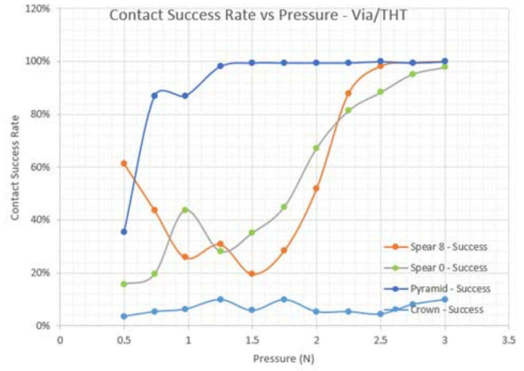
1. ERSA - Joe Clure – Selective Soldering

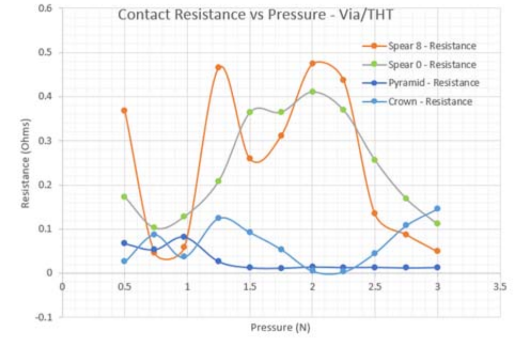
REFERENCES

[1] Ingun, Force-Stroke Measurements, Version 03/14
[2] ICP SEP010 LF242
[3] IPC-TM-650

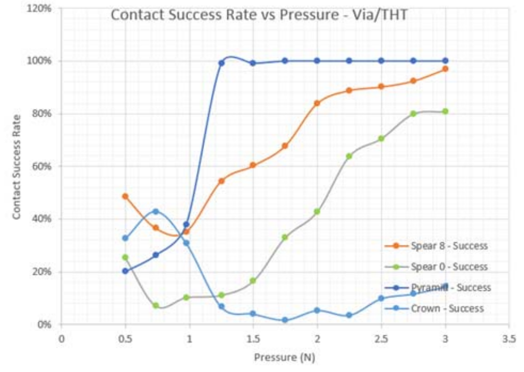
APPENDIX A: Via’s

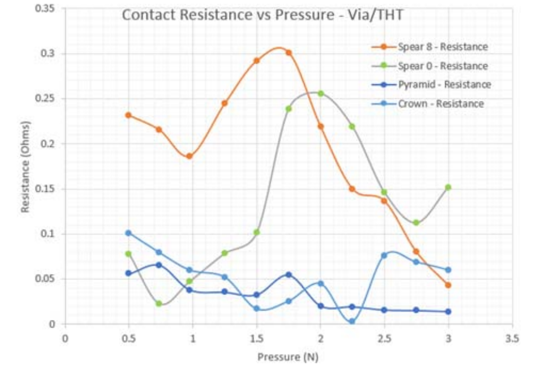
General Market Paste – via – High Speed



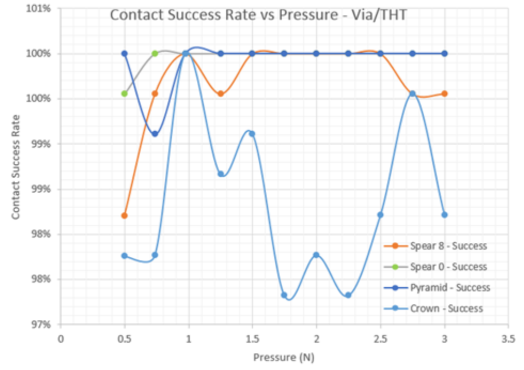


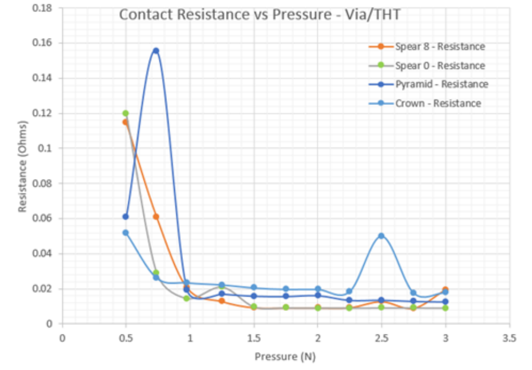
High Reliability Paste – via – High Speed



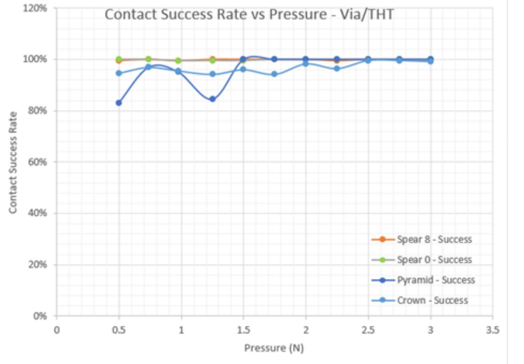


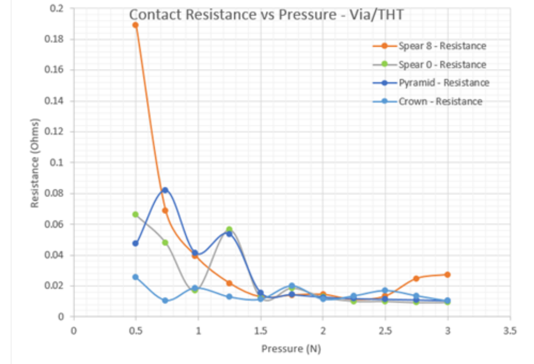
Selective Solder Flux – via – High Speed



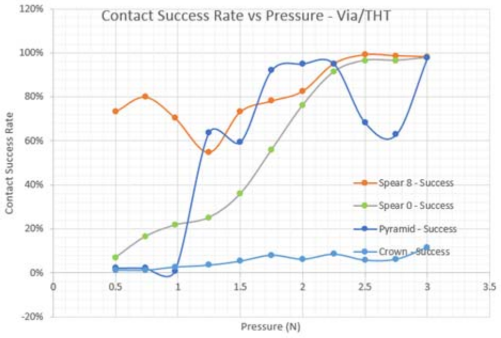


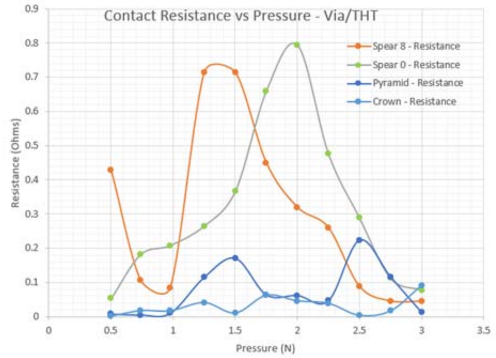
Wave Soldering Flux – via – High Speed





General Market Paste – via – Low Speed





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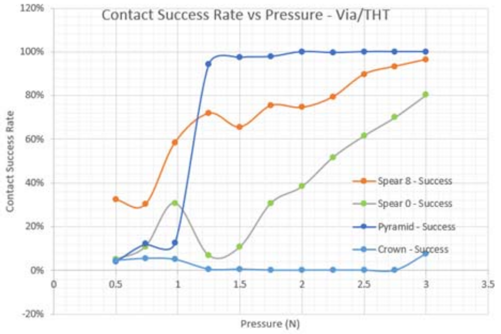
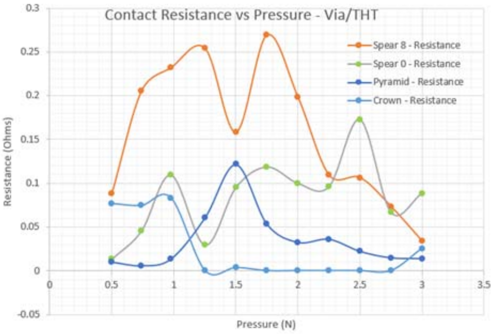
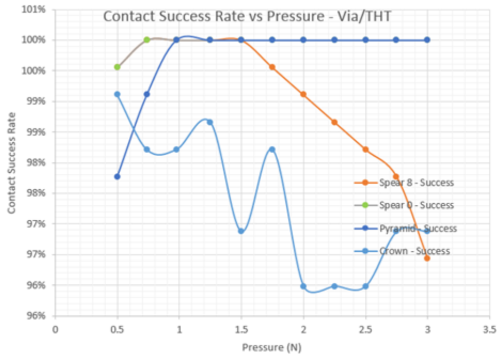
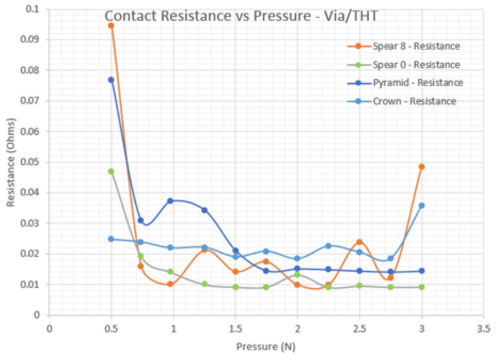


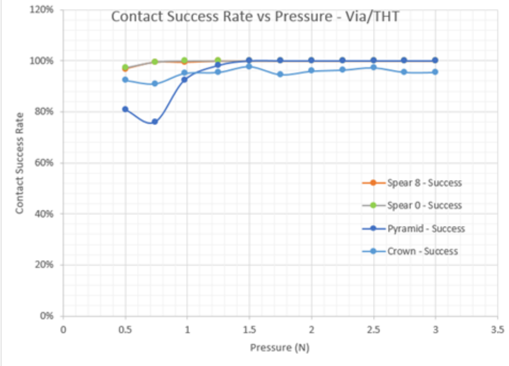


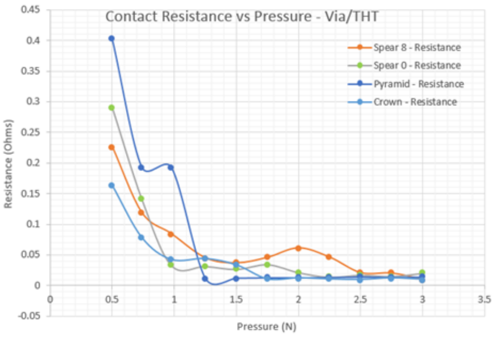
Selective Solder Flux – via – Low Speed



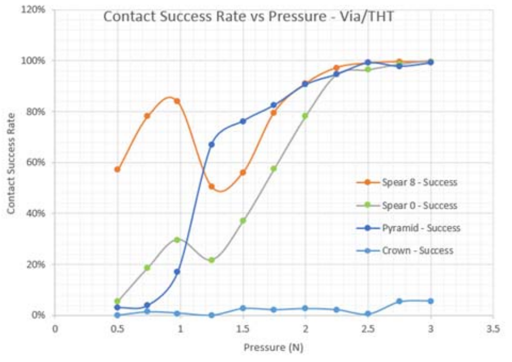


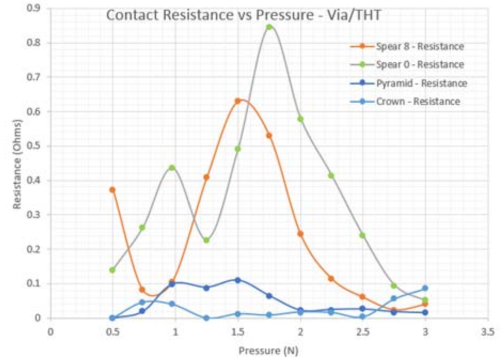
Wave Soldering Flux – via – Low Speed



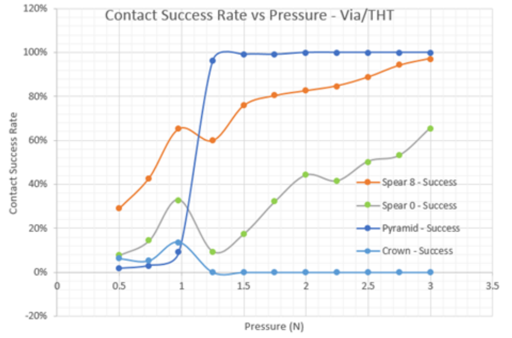


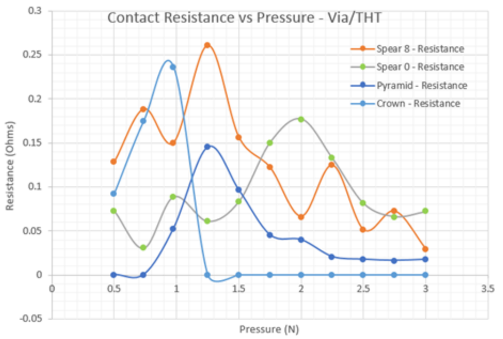
General Market Paste – via – Soft Landing



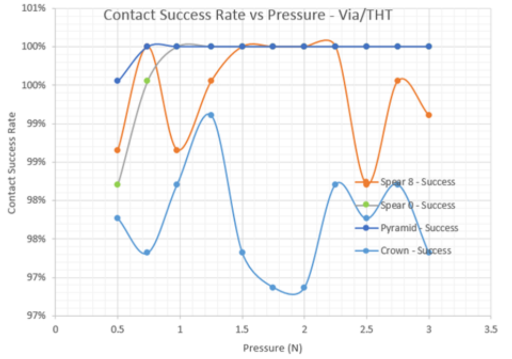


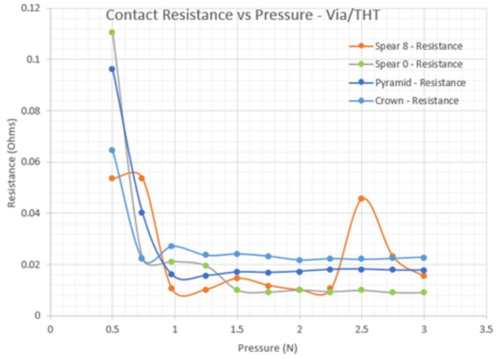
High Reliability Paste – via – Soft Landing



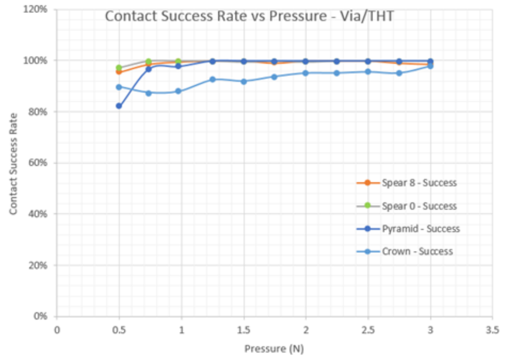


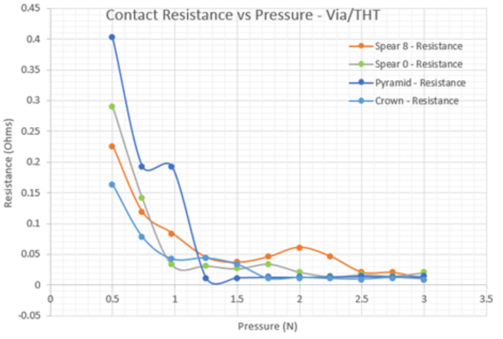
Selective Solder Flux – via – Soft Landing





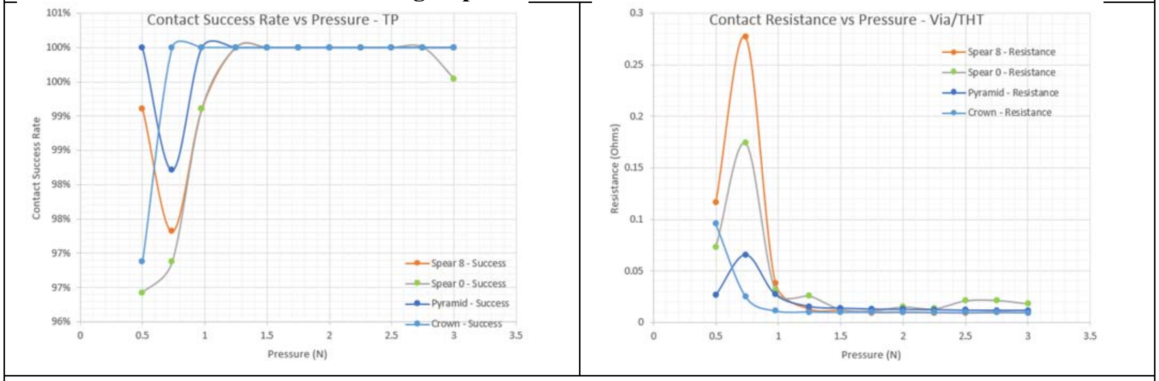
Wave Soldering Flux – via – Soft Landing



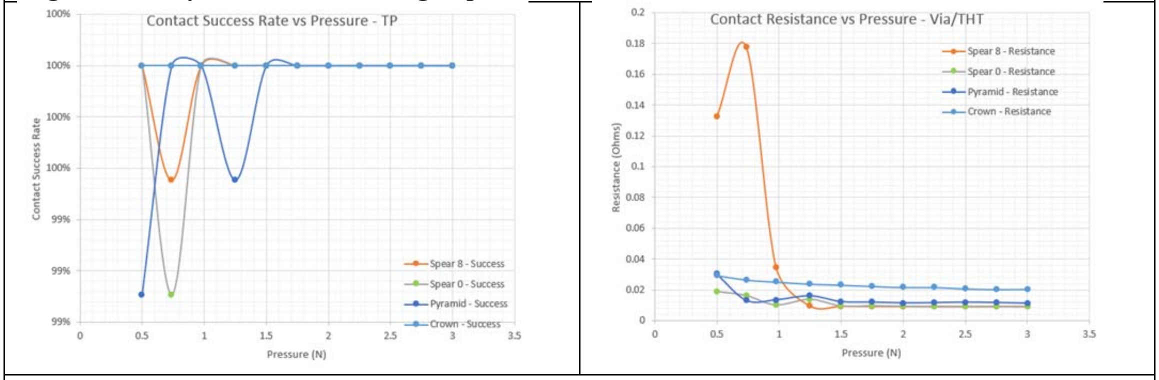


APPENDIX B: For Lands, Test Points and Soldered SMD Pads

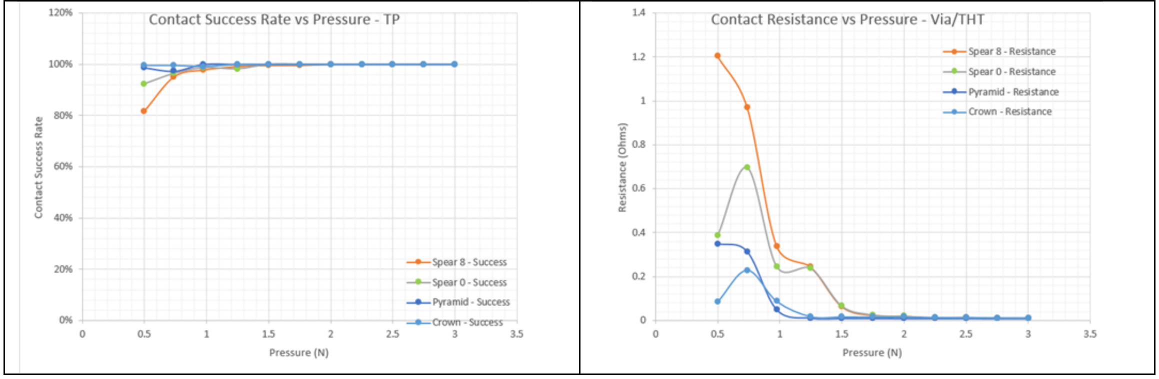
General Market Paste – Land – High Speed



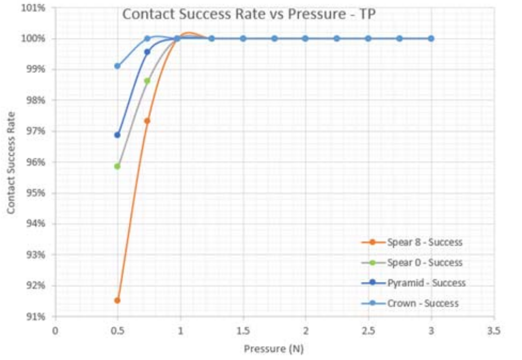
High Reliability Paste – Land – High Speed

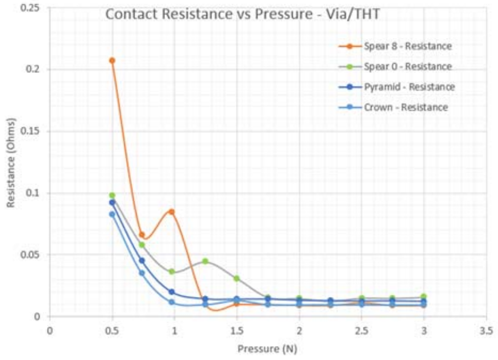


Selective Solder Flux – Land – High Speed

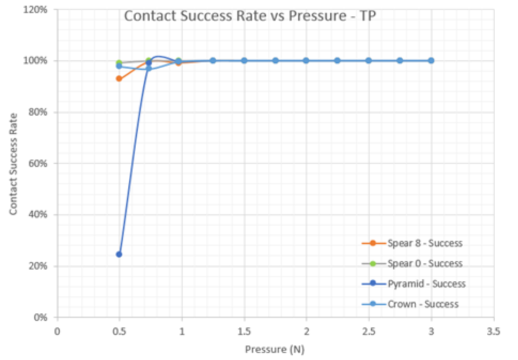


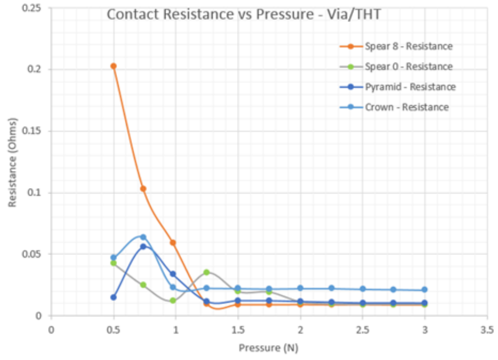
General Market Paste – Land – Low Speed



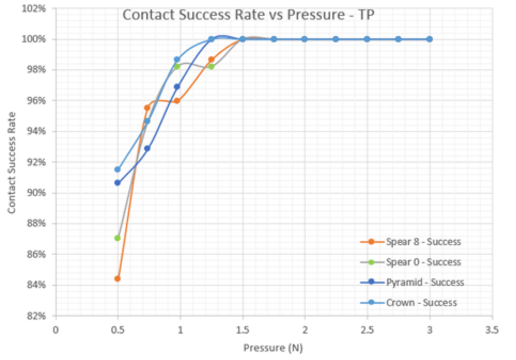


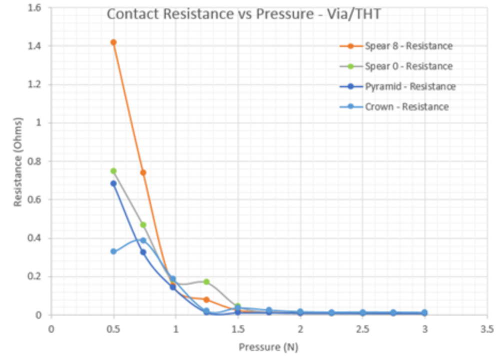
High Reliability Paste) – Land – Low Speed



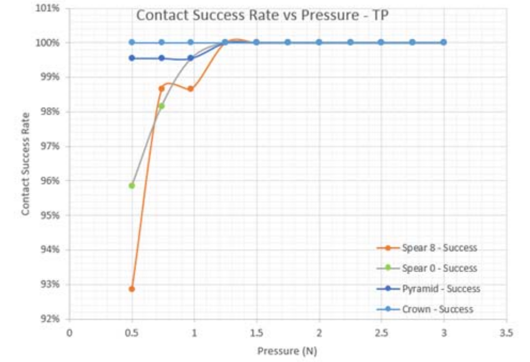


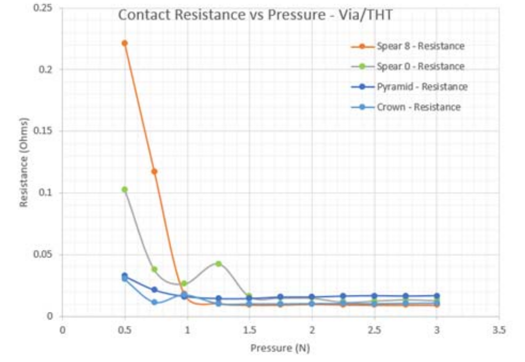
Selective Solder Flux – Land – Low Speed



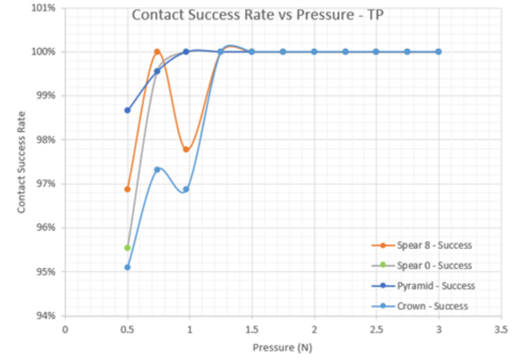


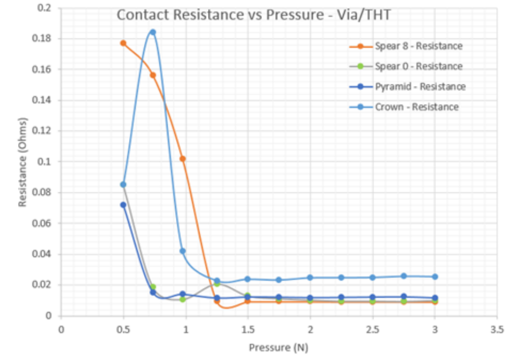
General Market Paste – Land – Soft Landing





High Reliability Paste – Land – Soft Landing





Selective Solder Flux – Land – Soft Landing