## Thin Foil Printing in Today's Miniaturized World: Do Printing Rules Change?

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#### ABSTRACT

As components get smaller, assembling them gets harder. To conquer the never-ending challenges of SMT processing, engineers rely on design rules to help nip problems in the bud. One of the most popular rules is the Area Ratio of stencil apertures, which helps predict the amount of solder paste released onto the PCB pad, as well the print process' repeatability.

A series of experiments were devised and executed to test the well-known Area Ratio rule at stencils with foil thicknesses of less than 4 mil (100  $\mu$ m). Different solder paste powder types and nanocoatings were also variables in the tests. The results will be discussed in terms of the currently accepted Area Ratio Rule, the Five Ball Rule and the Three Ball Rule.

Key words: Area Ratio, Stencil Printing, Thin foils, SMT Miniaturization, Nanocoating, SMD Pads

#### INTRODUCTION

A stencil aperture's **Area Ratio** (**AR**) is a simple calculation that divides the area of the aperture opening by the area of its wall. It was derived in the 1990's and compares the adhesive forces of the solder paste deposit on the PCB pad with the adhesive forces of the solder paste on the stencil walls. For the material to transfer efficiently, the forces holding it to the pad must overcome the forces holding it to the aperture walls. Therefore, calculating the relative areas represents the relative adhesive forces affecting solder paste release.

The amount of solder paste released from an aperture is referred to as **Transfer Efficiency (TE)** and expressed as a percent of total aperture volume. Stencil or solder paste release characteristics are often illustrated by plotting TE against AR.

AR guidelines were originally set at 0.66 as a minimum to ensure good (>80%) TE. Many of these original guidelines have been relaxed due to improvements in solder paste, stencil materials and

nanocoatings. With good materials, equipment and tooling, and robust printing practices, apertures with ARs as low as 0.50 can often be printed in production on 4 mil thick stencil foils with excellent results.

Maintaining ARs of 0.50 or greater can be difficult for the stencil designer. Miniaturization is now driving finer and finer features, which, in turn, is driving thinner foils to meet classic AR design rules. This raises the question:

#### Do classic design rules apply in the case of thin foils?

#### EXPERIMENT Design



Figure 1. Print-To-Fail Patterns and Aperture Shapes

A simple 2x2 factorial experiment was devised using the Print-To-Fail (PTF) patterns of the SMTA Miniaturization Test Vehicle<sup>1</sup> shown in Figure 1. The PTF patterns have pads that are square, circular or rectangular, solder mask- and non-solder mask-defined, in widths of 3 to 15 mils. Solder Mask Defined (SMD) pads are also referred to as simply "mask defined;" Non-Solder Mask Defined (NSMD) pads are also referred to as metal- defined or copperdefined. Each pad's corresponding apertures are either the same shape as the pad (S) or are square/rectangular with radiused corners (R). There are 32 datapoints on each print. Each dataset is made up of 20 prints, for a total of 640 datapoints for each combination of shape, definition, size and aperture geometry in the database.

Four stencils were tested: 2 and 3 mil thickness, with and without nanocoating.  $^{\rm 3,4}$ 

The solder paste used in this test was Indium 8.9 HF Type 5-MC. The powder particle size distribution was the standard 15-25  $\mu$ m diameter. Type 4 was tried but showed too much variation on thin foils to be considered acceptable; therefore, the results for the Type 5 solder paste are analyzed and presented.

#### Execution

Print tests were performed in Koh Young America's demo room in Duluth, GA, using the following equipment set:

- Printer: MPM Momentum BTB
- Support tooling: Quick Tool; 3 modules
- Clamps: EdgeLoc with retracting top foils
- Squeegees: MPM FP100, 250 mm length
- Stencils: 2 and 3 mil BlueRing Nano-Slic Gold and Uncoated Fine Grain (Slic) stencils
- SPI: Koh Young 10 um aSPIer3
- SPI Height Threshold: 20 μm

The print parameters were:

- Speed: 30 mm/sec
- Pressure: 7.0 kg
- Separation Speed: 5.0 mm/sec
- Separation Distance: 3.0 mm

The under-stencil wipe parameters were:

- Speed: 30 mm/sec
- Sequence: wet/vac/vac or wet/vac/vac/dry
- Frequency: 1 (after each print)

Each test run began with 4–6 knead strokes to assure the solder paste reached its working viscosity and 2–7 setup prints to verify proper print performance and paste alignment before running the 20 data-producing prints. Execution time for the tests were approximately 30 minutes each, with continuous printing, under wiping and inspection.

#### Analysis

Data was exported to a \*.csv file and imported to Excel for manipulation. A pivot table was created to review the solder paste volumes, TEs and CVs. Refer to Appendix A for details on the data manipulation methods.

#### Process Capability and the Coefficient of Variation

The Coefficient of Variation (CV, CoV or CofV) is calculated as the standard deviation of a population divided by its mean. Applied to solder paste deposits, CV represents the spread of the volume, height, area or offset data. Because the average volumes of solder paste deposits vary based on many input variables, basic standard deviations should not be used to evaluate different distributions of data. Expressing the variation as a percent of the average normalizes it for better comparison.

As solder paste deposits become smaller, minimizing their variation becomes more critical:

- As passive devices get smaller, they are more prone to positional, rotational or tombstone-type defects related to print quality.
- As integrated circuit packages get smaller and leadless, they are more prone to Head-in-Pillow, insufficient solder joints, voids and intermittent opens related to print quality.

Controlling the variation in print volumes limits the opportunities for defective solder joints and their associated rework or failure costs.

A widely accepted guideline for solder paste deposit CVs is:

- <10%: preferred
- 10-15%: acceptable
- >15%: unacceptable



**Figure 2.** Normal Distribution as it relates to solder paste volume variation

These guidelines are based on principles of Statistical Process Control (SPC). Assuming a normal distribution of data as seen in Figure 2, 99.7% of the data should fall within  $\pm$ -3 standard

deviations of the mean. If we apply a typical SPI control limit of +/-50%:

- CVs of 10% will produce 99.7 % of deposits within +/-30% of the target volume, leaving plenty of room for outliers or special causes of variation.
- CVs of 15% will produce 99.7% of deposits within +/-45% of the target volume, leaving little room for variation.
- CVs of 16.7% or higher will produce deposits outside the control limits, indicating an out-of-control process.<sup>2</sup>

In this study, CVs were analyzed first to distinguish datasets worth investigating from those that were not. Datasets with CVs of 15% were reviewed prior to inclusion into the database.

#### Disqualification of the smallest deposits

Upon review of the data and PCBs, 3 and 4 mil deposits were removed from the results. Their CVs were all greater than 15%, and inspection of the PCBs revealed that many of the NSMD pads less than 5 mils were missing from the bare PCBs. This did not come as a surprise, as features that size present challenges to fabricators, who were granted waivers for features 5 mils or less.



Figure 3. Missing pads in PTF test patterns

The pivot table results of the different combinations of foil thickness, coating, pad shape and pad definition and the calculated CVs can be seen in Appendix B.

Unacceptable levels of variation were demonstrated by the 3 and 4 mil feature sizes; further statistical analysis was performed on the data from pads 5 mils and larger.

#### RESULTS

The SPC Run Charts shown in Table 1 illustrate the effects of pad definition.

There is a sharp contrast in print variation between the solder mask defined and the copper-defined pads. In the best-case printing scenario of solder mask defined square pads, the CV of 12% indicates that 5 mil features can be printed repeatably using a 2 mil coated foil; the CV of 11% indicates the same for a capability with a coated 3 mil foil.

The CVs for copper defined pads were over 20% for both 5 and 6 mil features. The process of printing on copper defined pads did not show preferred capability (CV < 10%) until feature sizes of 7 mils, even with square pads, which performed better than round ones.



#### Table 1. Run charts of print data for square SMD and NSMD pads



Figure 4. TE chart for 2 mil coated foil



Figure 5. TE chart for 3 mil coated foil

The transfer efficiencies also vary greatly between solder mask and copper defined pads. Solder mask defined pads offer better gasketing than copper defined ones, and limit the amount of "squeeze out," or excess solder paste to transfer from the aperture to the PCB.

Figures 4 and 5 show the contrast in TE between the two pad designs for the 2 and 3 mil foils, respectively.

Regardless of foil thickness, the TE curves both show the same trends regardless of pad or aperture shape: for mask defined pads, TE's showed typical behavior, but on copper defined pads, excess paste was the rule rather than the exception.

On solder mask defined pads, TE is approximately:

- 70% at 5 mil
- 80% at 6 mil
- 90% at 7 mil
- 96% at 8 mil

These are all reasonable transfer rates with preferred or acceptable CVs.

On copper defined pads, TEs averaged:

- 140% at 5 mil
- 140% at 6 mil
- 130% at 7 mil
- 125% at 8 mil

These TE rates, coupled with highly unacceptable CVs on copper defined pads most likely indicate a lack of good gasketing between the pad and the stencil.



Figure 6. Main Effects Plot and Pareto Diagrams Presented at SMTA International 2021

The run charts also show unanticipated spread in the data for prints 3, 13 and 19. The effects are more pronounced on the smaller features. This will be discussed in detail in the discussion section addressing pad definition.

The Main Effects Plot shown in Figure 6 demonstrates the influence of the individual factors on print volume repeatability. The axis values have been omitted to focus on the relative impact of each and the inputs that minimize it.

The #1 factor influencing print repeatability was the stencil coating. Feature size was a close second, followed by pad definition. With lesser influence, the 2 mil foil produced more consistent print volumes than the 3 mil foil. Pad shape and aperture corner type had negligible influence on print variation.

#### DISCUSSION

#### **Top Factors in Variability**

As indicated in Figure 6, the stencil coating is the top factor in minimizing variation. It is also obvious in the side-by-side comparisons of TE and CV in appendix B, which show that the coating provides better print repeatability (lower CV) for every pad design configuration.

Although not quantified, cleanability was a considerable factor noticed during the testing. It was observed that the coated stencil released the paste to the automatic underwiping system far better than the uncoated one. The thin layer of smeared solder paste particles and flux that was left behind on the stencil after the auto wipe likely factored into its poorer print results.

The influence of pad size – the fact that the bigger the feature the easier it is to print – is related to AR, but does not necessarily follow general AR rules.

#### **Pad Definition**



Figure 7. Comparison of PCB Pad definition

Figure 7 shows a basic diagram comparing the two methods of designing PCB solder pads. Non-Solder Mask Defined (NSMD) pads are etched onto the PCB at their nominal size. It is not uncommon however, to find pads over etched – *or undersized* – by up to 2 mils.



Figure 8. DFX impacts of pad definition

Figure 8 further describes features of the different types of pad definition. Given that smaller pad sizes are more susceptible to overetching, growing the copper size by 6 mils makes it much easier for the fabricator to etch – even it if gets overetched by (an acceptable) 2 mils, there is still enough room for the solder mask to encroach on all sides. When all edges of the pad are covered with solder mask, the mask provides an excellent gasketing surface for the stencil, resulting in less variation in print quality, and typically, slightly higher volumes.

When pads are metal defined they are naturally harder to gasket to than mask defined pads, but their propensity to be overetched exacerbates the gasketing problem. Poor gasketing of NSMD pads leads to excess solder paste deposition, as seen in Figures 4 and 5.

Another deleterious effect of overetched PCB pads is their impact on true AR. Recall that AR is calculated as the ratio of the area of the aperture opening to its walls. This calculation is based upon the assumption that the aperture opening fully contacts the PCB pad. When the pad is smaller than the stencil aperture, it does not offer as much area for the solder paste to stick to, thereby reducing the true AR and introducing additional variation to the process.

Traditional pad design, especially for BGAs, generally trends toward NSMD pads, because the solder mask relief enables molten solder to wrap around the edges of the pad, giving the solidified joint more shear strength than with SMD pads (Figure 8). For larger BGAs with feature sizes that are more easily printed and experience greater displacement during thermal expansion, NSMD pads are still generally preferred But in the case of very small features, mask defining them can actually add shear strength between the pad and the PCB due to the larger area of the pad and the reinforcement of the mask. As previously mentioned, the fabrication notes for this test PCB allow a waiver for pads 5 mils and smaller. Inspection of the incoming PCBs showed many were missing their 3 and 4 mil NSMD pads (Figure 3) and some of the 5 mil NSMD pads were barely visible. The run charts in Table 1 show excessive noise for print numbers 3, 13 and 19, particularly on the NSMD pads. The issue appears to resolve as the feature sizes get larger, and only appears on the smallest SMD pads. The source of the noise in these three prints could likely be attributed to overetch of the pads on those specific PCBs.

#### **Aperture Shape**

Aperture shape had very little impact on print quality. This appears to contradict prior data generated on larger feature sizes and generally accepted design rules relating to radiusing aperture corners to improve paste release and repeatability.



**Figure 9.** The effect of rounding aperture corners as aperture sizes shrink.

Typically, stencil manufacturers put a 2 mil radius on square apertures, and often apply the "squircle" aperture to round pads. At feature sizes under 8 mil, the radius is 25% of the side length of the square. As the squares get smaller and 50% of their side length is part of the corner radii, the squircle shapes become more circular than square, as seen in Figure 9, and the performance difference becomes relatively inconsequential.

#### **Pad Shape**

In a trend similar to the contradictory nature of the aperture shape results, pad shape had very little influence on print variability. The advantages of square pads (from a print perspective) also appear to dwindle as their size shrinks.

#### The Area Ratio Rule

Area ratios increase as foil thicknesses decrease. But with foils less than 4 mils thick, the difference is more dramatic.



**Figure 10.** AR of small features increases dramatically as the foil gets thinner.

An 8 mil feature size has an AR of 0.50 on a 4 mil foil, 0.67 on a 3 mil foil, 1.0 on a 2 mil foil! Similarly, the AR for a 6 mil feature climbs from 0.5 on a 3 mil foil to 0.75 on a 2 mil foil!

With respect to print volume variation, size was a greater factor than AR. In many cases of mask defined pads, variation was acceptable or preferred for features 5 mils and larger.

With respect to TE, pad definition had a far greater effect on print capability than AR.

In the best cases of SMD pads and coated stencils, 5 and 6 mil features were the smallest to print successfully – on both 2 and 3 mil foils. The lowest AR of this combo was 0.42 and the highest was 0.75. However, in other scenarios, acceptable printing wasn't achieved until 8 or 9 mil feature sizes, with much higher ARs.

The Area Ratio Rule of 0.60 or higher cannot be applied to all situations when using thinner foils. Considering that foil thickness has 4 times the influence of aperture size on AR (the algebraically reduced AR calculation for circles is D/4t, where D is the diameter of the circle and t is the foil thickness and similar for squares as S/4t, where S is the side length of the square and t is the foil thickness), AR may no longer be the best overall indicator of solder paste release.

In this test, pad size and definition are the key design factors, and stencil coating is the key manufacturing factor. Size may be related to the three- and five-ball rules, yet to be discussed, but pad definition is related to design. Having the correct pad contact area to produce a true AR scenario and the benefit of good gasketing makes the biggest difference in printability of these fine features with thin foils.

When considering stepping a 4 mil stencil down to 2 or 3 mils to accommodate fine features, it should be noted that in these tests, both the 2 and 3 mil coated foils printed relatively comparably. Given similar results between the two thicknesses and faced with a choice, an assembler might consider stepping down to 3 mils as opposed to a 2 mils, as it would result in a more robust stencil with a longer production life.

#### **Three Ball Rule**



Figure 11. The "Three-Ball" Rule

The Three Ball Rule states that a stencil's thickness should be at least three times the diameter of the *largest* ball. A common corollary states that it should be at least three times larger than the *average* ball diameter. They are illustrated in Figure 11.

The Type 5 solder paste had the majority of its particles in the 15-25 micron range. Assuming the largest is 25  $\mu$ m and the median is 20  $\mu$ m, both scenarios can be theoretically tested:

- 3\*25=75µ, or 3 mil
- 3\*20=60µm. or 2.4 mil

The thinnest foil to produce good prints was 2 mils. Again, it appears that pad design and stencil coating enable this capability. For the uncoated stencils, the 2 mil printed better than the 3 mil for SMD pads; for the coated stencils, the 2 and 3 mil foils both printed comparably on the SMD pads.

The three ball rule does not appear to apply to SMD pads in this test, perhaps because the mask definition creates a "well" that effectively increases the depth of the aperture with respect to solder paste filling, but does not negatively influence release from the aperture.

#### **Five Ball Rule**



#### Figure 12. The "Five Ball" Rule

The Five Ball Rule states that a stencil's minimum aperture width should be at least five times the diameter of the largest ball. As with the Three Ball Rule, an existing corollary states that it should be at least five times larger than the average ball diameter, as seen in Figure 12.

So again, assuming the largest particle has a 25  $\mu$ m diameter and the median has a 20  $\mu$ m diameter, both scenarios can be theoretically tested:

- 5\*25=125 µm, or 5 mil
- 5\*20=100 μm, or 4 mil

The finest feature to print successfully on SMD pads, was 5 mils. Even in the best-case scenario, the 4 mil pads demonstrated too much variation to be considered valid data worth analyzing.

To interpret the Five Ball Rule with respect to thin foil printing, this data indicates that the largest ball diameter should be applied. However, it can only be applied to SMD pads, as NSMD pads produced unacceptable print volume variation.

#### CONCLUSIONS

In the context of solder paste stencil printing, reducing variation has always been as important as maintaining high transfer rates. However, in leading edge electronic miniaturization, where excess variation is the root cause of most soldering problems, it is arguably more important than average paste transfer rates. This analysis reviewed transfer rates, actual volumes and variation, with the focus on factors that minimize variation.

The factors that minimize variation can be grouped into two distinct categories: *Design* and *Manufacturing*.

With respect to product design, Solder Mask Defined pads and the sizes of those pads had the largest influence on repeatability. SMD pads are easier for PCB fabricators to make, and easier for SMT assemblers to print. It is highly recommended that any PCB features smaller than 8 mils should be mask defined (when using a Type 5 solder paste), and as pad sizes get smaller, the positive effects of mask defining the pads becomes more obvious.

With respect to manufacturing, coating the foil with the flux-repelling ceramic nanocoating has the largest influence on reducing variation. In fact, on Non-Solder Mask Defined (NSMD) pads, uncoated stencils were not capable of meeting the preferred CV metric of <10% for any features 8 mils or smaller, and in only one situation met the acceptable value of <15%. Uncoated stencils were also very difficult to clean using automatic underwipe.

Foil thickness appeared to have a considerable effect on print variation; however, a very profound effect was seen on the

uncoated stencils, and detailed review of the actual results between 2 and 3 mil coated foils are extremely close with respect to both actual volumes and CVs.

With respect to the traditional guidelines of The Area Ratio Rule, the Three Ball Rule and the Five Ball Rule, some principles may still apply, and some may not.

In the context of SMD pads and coated stencils, an AR of 0.6 or higher can be applied to the 2 and 3 mil stencils. Both fell a little shy of 80% TE goals, but met CV goals of <10%, indicating viable processes that could likely be optimized with further statistical analysis of the stencil design and processing parameters.

The Three Ball Rule was tested with both the largest and average sized solder particle and did not comply with the 3X guidance. It predicted minimum foil thicknesses of 3.0 and 2.4 mils, respectively, for the largest and average size particles. The thinnest foil to print successfully was actually 2 mils thick, thinner than the rule predicts. It should be noted again that the difference between SMD and NSMD pads was pronounced, and the successful printing occurred on the SMD pads. SMD pads may offer an advantage in aperture filling due to the extra depth they provide, but do not offer a disadvantage in paste release, which is based on stencil wall contact.

The Five Ball Rule may still partially apply. The finest feature to print repeatably was 5 mils, or  $125 \,\mu\text{m}$ , exactly 5X the diameter of the largest ball, and only with coated stencils. None of the 4 mil features printed repeatability, even when mask defined and with a coated stencil.

#### **DFX Takeaways:**

- The best thing that designers can do to improve the producibility and reduce the cost of miniaturized electronics, is to *solder mask define the PCB pads*.
- The best thing that a PCB assembler can do to limit variation and improve yields is to *nanocoat the foils, no matter how thin they are.*

#### POTENTIAL FUTURE WORK

Similar tests using the same solder paste formulation<sup>5</sup> have been performed with Type 4 solder paste and 4 mil foils. Those tests have indicated that the T4/4mil combination

repeatably prints (CV<10%) NSMD pads down to 10 mil, and SMD down to 9 mil and in some cases, 8 mil. Because the data were generated on different equipment sets at different locations and times, the data cannot be directly compared. Ideally, however, a consistent data set that compares performance of T4 with 4 mil foil and T5 with the 4 mil foil can help determine the best print scenarios for features in the 6-10 mil size range.

Smaller particle sizes present greater reflow challenges. If possible, on future print tests, a few extra boards should be printed at the end of the test and reflowed to help determine fusion (non-graping) characteristics of the solder paste, and the possible effects of inerting the reflow environment.

Ultimately feature sizes will continue to shrink, and technology will continue to develop. Type 5.5 and 6 solder pastes will probably be tested in the near term, as will newer foil materials that can retain specific print properties with lower profiles.

Type 5 solder paste presented underside cleaning issues with uncoated stencils in this test. In other tests, it has also presented similar issues in off-line stencil cleaning and misprinted board cleaning. Studies comparing the cleanability of wet T4 and T5 solder pastes would be beneficial in preparing for the inevitable transition to finer powders as electronic assemblies continue to shrink.

#### REFERENCES

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# APPENDIX A Export and Analysis of SPI data

## Step 1: Select Data

Note: The directions given here are for the SPI system used in this test. Users should consult with their manufacturer for specific export directions. In the SPC setup menu, choose the data and format to export:



Exporting just the data needed limits the size of the database, and reduces the cleanup work during analysis. Furthermore, exporting in mils precludes the need to convert it once in Excel or Minitab, and presents more user-manageable values versus inches or µms.

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## Step 2: Export Data

- Go to "ListView" in the SPC program
- Select the Start and End Dates and click "View"
- Locate and select the desired records
- Click "Result Export"
- Repeat for each of the individual runs (stencil thickness, coating)

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| 128 Local         | 412 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 9:0    | 9:58 AM     | : 10:05 AM    | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG Setup   |
| 129 Local         | 413 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 9:1    | 15:40 AM 9  | :15:47 AM     | sv        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG Setup   |
| 130 Local         | 414 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 9:1    | 19:31 AM 9  | 19:38 AM      | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG Setup   |
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| 132 Local         | 416 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 9:4    |             |               |           | PASS     | C: \Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb   | SMTA V2 PTF Bottom V2 2 mils NSG   |
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| 139 Local         | 423 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 9:5    | 58:38 AM    | :58:45 AM     |           | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 140 Local         | 424 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :02:23 AM   | 0:02:30 AM    | sv        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2-2 mils NSG   |
| 141 Local         | 425 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :03:38 AM   | 0:03:45 AM    | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 142 Local         | 426 SMTA V2 PTF Bottom V2 2 mis   |                   | :05:08 AM   |               |           |          | C: \Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb   | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 143 Local         | 427 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :06:28 AM 1 | 10:06:35 AM   |           | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 144 Local         | 428 SMTA V2 PTF Bottom V2 2 mis   | 2021-08-24 10     | :08:30 AM   | L0:08:37 AM   |           | PASS     | C: Kohyoung Job (SMTA V2/SMTA V2 PTF Bottom V2 2 mils.mdb   | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 145 Local         | 429 SMTA V2 PTF Bottom V2 2 mis   | 2021-08-24 10     | :10:07 AM   | 0:11:42 AM    |           | PASS     | C: Kohyoung Job SMTA V2/SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mills NSG  |
| 147 Local         | 431 SMTA V2 PTF Bottom V2 2 mis   | 2021-08-24 10     | -12-51 AM   | 0-12-58 AM    |           | PASS     | C: Wohyoung Job SMTA V2/SMTA V2 PTF Bottom V2 2 mils mdb  | SMTA V2 PTF Bottom V2 2 mile NSG   |
| 148 Local         | 432 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :14:01 AM   | 0:14:08 AM    |           | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 149 Local         | 433 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :15:42 AM   | 0:15:49 AM    |           | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 150 Local         | 434 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :17:13 AM   | 0:17:20 AM    | SV        | PASS     | C: \Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb   | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 151 Local         | 435 SMTA V2 PTF Bottom V2.2 mils  | 2021-08-24 10     | :18:27 AM 1 | 10:18:34 AM   | SV        | FAIL     | C: \Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb   | SMTA V2 PTF Bottom V2 2 mils NSG   |
| 152 Local         | 436 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :31:20 AM   | L0:31:27 AM   | SV        | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 153 Local         | 437 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :32:13 AM 1 | 10:32:20 AM   | sv        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 154 Local         | 438 SMTA V2 PTF Bottom V2 2 mis   | 2021-08-24 10     | :33:30 AM   | 0.24.00 AM    | SV        | PASS     | C: Konyoung Job SMTA V2/SMTA V2 PTF Bottom V2 2 mis.mdb   | SMTA V2 PTF Bottom V2 2 mis NSG 10 um  |
| 156 Local         | 440 SMTA V2 PTF Bottom V2 2 mile  | 2021-08-24 10     | :34:44 AM   | 0:34:51 AM    | SV        | PASS     | C: Kohyoung 200 pm1A 12 pm1A 12 pm1 A 12 pm1 A 12 pm<br>C: Kohyoung 10b (SMTA 12 SMTA 12 PTF Bottom 12 2 mile mdb | SMTA V2 PTF Bottom V2 2 mile NSG 10 um<br>SMTA V2 PTF Bottom V2 2 mile NSG 10 um |
| 157 Local         | 441 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :35:18 AM   | 0:35:25 AM    | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 158 Local         | 442 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :35:57 AM   | 10:36:04 AM   | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 159 Local         | 443 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :37:06 AM   | 10:37:13 AM   | SV        | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 160 Local         | 444 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :39:25 AM 1 | 10:39:32 AM   | SV        | PASS     | C:\Kohyoung\Job\SMTA V2\SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 161 Local         | 445 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :39:57 AM   | 10:40:04 AM   | SV        | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 162 Local         | 446 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :40:35 AM 1 | 10:40:42 AM   | SV        | PASS     | C: Kohyoung Job SMTA V2 SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 163 Local         | 447 SMTA V2 PTF Bottom V2 2 mils  | 2021-08-24 10     | :41:41 AM 1 | 10:41:48 AM   | SV        | PASS     | C: Kohyoung Job SMTA V2/SMTA V2 PTF Bottom V2 2 mils.mdb  | SMTA V2 PTF Bottom V2 2 mils NSG 10 um   |
| 164 LOCAL         | 440 SMTA V2 PTF Bottom V2 2 mis   | 2021-08-24 10     | -42-19 AM   | 0:42:21 AM    | SV        | PASS     | C: Wohyoung Job SMTA V2/SMTA V2 PTF Bottom V2 2 mis.mdb   | SMTA V2 PTF Bottom V2 2 mis NSG 10 um  |
| 16.5 0.00         | TTP SMITA V2 FIF DULUMI V2 2 MIS  | 2021-00-24 10     |             | 101-10:20 AM  | 24        | r 433    | C. Youryoung you pint A 12 pint A 12 PTF buttom V2 2 mils.mob   | SIMINA VZ PIE DOLLOIN VZ ZIMIS INSG 10 UM  |
| 165 Local         |                                   |                   |             |               |           |          |   |  |
| 165 Local         |                                   |                   |             |               | e         |          |   |  |

## Step 3: Import Data to Excel

The files are in a \*.CSV format. In Excel, click on Open, and choose "All Files" from the dropdown in the lower right corner. This will allow you to see the CSV files.

Double click the file you want to import or click on it and then click "Open."

| nize * New folde  | r   |                    |                    |            |          | · ·   |
|-------------------|---|--------------------|--------------------|------------|----------|-------|
| Download ^        | Name  | Date modified      | Туре               | Size       |          |       |
| Export SPI Data f | Old databases   | 10/7/2021 12:48 PM | File folder        |            |          |       |
| Paper             | 2 and 3 mil bare and coated consolidated REV 6 (version 1)          | 10/7/2021 12:49 PM | Microsoft Excel W  | 110,852 KB |          |       |
| Microsoft Excel   | 2 and 3 mil bare and coated consolidated                            | 9/7/2021 2:22 PM   | Microsoft Excel W  | 108,296 KB |          |       |
| VIICIOSOTI EXCEL  | 2 mil bare  | 8/29/2021 4:53 PM  | Microsoft Excel Co | 24,849 KB  |          |       |
| OneDrive          | 2 mil coated  | 8/29/2021 4:58 PM  | Microsoft Excel Co | 25,093 KB  |          |       |
| This PC           | 3 mil Bare  | 8/29/2021 4:54 PM  | Microsoft Excel Co | 24,387 KB  |          |       |
| 2D Objects        | 3 mil coated  | 8/29/2021 5:01 PM  | Microsoft Excel Co | 25,188 KB  |          |       |
| 50 Objects        | Copy of 2 and 3 mil bare and coated consolidated REV 4 - Compa      | 9/16/2021 1:21 PM  | Microsoft Excel W  | 47 KB      |          |       |
| Desktop           | SMTA V2 PTF Bottom KYA 2 mils_1016_0747_16_20um_Nano-Slic           | 8/11/2021 5:14 PM  | Microsoft Excel Co | 18,010 KB  |          |       |
| Documents         | SMTA V2 PTF Bottom V2 2 mils No Coating HT 20 um_0826_1326          | 8/29/2021 4:51 PM  | Microsoft Excel Co | 24,849 KB  |          |       |
| Downloads         | SMTA V2 PTF Bottom V2 2 mils NSG HT 20 um_0824_0947_20 mo           | 8/29/2021 4:50 PM  | Microsoft Excel Co | 25,093 KB  |          |       |
| Music             | SMTA V2 PTF Bottom V2 3 mils No Coating HT 20 um_0826_0730          | 8/29/2021 4:49 PM  | Microsoft Excel Co | 24,387 KB  |          |       |
| Pictures          | 🔯 thee and five ball rule   | 9/16/2021 9:30 AM  | Microsoft Excel W  | 10 KB      |          |       |
| Videos            |   |                    |                    |            |          |       |
| Local Disk (C:)   |   |                    |                    |            |          |       |
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| vetwork           |   |                    |                    |            |          |       |
| File and          | CMTA V/2 DTE Rattern KVA 2 mile 1016 0747 16 20um Name Clie DEK (1) |                    |                    |            | <b>1</b> | 1. 61 |

Importing and opening may take a few moments, as the file sizes are generally large.

As soon as the file is imported, save it as an Excel Workbook with the term "\_modified" added after the filename. This is in case the file gets corrupted; the original data will still be safe.

Depending on the size of the database and the speed of the computer, saving may also take a few moments.

| s  | MTA V2 PTF Bottom V2 2 mils NSG HT 20 um_0824_0947_20 modified  | 🛆 Chrys Shea 🥵 🏶 🙂 🙁 ? — 🗗 |
|--|---|----------------------------|
| Save As                                    |   |                            |
| L Recent                                   | ↑ ▷ Documents > Thin Foils > DataBase           SMTA V2 PTF Bottom V2 2 mils NSG HT 20 um_0824_0947_20 modified |                            |
| Personal                                   | Excel Workbook (*.xlsx)   | ▼ 🖓 Save                   |
| OneDrive - Personal<br>chrysshea@gmail.com | More options  |                            |
| Other locations                            | Name 1  | Date modified              |

## Step 4: Manipulate and Consolidate

|   |              |          |       |           |       |           |             | 7041    |            |             | 110.00    |
|---|--------------|----------|-------|-----------|-------|-----------|-------------|---------|------------|-------------|-----------|
|   | A            | В        | С     | D         | E     | F         | G           | Н       |            | J           | K         |
| 1 | Foil Thickne | Coating  | Panel | Componen  | PadID | Volume(%) | Height(mil) | Area(%) | OffsetX(mi | OffsetY(mil | Volume(mi |
| 2 | 2            | Coated   | 1     | PTF1_CICU | 1     | 50.985    | 1.268       | 80.447  | 0.669      | -1.285      | 8         |
| 5 | 2            | Coated   | 1     | PTF1_CICU | 2     | 34.268    | 1.182       | 57.993  | 0.664      | -1.273      | 5         |
| 4 | 2            | Coated   | 1     | PTF1_CICU | 3     | 35.653    | 1.116       | 63.89   | 0.618      | -1.532      | 5         |
| 5 | 2            | Coated   | 1     | PTF1_CICU | 4     | 74.278    | 1.383       | 107.424 | 0.339      | -0.401      | 11        |
| 6 | 2            | Coated   | 1     | PTF1_CICU | 5     | 132.681   | 1.862       | 142.551 | 0.517      | -0.307      | 34        |
|   | 2            | Coated   | 1     | PTF1_CICU | 6     | 121.139   | 1.91        | 126.86  | 0.27       | -0.736      | 31        |
| В | 2            | Coated 🥊 | 1     | PTF1_CICU | 7     | 126.52    | 1.925       | 131.482 | 0.095      | -0.897      | 33        |
| Ð | 2            | Coated   | 1     | PTF1_CICU | 8     | 108.457   | 1.838       | 117.99  | 0.399      | -0.534      | 28        |
| 0 | 2            | Coated   | 1     | PTF1_CICU | 9     | 160.234   | 2.269       | 141.208 | 0.448      | -0.353      | 65        |
| 1 | 2            | Coated   | 1     | PTF1_CICU | 10    | 163.412   | 2.404       | 135.936 | 0.221      | -0.555      | 66        |
| 2 | 2            | Coated   | 1     | PTF1_CICU | 11    | 133.387   | 2.112       | 126.302 | 0.546      | -0.517      | 54        |
| 3 | 2            | Coated   | 1     | PTF1_CICU | 12    | 118.754   | 1.981       | 119.917 | 0.196      | -0.546      | 48        |

## Add columns for stencil (foil) thickness and coating to each individual database.

Rename each individual database according to its contents (stencil thickness, coating), then combine them into a new workbook. Excel can handle up to 1,048,576 rows of data.

| This PC  | > Documents > Thin Foils > DataBase                         | ~                  | Ū | ○ Search DataBas     | se         |
|----------|---|--------------------|---|----------------------|------------|
| <u>^</u> | Name  | Date modified      |   | Туре                 | Size       |
|          | 📕 Old databases   | 10/7/2021 12:48 PM |   | File folder          |            |
|          | 2 and 3 mil bare and coated consolidated                    | 9/7/2021 2:22 PM   |   | Microsoft Excel Work | 108,296 KB |
|          | 🔊 2 mil bare  | 8/29/2021 4:53 PM  |   | Microsoft Excel Com  | 24,849 KB  |
| r        | 2 mil coated  | 8/29/2021 4:58 PM  |   | Microsoft Excel Com  | 25,093 KB  |
| r i      | 💶 3 mil Bare  | 8/29/2021 4:54 PM  |   | Microsoft Excel Com  | 24,387 KB  |
| r i      | 3 mil coated  | 8/29/2021 5:01 PM  |   | Microsoft Excel Com  | 25,188 KB  |
|          | Copy of 2 and 3 mil bare and coated consolidated REV 4 - Co | 9/16/2021 1:21 PM  |   | Microsoft Excel Work | 47 KB      |
|          | SMTA V2 PTF Bottom KYA 2 mils_1016_0747_16_20um_Nano        | 8/11/2021 5:14 PM  |   | Microsoft Excel Com  | 18,010 KB  |
| f        | SMTA V2 PTF Bottom V2 2 mils No Coating HT 20 um_0826_1     | 8/29/2021 4:51 PM  |   | Microsoft Excel Com  | 24,849 KB  |
|          | SMTA V2 PTF Bottom V2 2 mils NSG HT 20 um_0824_0947_20      | 8/29/2021 4:50 PM  |   | Microsoft Excel Com  | 25,093 KB  |
|          | SMTA V2 PTF Bottom V2 3 mils No Coating HT 20 um_0826_0     | 8/29/2021 4:49 PM  |   | Microsoft Excel Com  | 24,387 KB  |

## Step 5: Parse

Look at Column D in the spreadsheet. The Component ID is a code for the location, pad shape, pad definition, aperture corners, CAD identifier, aperture size and replicate. It should be parsed into separate columns, using the "Text to Columns" function in Excel.

Note: Any rows of data with blank Component IDs, such as the large QFP used to verify print quality, should be deleted.

First, make room for the parsed data by inserting six columns to the right of Column D.

• Highlight columns E through J

| F       | ile H             | ome   | nsert  | Drav  | V   | Page Layo        | out Form                           | nulas                                 | Data        | a Review  | v View                 | Help     |                  |             |          |
|---------|-------------------|---|--------|-------|-----|------------------|------------------------------------|---------------------------------------|-------------|-----------|------------------------|----------|------------------|-------------|----------|
| (<br>Di | Get<br>ata ~ II F | From Text/CSV     From Veb     From Veb     From Table/Range     Get & Transform Data |        |       |     | Refresh<br>All ~ | Que<br>Prop<br>C Edit<br>Queries & | ries & C<br>erties<br>Links<br>Connec | Connections | Stoc      | ks Curre<br>Data Types | encies v | 2↓ ZA<br>Z↓ Sort | Filter C    |          |
| E1      |                   |   | ×      | ~     | fx  | PadID            |                                    |                                       |             |           |                        | -        | -                | -           |          |
|         | A                 | В   |        | с     |     |                  | D 🦯                                |                                       | E           | F         | G                      | н        | 1                | J           | -        |
| 1       | Foil Thic         | ne Coatir   | g      | Panel | C   | omponent         | D                                  | Padl                                  | )           | Volume(%) | Height(mil)            | Area(%)  | OffsetX(mi       | OffsetY(mil | Volum (m |
| 2       |                   | 2 Coate   | ł      |       | 1 P | TF1_CICU_I       | R-03-03A                           |                                       | 1           | 50.985    | 1.268                  | 80.447   | 0.669            | -1.285      |          |
| 3       | _                 | 2 Coate   | ł      |       | 1 P | TF1_CICU_I       | R-03-03B                           |                                       | 2           | 34.268    | 1.182                  | 57.993   | 0.664            | 1273        |          |
| 4       | -                 | 2 Coate   | 4      |       | 1 P | TF1_CICU_I       | R-03-03C                           |                                       | 3           | 35.653    | 1.110                  | - 03.89  | 0.618            | -1.532      | !        |
| 5       |                   | 2 Coate   | 4      |       | 1 P | TF1_CICU_I       | R-03-03D                           |                                       | 4           | 74.278    | 1.383                  | 107.424  | 0.339            | -0.401      | 1:       |
| 6       | -                 | 2 Coate   | ł      |       | 1 P | TF1_CICU_I       | R-03-04A                           |                                       | 5           | 132.681   | 1.862                  | 142.551  | 0.517            | -0.307      | 34       |
| 7       |                   | 2 Coate   | d .    |       | 1 P | TF1_CICU_I       | R-03-04B                           |                                       | 6           | 121.139   | 1.91                   | 126.86   | 0.27             | -0.736      | 3:       |
| 8       |                   | 2 Coate   | 3      |       | 1 P | TF1_CICU_I       | R-03-04C                           |                                       | 7           | 126.52    | 1.925                  | 131.482  | 0.095            | -0.897      | 3        |
| 9       | -                 | 2 Coate   | 1      |       | 1 P | TF1_CICU_I       | R-03-04D                           | _                                     | 8           | 108.457   | 1.838                  | 117.99   | 0.399            | -0.534      | 2        |
| 10      |                   | 2 Coate   | 1      |       | 1 P |                  | (-03-05A                           |                                       | 9           | 160.234   | 2.269                  | 141.208  | 0.448            | -0.353      | 6:       |
| 11      |                   | 2 Coate   | 2<br>J |       | 1 0 |                  | -03-05B                            |                                       | 10          | 103.412   | 2.404                  | 135.930  | 0.221            | -0.555      | 5        |
| 12      |                   | 2 Coate   | 4      |       | 1 0 |                  | 1-03-05C                           |                                       | 12          | 110 754   | 2.112                  | 110.017  | 0.540            | -0.517      | 24       |
| 11      |                   | 2 Coate   | 4      |       | 1 0 |                  | 02 060                             |                                       | 12          | 140.029   | 2 269                  | 119.917  | 0.190            | -0.340      |          |
| 14      |                   | 2 Coate   | 4      |       | 1 P |                  | 2-03-06R                           |                                       | 14          | 140.038   | 2.308                  | 107 373  | 0.702            | -0.895      | 8        |
| 16      |                   | 2 Coate   | 4      |       | 1 P | TF1 CICU I       | 3-03-060                           |                                       | 15          | 141 301   | 2.701                  | 113 692  | 0.365            | -0.92       | 7        |
| 17      |                   | 2 Coate   | 4      |       | 1 P | TF1 CICU I       | R-03-06D                           |                                       | 16          | 149.013   | 2.512                  | 118.64   | 0.467            | -0.582      | 8        |

• Right click and insert

| F      | ile          | Hom       | ie Insert                           | t Draw    | Page Layout                 | Formula          | is Data                                 | Review     | View | Help     | )          |                   |   |        |
|--------|--------------|-----------|-------------------------------------|-----------|-----------------------------|------------------|---|------------|------|----------|------------|-------------------|---|--------|
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| E1     | 1            |           |                                     | √ f.      | e l                         |                  |   |            |      |          |            |                   | -   |        |
|        | 4            | •         | P                                   | 6         | D                           | ( ·              | -                                       | r.         | C    | ñ        | 1 a        | 1 x               |   | ~      |
| 1      | Foil         | A         | Coating                             | Panel     | Component ID                |                  | E                                       | F          | 6    | п        | 1          | J                 | Pade  |        |
| 2      | 1011         | 2         | Coated                              | 1 41101   | PTF1 CICU B-03              | 3-03A            | -                                       |            |      |          |            | -                 | -   | 1      |
| 3      | -            | 2         | Coated                              | 1         | PTF1 CICU B-03              | 3-03B            | _                                       |            | _    |          |            | _                 |   | 2      |
| 4      | -            | 2         | Coated                              | 1         | PTF1 CICU B-0               | 3-030            |   |            |      |          |            |                   |   | 3      |
| 5      | -            | 2         | Coated                              | 1         | PTF1 CICU R-0               | 3-03D            |   |            |      |          |            |                   |   | 4      |
| 6      |              | 2         | Coated                              | 1         | PTF1 CICU R-0               | 3-04A            |   |            |      |          |            |                   |   | 5      |
| 7      |              | 2         | Coated                              | 1         | PTF1 CICU R-0               | 3-04B            |   |            |      |          |            |                   |   | 6      |
| 8      |              | 2         | Coated                              | 1         | PTF1 CICU R-0               | 3-04C            |   |            |      |          |            |                   |   | 7      |
| 9      |              | 2         | Coated                              | 1         | PTF1 CICU R-0               | 3-04D            |   |            |      |          |            |                   |   | 8      |
| 10     | )            | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-05A            |   |            |      |          |            |                   |   | 9      |
| 11     | -            | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-05B            |   |            |      |          |            |                   |   | 10     |
| 12     | 1            | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-05C            |   |            |      |          |            |                   |   | 11     |
| 13     |              | 2         | Coated                              | 1         | PTF1_CICU_R-0               | 3-05D            |   |            |      |          |            |                   |   | 12     |
| 14     | 1            | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-06A            |   |            |      |          |            |                   |   | 13     |
| 15     |              | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-06B            |   |            |      |          |            |                   |   | 14     |
| 16     | ;            | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-06C            |   |            |      |          |            |                   |   | 15     |
| 17     |              | 2         | Coated                              | 1         | PTF1 CICU R-03              | 3-06D            |   |            |      |          |            |                   |   | 16     |
| 18     |              | 2         | Coated                              | 1         | PTF1_CICU_R-0               | 3-07A            |   |            |      |          |            |                   |   | 17     |
| 1.0    |              | -         | -                                   |           |                             |                  |   |            |      |          |            |                   |   |        |

Highlight Column D, click on Data, then on Text to Columns to open up a wizard.

| In Step 1 of the Wizard, click Fixed Width; click ne | ext |
|--|-----|
|--|-----|

|     | -                               |                                     |                          |   |           |                                     |                      |                  |                 |               |                |               | 20 C C C C C C C C C C C C C C C C C C C |                      |                    |
|-----|---------------------------------|-------------------------------------|--------------------------|---|-----------|-------------------------------------|----------------------|------------------|-----------------|---------------|----------------|---------------|--|----------------------|--------------------|
| Fil | e Hom                           | e Insert                            | Draw                     | Page Layout Forn                                | nulas 🚦   | Data Revie                          | ew Vi                | ew Help          | •               |               |                |               |  | ******               | •                  |
| Ge  | From<br>From<br>t<br>a ~ E From | n Text/CSV<br>n Web<br>n Table/Rang | Recen Existin            | t Sources<br>ng Connections<br>Refresh<br>All ~ | Quer      | ies & Connection<br>erties<br>Links | s                    | Stocks (         | Currencies      | ^ Z↓<br>▼ Z↓  | Sort Fi        | Iter Adv      | an (<br>apply 1<br>valiced Co            | ext to<br>blumns № ~ |                    |
|     |                                 | Get & Trans                         | form Data                |   | Queries & | Connections                         |                      | Data T           | /pes            |               | Sort           | & Filter      |  | Data Tools           | ••                 |
|     |                                 |                                     |                          |   |           |                                     |                      |                  |                 |               |                |               |  |                      |                    |
| DI  |                                 |                                     | <ul> <li>✓ J;</li> </ul> | component ID                                    |           |                                     |                      |                  |                 |               |                |               |  |                      |                    |
|     | А                               | В                                   | С                        | D   | E         | F                                   | G                    | Н                | I.              | J             | K              | L             | М  | N                    | 0                  |
| 1   | oil Thickne                     | Coating                             | Panel                    | Component ID                                    |           |                                     |                      |                  |                 |               | PadID          | Volume(       | %) Height(m                              | il) Area(%)          | Offset)            |
| 2   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-03A                              |           |                                     |                      |                  |                 |               |                | 1 50.98       | 35 1.26                                  | 8 80.44              | 7 0.               |
| 3   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-03B                              |           |                                     |                      |                  |                 |               |                | 2 24.26       | 1.18                                     | 2 57.99              | 3 0.               |
| 4   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-03C                              |           | Convert Text to                     | Columns              | Wizard - Step    | 1 of 3          |               |                | ?             | × 1.11                                   | 6 63.8               | 9 0.               |
| 5   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-03D                              |           |                                     |                      |                  |                 |               |                |               | 1.38                                     | 3 107.42             | 4 0.               |
| 6   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-04A                              |           | The Text Wizard h                   | as determin          | ed that your da  | ata is Delimite | d.            |                |               | 1.86                                     | 2 142.55             | 1 0.               |
| 7   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-04B                              |           | If this is correct, ch              | noose Next,          | or choose the    | data type that  | best describ  | es your data.  |               | 1.9                                      | 1 126.8              | 6 (                |
| 8   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-04C                              |           | Original data type                  | e                    |                  |                 |               |                |               | 1.92                                     | 5 131.48             | 2 0.               |
| 9   | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-04D                              |           | Choose the file t                   | une that he          | st describes vo  | ur data:        |               |                |               | 1.83                                     | 8 117.9              | 9 0.               |
| 10  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-05A                              |           |                                     |                      | st describes yo  | ui uata.        |               |                |               | 2.26                                     | 9 141.20             | 8 0.               |
| 11  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-05B                              |           |                                     | - Char               | acters such as o | commas or tat   | os separate e | ach field.     |               | 2.40                                     | 4 135.93             | 6 0.               |
| 12  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-05C                              |           | Fixed wid                           | Ith Field            | s are aligned in | columns with    | spaces betw   | een each field |               | 2.11                                     | 2 126.30             | 2 0.               |
| 13  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-05D                              |           |                                     |                      |                  |                 |               |                |               | 1.98                                     | 1 119.91             | 7 0.               |
| 14  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-06A                              |           |                                     |                      |                  |                 |               |                |               | 2.36                                     | 8 118.29             | 7 0.               |
| 15  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-06B                              |           |                                     |                      |                  |                 |               |                |               | 2.70                                     | 1 107.37             | 3 0.               |
| 16  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-06C                              |           |                                     |                      |                  |                 |               |                |               | 2.48                                     | 6 113.69             | 2 0.               |
| 17  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-06D                              |           |                                     |                      |                  |                 |               |                |               | 2.51                                     | 2 118.6              | 4 0.               |
| 18  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-07A                              |           | Preview of select                   | ed data:             |                  |                 |               |                |               | 2.53                                     | 3 118.07             | 2 0.               |
| 19  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-07B                              |           | 1 brown and the                     | TD                   |                  |                 |               |                |               | 2.52                                     | 6 116.14             | 9 0.               |
| 20  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-07C                              |           | 2 PTF1_CICU_                        | R-03-03P             | L                |                 |               |                |               | 2.83                                     | 4 115.79             | 7 (                |
| 21  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-07D                              |           | 3 PTF1_CICU<br>4 PTF1_CICU          | R-03-03E<br>R-03-03C | 5                |                 |               |                |               | 2.63                                     | 7 117.03             | 9 0.               |
| 22  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-08A                              |           | 5 PTF1 CICU                         | R-03-03E             | )                |                 |               |                |               | 2.65                                     | 8 106.96             | 4 0.               |
| 23  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-08B                              |           | 7 PTF1_CICU                         | R-03-04P             | 5                |                 |               |                |               | 2.74                                     | 1 103.36             | 9 (                |
| 24  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-08C                              |           | 8 PTF1_CICU_                        | R-03-040             |                  |                 |               |                |               | × 2.69                                   | 6 99.6               | 7 0.               |
| 25  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-08D                              |           | <                                   |                      |                  |                 |               |                | >             | 2.47                                     | 1 110.32             | 8 0.               |
| 26  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-09A                              |           |                                     |                      |                  |                 |               |                |               | 2.52                                     | 2 103.80             | 9 0.               |
| 27  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-09B                              |           |                                     |                      | Can              | cel             | < Back        | <u>N</u> ext > | <u>Eini</u> : | sh 2.41                                  | 4 106.45             | 1 0.               |
| 28  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-09C                              |           |                                     |                      | -                | _               |               | *****          | / 121.0       | 2.62                                     | 8 100.25             | 2 0.               |
| 29  | 2                               | Coated                              | 1                        | PTF1_CICU_R-03-09D                              |           |                                     |                      |                  |                 |               | 2              | 8 130.05      | 2.66                                     | 6 97.54              | 6 <mark>0</mark> . |
| 20  | 2                               | Contrad                             | 1                        | DTE1 CICLI D 02 104                             |           |                                     |                      |                  |                 |               | 2              | 0 127.2       | 2 2 40                                   | 1 102 22             | 2 0                |

In *Step 2 of the Wizard*, set the column breaks as shown:



In *Step 3 of the Wizard*, individually highlight the unwanted columns - the underscores and dashes - and click on "Do not import column (skip)" for each one. Click Finish.

| Convert Text to Columns Wizar            | d - Step 3 of 3  |                |        | ?        | ×    |  |  |  |
|--|--|----------------|--------|----------|------|--|--|--|
| This screen lets you select each colu    | imn and set the Dat  | a Format.      |        |          |      |  |  |  |
| Column data format                       |  |                |        |          |      |  |  |  |
| O <u>G</u> eneral                        |  |                |        |          | 10.1 |  |  |  |
| ◯ <u>I</u> ext                           | 'General' converts numeric values to numbers, date values to da<br>and all remaining values to text. |                |        |          |      |  |  |  |
| O Date: MDY                              |  | Advand         | ed     |          |      |  |  |  |
| Do not import column (skip)              | ÷  |                |        |          |      |  |  |  |
| D <u>e</u> stination: \$D\$1             |  |                |        |          | Ť    |  |  |  |
|  |  |                |        |          |      |  |  |  |
| Data <u>p</u> review                     |  |                |        |          |      |  |  |  |
| GeneSGeGeSGSGeSGeGeneral                 |  |                |        |          | -    |  |  |  |
| Component ID<br>PTF1 CICU R-03-03A       |  |                |        |          | ^    |  |  |  |
| PTF1 CICU R-03-03B<br>PTF1 CICU R-03-03C |  |                |        |          |      |  |  |  |
| PTF1 CICU R-03-03D<br>PTF1 CICU R-03-04A |  |                |        |          |      |  |  |  |
| PTF1 CICU R-03 04B<br>PTF1 CICU R-03 04C |  |                |        |          | ~    |  |  |  |
| <pre></pre>                              |  |                |        |          | >    |  |  |  |
|  |  |                |        |          |      |  |  |  |
|  | Cancel   | < <u>B</u> ack | Next > | <u> </u> | iish |  |  |  |

After the columns populate, hide column H (CAD ID), and add the column headings shown below:

| F  | ile Hom      | e Insert                       | Draw                             | Page La | ayout F              | ormulas      | Data Rev   | view Vi            | ew Hel     | р                    |           |
|----|--------------|--------------------------------|----------------------------------|---------|----------------------|--------------|------------|--------------------|------------|----------------------|-----------|
| Pa | aste         | Calibri<br><b>B</b> I <u>U</u> | <ul> <li>11</li> <li>↓</li></ul> | - A^    | A <sup>*</sup>   Ξ : | = <u>-</u> » | v eb Wrap  | Text<br>e & Center | Gene       | eral<br>~ % <b>9</b> |           |
| C  | ipboard 🗔    |                                | Font                             |         | ГЪ                   |              | Alignment  |                    | ۲ <u>۵</u> | Number               | FC        |
| M1 | 15           |                                | √ fx                             | 13.10   | 6                    |              |            |                    |            |                      |           |
|    | А            | В                              | C 🔸                              | D       | E                    | F            | G          |                    | • К        | Ĺ                    | М         |
| 1  | Foil Thickne | Coating                        | Panel                            | Block   | Shape                | Pad Def      | Ap CoSneSR | Size               | Replicate  | PadID                | Volume(%) |
| 2  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 3                  | В          | 1                    | 28.541    |
| 3  | 2            | Bare                           | 1                                | PTF1    | C .                  | CU           | S          | 3                  | С          | 2                    | 6.75      |
| 4  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 3                  | D          | 3                    | 11.168    |
| 5  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 4                  | А          | 4                    | 78.793    |
| 6  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 4                  | В          | 5                    | 62.549    |
| 7  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 4                  | С          | 6                    | 5 73.02   |
| 8  | 2            | Bare                           | 1                                | PTF1    | CI                   | CU           | S          | 4                  | D          | 5                    | 63.075    |

Save the database! It is now ready for pivoting in excel or exporting into statistical software package.

The codes for the different pad stacks are as follows:

### **PTF Pattern Codes**

PTF(block #)\_(shape)(pad definition)\_(aperture corners)\_(CAD identifier).(size)(replicate)

| Block #:          | 1 to 8 (there are 8 individual blocks in the test area)                    |
|-------------------|--|
| Shape:            | CI = Circle  |
|                   | SQ = Square  |
|                   | HR = Horizontal Rectangle  |
|                   | VR = Vertical Rectangle  |
| Pad Definition:   | Cu = Copper (metal, or NSMD) defined                                       |
|                   | SM = Solder Mask Defined   |
| Aperture Corners: | R = Radiused or Squircles  |
|                   | S = Square or Circular   |
| CAD Identifier:   | 03 or 15; the size of the first feature on the line for CAD reference only |
| Size:             | 03 to 15 mils  |
| Replicate         | A, B, C or D (there are 4 replicates per paired row of features)           |

## Step 6: Pivot Table

The pivot tables are easy to build:

- Click on the upper left corner of the sheet to highlight all contents
- Go to Insert, click on Pivot Table
- In the dialogue box, click New Worksheet and OK



• A new worksheet will appear:

| File   | Home I                               | nsert Draw   | Page Layout  | Formulas Da  | ta Review    | View Help               | PivotTable .                      | Analyze Design                                    |   | 암 Share 🛛 🖵 Comments   |
|--|--------------------------------------|--|--|--|--------------|-------------------------|-----------------------------------|---|---|--|
| PivotTa<br>PivotT<br>IIII Or<br>Piv  | able Name: Acti<br>able1<br>otions ~ | ve Field:<br>Dri<br>Field Settings Dov<br>Active Field | ・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・<br>・ | → Group Selection<br>1 Ungroup<br>2 Group Field<br>Group | Insert Slice | er<br>eline<br>hections | h Change Data<br>Source ~<br>Data | Clear ~<br>Select ~<br>Move PivotTable<br>Actions | Fields, Items, & Se<br>C. OLAP Tools ~<br>Relationships<br>Calculations | Its * PivotChart Recommended<br>PivotChart Recommended<br>PivotEibles<br>Tools Show ~  |
| A3   | ¥ 1                                  | $\times  \checkmark  f_X$                              |  |  |              |                         |                                   |   |   | ~  |
|  | А                                    | В  | С  | D  | Е            | F                       | G                                 | Н   | 1   | PivotTable Fields × ×  |
| 1  |                                      |  |  |  |              |                         |                                   |   |   | Choose fields to add to report:  |
| 3  |                                      | ]  |  |  |              |                         |                                   |   |   | Search D   |
| 4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14<br>15<br>16<br>17 | To build a from the                  | PivotTable1<br>a report, chc<br>PivotTable             | pose fields<br>Field List  |  |              |                         |                                   |   |   | Poll Thickness         ▲           Coating         ■           Panel         ■           Block         □           Pad Def         Ap CoSnesR           CAD ID         □           Size         ■           Area Ratio         Ψ           Drag fields between areas below:         Ψ           T Filters         II Columns           III Rows         Σ Values |
| 18<br>19<br>20   |                                      |  |  |  |              |                         |                                   |   |   |  |

There are many different ways to view data in pivot tables. This method was used to analyze the data from the Thin Foils experiment.



|  | E       F         Value Field Settings       ?         Source Name:       Volume(mil3)         Qustom Name:       Average of Volume(mil3)         Summarize value field by       Choose the type of calculation that you want to use to summarize data from the selected field         Sum       Count         Average       Max         Max       Min         Product       OK         Cancel       0% | PivotTable Fields | In the Σ Values field, click<br>on the arrow next to<br>Volume (mils3) and click<br>on "Value Field Settings."<br>Choose the Average and<br>Standard Deviation for the<br>Volume (mils3) and the<br>Average for Volume %. |
|--|---|-------------------|---|
|--|---|-------------------|---|

The basic pivot table is now constructed. Click the Decrease Decimal point icon to the desired number of decimal points.

| Fil                        | e <mark>Home</mark> In:  | sert Draw Page Layout F   | ormulas Data Review V  | /iew Help PivotTa                  | able Analyze Design                 |              | E  | Share 🖵 Comments                                   |
|----------------------------|--|---|--|------------------------------------|-------------------------------------|--------------|--|--|
| Pa:<br>Cli                 | ste 💞 Kalibri<br>B I   | $\begin{array}{c c} & & & \\ & & & \\ \hline \\ \hline$ | E E ≫ v 8b Wrap Text<br>E E E E E E Merge & Cente<br>Alignment | General<br>\$ ~ % 5.0<br>F_ Number | 0 00<br>Formatting ~ Table ~ Styles | Insert Delet | $\begin{array}{c c} \sum & A \\ \hline \\ e \ Format \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$ | Analyze<br>Data<br>Analysis Λ                      |
| B3                         | ¥ 1  | $\times$ $\checkmark$ $f_x$ SQ  |  |                                    |                                     |              |  | ~  |
| 1<br>2<br>3<br>4<br>5<br>6 | A<br>Coating<br>Foil Thickness<br>Shape<br>Pad Def<br>Ap CoSneSR | B<br>Coated 77<br>2 77<br>SQ 77<br>SM 77<br>S 7   | С  | D                                  | F                                   | G            | PivotTable Fields<br>Choose fields to add to report:<br>Search<br>Foil Thickness<br>Coating                    | × ×<br>• @ •<br>•<br>•                             |
| 7                          | Row Labe -   | Average of Volume(mil3)   | StdDev of Volume(mil3)   | Average of Volume                  | e(%)                                |              | Panel<br>Block   |  |
| 8<br>9<br>10<br>11<br>12   | 3<br>4<br>5<br>6<br>7  | 1<br>15<br>35<br>56<br>84   | 1<br>5<br>4<br>5<br>6  | 6<br>47<br>69<br>81<br>90          |                                     |              | Shape Shape ApCoSneSR CAD ID Size Area Ratio   | 2<br>2<br>2<br>2                                   |
| 13<br>14                   | 8  | 120<br>158  | 6<br>7   | 98<br>97                           |                                     |              | Drag fields between areas belo   | DW:  |
| 15                         | 10   | 203   | 9  | 101                                |                                     |              | ▼ Filters  | III Columns  |
| 16<br>17<br>18<br>19       | 11<br>12<br>13<br>14   | 241<br>299<br>350<br>407  | 11<br>13<br>17<br>22   | 100<br>104<br>104<br>104           |                                     |              | Foil Thickness     •       Shape     •       Pad Def     •   | ∑ Values ▼   |
| 20                         | 15   | 470   | 26   | 104                                |                                     |              | E Rows   | $\Sigma$ Values                                    |
| 21                         | Grand Total  | 188   | 150  | 85                                 |                                     |              | Size 💌   | Average of Volume(mi 🔻                             |
| 22<br>23<br>24             | -  |   |  |                                    |                                     |              |  | StdDev of Volume(mil3) ▼<br>Average of Volume(%) ▼ |

It is very helpful to add a column that calculates the Coefficient of Variation, or CV. It is the StdDev of Volume(mil3) divided by the Average of Volume(mil3).

| 11 | × :            | × / 1   | fx =GETPIVOTDATA | ("StdDev of Volume(mil3)",\$A\$7, | "Size",6)/GETPIVOTDATA("Ave | rage of Volume(mil3)",\$A |
|----|----------------|---------|------------------|-----------------------------------|-----------------------------|---------------------------|
|    | А              |         | в                | с                                 | D                           | *****                     |
| 1  | Coating        | Coated  | ज                |                                   |                             |                           |
| 2  | Foil Thickness | 2       | ज                |                                   |                             |                           |
| В  | Shape          | SQ      | ज                |                                   |                             |                           |
| 4  | Pad Def        | SM      | ज                |                                   |                             |                           |
| Б  | Ap CoSneSR     | S       | ज                |                                   |                             |                           |
| 6  |                |         |                  |                                   |                             |                           |
| 7  | Row Labe -     | Average | of Volume(mil3)  | StdDev of Volume(mil3)            | Average of Volume(%)        | ) CV                      |
| В  | 3              |         | 1                | 1                                 | 6                           | 147%                      |
| Ð  | 4              |         | 15               | 5                                 | 47                          | 30%                       |
| 0  | 5              |         | 35               | 4                                 | 69                          | 12%                       |
| 1  | 6              |         | 56               | 5                                 | 81                          | 8%                        |
| 2  | 7              |         | 84               | 6                                 | 90                          | 7%                        |
| 3  | 8              |         | 120              | 6                                 | 98                          | 5%                        |
| 4  | 9              |         | 158              | 7                                 | 97                          | 4%                        |
| 5  | 10             |         | 203              | 9                                 | 101                         | 4%                        |
| 6  | 11             |         | 241              | 11                                | 100                         | 4%                        |
| 7  | 12             |         | 299              | 13                                | 104                         | 4%                        |
| 8  | 13             |         | 350              | 17                                | 104                         | 5%                        |
| 9  | 14             |         | 407              | 22                                | 104                         | 5%                        |
| 0  | 15             | C.      | 470              | 26                                | 104                         | 6%                        |
| 1  | Grand Total    |         | 188              | 150                               | 85                          |                           |
| 10 |                |         |                  |                                   |                             |                           |

Use conditional formatting to color code the CVs:

| Fil                   | e Home  | Insert                         | Draw                             | Page Layout           | Formulas                  | Data           | Review                  | View       | He          | lp              |            |                           |                    |                  |
|-----------------------|---|--------------------------------|----------------------------------|-----------------------|---------------------------|----------------|-------------------------|------------|-------------|-----------------|------------|---------------------------|--------------------|------------------|
| Pas                   | te ≪  | <b>В</b> I <u>U</u>            | <ul><li>11</li><li>↓ □</li></ul> | → A^ A <sup>*</sup> = | = = =  », -<br>= = =  = = | , ab<br>→= III | Wrap Text<br>Merge & Ce | nter ~     | Perce<br>\$ | entage<br>× % 9 | 0 Co<br>Fo | onditional Formatting ~ 1 | ormat as<br>able ~ | Cell<br>Styles Y |
| Cli                   | board 😼   |                                | Font                             | 15                    | A                         | lignment       |                         | Ľ2         |             | Number          | 5          | Sty                       | rles               |                  |
| 11                    | -   | $\pm$ ×                        | √ fx                             | =GETPIVOTD            | ATA("StdDev of            | Volume         | (mil3)",\$A\$           | 7,"Size",6 | )/GET       | PIVOTDATA("Ave  | erage o    | f Volume(m                | il3)" <i>,</i> \$A | \$7,"Size"       |
| 1                     | А   |                                | В                                |                       | С                         |                |                         | D          |             | E               |            | F                         |                    | G                |
| 1<br>2<br>3<br>4<br>5 | Coating<br>Foil Thickne<br>Shape<br>Pad Def<br>Ap CoSneSI | Coated<br>2<br>SQ<br>SM<br>R S | 3                                | र<br>र<br>र<br>र<br>र |                           |                |                         |            |             |                 |            |                           |                    |                  |
| 7                     | Row Lab   | - Avera                        | ge of Volum                      | ne(mil3) StdD         | ev of Volume(I            | mil3)          | Average o               | f Volume   | (%)         | cv              |            |                           |                    |                  |
| В                     |   | 3                              |                                  | 1                     |                           | 1              |                         | 6          |             | 147%            |            |                           |                    |                  |
| Ð                     |   | 4                              |                                  | 15                    |                           | 5              |                         | 47         |             | 30%             |            |                           |                    |                  |
| 0                     |   | 5                              |                                  | 35                    |                           | 4              |                         | 69<br>91   | ſ           | 12%             |            |                           |                    |                  |
| 2                     |   | 7                              |                                  | 84                    |                           | - 6            |                         | an         |             | 7%              | -          |                           |                    |                  |
| 3                     | c   | onditional F                   | ormatting Rul                    | es Manager            |                           |                |                         |            |             |                 |            |                           | ?                  | ×                |
| 4                     | s   | how formattin                  | g rules for: Cu                  | rrent Selection       | ×                         |                |                         |            |             |                 |            |                           |                    |                  |
| 5<br>6                |   | New Ru                         | ile                              | Edit Rule             | X Delete Rule             | D D            | upli <u>c</u> ate Rule  | ~ `        | /           |                 |            |                           |                    |                  |
| 7                     |   | Rule (applied                  | in order shown)                  |                       | Format                    |                |                         |            | Appli       | es to           |            |                           | Stop If            | True             |
| 8                     |   | Cell Value                     | e > 0.1501                       |                       |                           | AaBbCo         | YyZz                    |            | =\$E\$8     | 8:\$E\$20       |            | 1                         |                    |                  |
| 0                     |   | Cell Value                     | e between 0.100                  | 1 and 0.15            |                           | AaBbCo         | YyZz                    |            | =\$E\$8     | B:\$E\$20       |            | Ţ                         |                    |                  |
| 1                     | Grand   | Cell Value                     | e between 0 and                  | 0.1                   |                           | AaBbCo         | YyZz                    |            | =\$E\$8     | B:\$E\$20       |            | ſ                         |                    |                  |
| 2<br>3<br>4           |   |                                |                                  |                       |                           |                |                         |            |             |                 |            |                           |                    |                  |
| 6                     |   |                                |                                  |                       |                           |                |                         |            |             |                 | ок         | Close                     | A                  | Apply            |

The Pivot Table is ready to go. The results of the filtering by coating, foil thickness, shape and pad definition can be viewed in Appendix B.

# APPENDIX B Volume, TE and CV Data from Thin Foil Test

| Ľ | ] |   |  |
|---|---|---|--|
|   |   | Ċ |  |
| ( |   |   |  |
|   |   |   |  |
|   |   |   |  |

WORST CASE

Coating Coated Foil Thicknc2 Shape SQ Pad Def SM

| SIZE | VOL | TE % | cv   |
|------|-----|------|------|
| 3    | 1   | 8    | 124% |
| 4    | 16  | 49   | 30%  |
| 5    | 35  | 69   | 12%  |
| 6    | 57  | 81   | 8%   |
| 7    | 85  | 89   | 7%   |
| 8    | 122 | 98   | 5%   |
| 9    | 159 | 98   | 5%   |
| 10   | 204 | 102  | 4%   |
| 11   | 243 | 101  | 5%   |
| 12   | 300 | 104  | 4%   |
| 13   | 351 | 104  | 5%   |
| 14   | 408 | 104  | 5%   |
| 15   | 472 | 105  | 6%   |

Coating Coated Foil Thickn¢2 Shape Cl Pad Def CU

| SIZE | VOL | TE % | CV  |
|------|-----|------|-----|
| 3    | 11  | 72   | 34% |
| 4    | 40  | 138  | 19% |
| 5    | 66  | 146  | 16% |
| 6    | 87  | 140  | 16% |
| 7    | 116 | 138  | 12% |
| 8    | 139 | 126  | 12% |
| 9    | 167 | 115  | 11% |
| 10   | 204 | 115  | 11% |
| 11   | 230 | 108  | 11% |
| 12   | 271 | 106  | 12% |
| 13   | 294 | 98   | 11% |
| 14   | 329 | 94   | 11% |
| 15   | 372 | 93   | 12% |

Coating Bare Foil Thickne2 Shape SQ Pad Def SM

| SIZE | VOL | TE % | CV   |
|------|-----|------|------|
| 3    | 2   | 9    | 111% |
| 4    | 12  | 37   | 47%  |
| 5    | 31  | 63   | 20%  |
| 6    | 58  | 83   | 9%   |
| 7    | 87  | 92   | 6%   |
| 8    | 124 | 99   | 5%   |
| 9    | 162 | 102  | 4%   |
| 10   | 209 | 107  | 4%   |
| 11   | 253 | 106  | 4%   |
| 12   | 311 | 109  | 4%   |
| 13   | 367 | 110  | 4%   |
| 14   | 426 | 110  | 5%   |
| 15   | 496 | 111  | 5%   |

| Coating      | Bare |
|--------------|------|
| Foil Thickne | 2    |
| Shape        | CI   |
| Pad Def      | CU   |

| SIZE | VOL | TE % | CV  |
|------|-----|------|-----|
| 3    | 3   | 21   | 86% |
| 4    | 19  | 65   | 44% |
| 5    | 42  | 91   | 45% |
| 6    | 61  | 97   | 47% |
| 7    | 97  | 114  | 30% |
| 8    | 132 | 120  | 19% |
| 9    | 168 | 118  | 15% |
| 10   | 212 | 122  | 14% |
| 11   | 251 | 119  | 14% |
| 12   | 295 | 116  | 15% |
| 13   | 328 | 110  | 14% |
| 14   | 372 | 107  | 14% |
| 15   | 426 | 107  | 15% |

CoatingCoatedFoil Thickne3ShapeSQPad DefSM

| SIZE | VOL | TE % | CV  |
|------|-----|------|-----|
| 3    | 3   | 13   | 75% |
| 4    | 21  | 43   | 19% |
| 5    | 40  | 53   | 11% |
| 6    | 63  | 59   | 8%  |
| 7    | 92  | 65   | 6%  |
| 8    | 140 | 75   | 5%  |
| 9    | 179 | 74   | 4%  |
| 10   | 230 | 77   | 4%  |
| 11   | 270 | 75   | 5%  |
| 12   | 334 | 77   | 5%  |
| 13   | 390 | 77   | 5%  |
| 14   | 445 | 76   | 6%  |
| 15   | 514 | 76   | 7%  |
|      |     |      |     |

Coating Coated Foil Thickne3 Shape Cl Pad Def CU

| SIZE | VOL | TE % | cv  |
|------|-----|------|-----|
| 3    | 17  | 76   | 34% |
| 4    | 54  | 124  | 16% |
| 5    | 84  | 125  | 13% |
| 6    | 107 | 115  | 12% |
| 7    | 138 | 109  | 11% |
| 8    | 163 | 98   | 12% |
| 9    | 193 | 89   | 12% |
| 10   | 237 | 89   | 12% |
| 11   | 266 | 83   | 12% |
| 12   | 315 | 82   | 13% |
| 13   | 345 | 76   | 12% |
| 14   | 386 | 74   | 12% |
| 15   | 439 | 73   | 12% |

Coating Bare Foil Thickn€3 Shape SQ Pad Def SM

| SIZE | VOL | TE % | cv   |
|------|-----|------|------|
| 3    | 1   | 5    | 177% |
| 4    | 3   | 7    | 90%  |
| 5    | 18  | 25   | 67%  |
| 6    | 52  | 49   | 39%  |
| 7    | 104 | 73   | 12%  |
| 8    | 162 | 87   | 8%   |
| 9    | 224 | 94   | 5%   |
| 10   | 293 | 100  | 4%   |
| 11   | 358 | 100  | 4%   |
| 12   | 451 | 105  | 3%   |
| 13   | 538 | 107  | 3%   |
| 14   | 631 | 108  | 3%   |
| 15   | 737 | 110  | 3%   |

| Coating    | Bare |
|------------|------|
| Foil Thick | ne3  |
| Shape      | CI   |
| Pad Def    | CU   |

| SIZE | VOL | TE % | CV   |
|------|-----|------|------|
| 3    | 0   | 1    | 575% |
| 4    | 5   | 12   | 158% |
| 5    | 18  | 26   | 122% |
| 6    | 21  | 22   | 145% |
| 7    | 69  | 53   | 93%  |
| 8    | 150 | 90   | 44%  |
| 9    | 233 | 109  | 18%  |
| 10   | 304 | 117  | 13%  |
| 11   | 366 | 115  | 11%  |
| 12   | 441 | 116  | 12%  |
| 13   | 506 | 113  | 11%  |
| 14   | 577 | 111  | 12%  |
| 15   | 661 | 111  | 12%  |

# CoatingCoatedFoil Thickne2ShapeSQPad DefCU

2nd BEST

2nd WORST

| SIZE | VOL   | TE %   | CV   |
|------|---|--|--|
| 3    | 15  | 90   | 37%  |
| 4    | 52  | 161  | 20%  |
| 5    | 67  | 135  | 27%  |
| 6    | 95  | 136  | 21%  |
| 7    | 130   | 137  | 9%   |
| 8    | 157   | 126  | 9%   |
| 9    | 192   | 118  | 9%   |
| 10   | 236   | 118  | 8%   |
| 11   | 268   | 111  | 8%   |
| 12   | 317   | 110  | 8%   |
| 13   | 349   | 103  | 7%   |
| 14   | 390   | 99   | 8%   |
| 15   | 443   | 99   | 8%   |
|      | SIZE<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14<br>15 | SIZE         VOL           3         15           4         52           5         67           6         95           7         130           8         157           9         192           10         236           11         268           12         317           13         349           14         390           15         443 | SIZE         VOL         TE %           3         15         90           4         52         161           5         67         135           6         95         136           7         130         137           8         157         126           9         192         118           10         236         118           11         268         111           12         317         110           13         349         103           14         390         99           15         443         99 |

#### Coating Bare Foil Thickn¢2 Shape SQ Pad Def CU

| SIZE | VOL | TE % | cv  |
|------|-----|------|-----|
| 3    | 6   | 34   | 79% |
| 4    | 26  | 80   | 47% |
| 5    | 32  | 63   | 81% |
| 6    | 62  | 88   | 59% |
| 7    | 110 | 115  | 29% |
| 8    | 158 | 126  | 13% |
| 9    | 202 | 127  | 10% |
| 10   | 253 | 130  | 9%  |
| 11   | 306 | 129  | 9%  |
| 12   | 359 | 126  | 8%  |
| 13   | 404 | 121  | 7%  |
| 14   | 464 | 120  | 7%  |
| 15   | 530 | 119  | 7%  |

CoatingCoatedFoil Thickne3ShapeSQPad DefCU

| SIZE | VOL | TE % | cv  |
|------|-----|------|-----|
| 3    | 19  | 80   | 33% |
| 4    | 66  | 137  | 15% |
| 5    | 90  | 121  | 14% |
| 6    | 120 | 115  | 12% |
| 7    | 153 | 107  | 9%  |
| 8    | 184 | 99   | 9%  |
| 9    | 221 | 91   | 9%  |
| 10   | 271 | 90   | 9%  |
| 11   | 311 | 86   | 9%  |
| 12   | 367 | 85   | 9%  |
| 13   | 403 | 80   | 7%  |
| 14   | 454 | 77   | 8%  |
| 15   | 514 | 76   | 8%  |

Coating Bare Foil Thickne3 Shape SQ Pad Def CU

| SIZE | VOL | TE % | CV   |
|------|-----|------|------|
| 3    | 2   | 6    | 289% |
| 4    | 5   | 11   | 168% |
| 5    | 7   | 9    | 170% |
| 6    | 18  | 17   | 134% |
| 7    | 67  | 47   | 95%  |
| 8    | 183 | 98   | 30%  |
| 9    | 273 | 114  | 9%   |
| 10   | 352 | 120  | 7%   |
| 11   | 429 | 120  | 6%   |
| 12   | 513 | 120  | 5%   |
| 13   | 588 | 117  | 5%   |
| 14   | 678 | 116  | 5%   |
| 15   | 780 | 116  | 5%   |

Coating Coated Foil Thickn¢2 Shape Cl Pad Def SM

| SIZE | VOL | TE % | CV   |
|------|-----|------|------|
| 3    | 1   | 5    | 158% |
| 4    | 12  | 39   | 45%  |
| 5    | 30  | 65   | 23%  |
| 6    | 49  | 79   | 15%  |
| 7    | 75  | 88   | 13%  |
| 8    | 106 | 96   | 9%   |
| 9    | 140 | 97   | 10%  |
| 10   | 179 | 101  | 10%  |
| 11   | 216 | 101  | 9%   |
| 12   | 267 | 104  | 10%  |
| 13   | 314 | 104  | 10%  |
| 14   | 367 | 105  | 10%  |
| 15   | 421 | 105  | 10%  |

Coating Bare Foil Thickn¢2 Shape Cl Pad Def SM

| SIZE | VOL | <b>TE %</b> | CV   |
|------|-----|-------------|------|
| 3    | 1   | 5           | 159% |
| 4    | 9   | 30          | 57%  |
| 5    | 26  | 58          | 29%  |
| 6    | 50  | 80          | 16%  |
| 7    | 77  | 91          | 12%  |
| 8    | 113 | 102         | 10%  |
| 9    | 148 | 104         | 10%  |
| 10   | 190 | 109         | 11%  |
| 11   | 232 | 110         | 10%  |
| 12   | 283 | 112         | 11%  |
| 13   | 336 | 113         | 11%  |
| 14   | 393 | 114         | 11%  |
| 15   | 456 | 115         | 11%  |

Coating Coated Foil Thickn€3 Shape Cl Pad Def SM

| SIZE | VOL | TE % | CV  |
|------|-----|------|-----|
| 3    | 3   | 15   | 74% |
| 4    | 17  | 40   | 31% |
| 5    | 34  | 50   | 20% |
| 6    | 54  | 58   | 15% |
| 7    | 80  | 63   | 13% |
| 8    | 122 | 74   | 10% |
| 9    | 160 | 74   | 10% |
| 10   | 203 | 76   | 10% |
| 11   | 243 | 76   | 10% |
| 12   | 299 | 78   | 11% |
| 13   | 352 | 78   | 10% |
| 14   | 407 | 78   | 10% |
| 15   | 466 | 78   | 11% |

| Coating   | Bare |
|-----------|------|
| oil Thick | ne3  |
| hape      | CI   |
| ad Def    | SM   |
|           |      |

| SIZE | VOL | TE % | CV   |
|------|-----|------|------|
| 3    | 0   | 0    | 585% |
| 4    | 2   | 5    | 117% |
| 5    | 15  | 21   | 82%  |
| 6    | 44  | 47   | 46%  |
| 7    | 91  | 71   | 23%  |
| 8    | 147 | 89   | 12%  |
| 9    | 204 | 96   | 11%  |
| 10   | 265 | 102  | 11%  |
| 11   | 327 | 103  | 10%  |
| 12   | 410 | 108  | 11%  |
| 13   | 490 | 110  | 11%  |
| 14   | 579 | 112  | 11%  |
| 15   | 676 | 113  | 11%  |