Using Electronic Coating Thickness Gauges Effectively in the Screen Printing Process

Are Your Measurements Accurate?

By Dawn M. Hohl

Electronic thickness gauges are very useful tools in the screen printing industry for a number of applications. Their basic purpose is to measure the dry thicknesses of non-magnetic coatings or objects in a non-destructive manner. Some of the most common screen printing "non-magnetic" samples that can be measured include mesh, stencils, dry ink deposits, and substrates. All four of these variables are vital to the process, and should be monitored or controlled by the screen printer. As will be discussed, these four applications require different measurement procedures to ensure accurate and reliable readings. Learning how to effectively use these instruments is essential if data gained with them is to be of value.

SPTF
Screen Printing Technical Foundation
10015 Main Street
Fairfax, Virginia 22031
Telephone: 703-385-1417
Fax: 703-273-0456

In the main part of this bulletin, SPTF will present procedures and techniques to correctly measure screen fabric, stencil, ink deposit, and substrate thicknesses with these instruments, including some graphs showing results with these techniques. Also to be covered will be the principle of operation, calibration, limitations, and accuracy of these instruments. Readers will have a working knowledge of these gauges upon completing this paper, enabling them to correctly take measurements on any of these screen printing variables.

Principle of Operation

Two methods of electronic measurement are appropriate for screen printing applications, magnetic induction and eddy current. Both measure nonmagnetic and nonferrous coatings, which includes screen mesh, stencils, most substrates, and dry ink deposits. The most common of these two methods currently being used in the screen printing industry is magnetic induction. Many know this type of instrument as a "Deltascope," but this is actually a model name used by one manufacturer for their magnetic induction device. Before going on, an explanation of how both of these methods work is an order.

Magnetic Induction

The magnetic induction instrument is so named after the measurement method by which it obtains thickness readings, that is, the magnetic induction principle. These gauges will be set up with either an AC or a DC magnetic field system, with the AC method being the most popular. Gauges employing the AC magnetic field derive their measurements from changes in strength of a magnetic field created by the proximity of a coil (probe) to a ferrous object. With changes in the distance between the coil and ferrous material created by the substance being measured, both the flux density and current flow vary accordingly, and can be monitored to determine thickness.

This method limits what can be measured to non-magnetic coatings on magnetic basis metals. These "coatings" can include things like copper, zinc, lead, chrome, rubber, tin, plastic, paint, enamel, ink, paper, and aluminum. In contrast, materials such as steel, iron, and nickel will cause erroneous readings due to their magnetic nature.

Typically these devices are used to measure coatings that have been applied to ferrous materials. In such a situation, the ferrous substrate becomes a base that reacts to the signal, making it the zero surface for the electronics to operate from. In common screen printing applications there is not a ferrous material involved in most measurements, so a ferromagnetic base must be introduced as the zero surface. The base is used in the calibration process, as well as during measurements, and is placed directly under the material being tested.

There are several measurement standards specific to this principle including ISO 2178, ASTM B-499, and DIN 50 981. These standards outline instrument specifications, calibration, factors affecting accuracy, and measurement procedures. Copies of these standards can be obtained from the respective organizations (listed in the back of this bulletin) if further information is required.

Eddy Current

An eddy current gauge works by energizing its probe with alternating current creating eddy currents in the metal substrate or base. Magnetic fields are created in the substrate that modify the electrical characteristics of the probe's coil. The distance between the probe and the metal dictates the extent of these changes, and can be translated into the thickness of the coating being measured. It is designed to measure electrically non-conducting coatings on non-magnetic basis metal substrates. (While these units are not necessarily intended to measure coatings on ferrous metal substrates, they are capable of doing so if calibrated to a ferrous substrate.) Acceptable items to be measured with eddy current are things like

Figure 1

Both types of electronic thickness gauges typically consist of a hand held unit and a probe connected on a flexible cable.

Figure 2

Some gauges have an integral probe built into the main housing of the unit, as seen on this particular eddy current gauge.

rubber, plastic, paint, enamel, ink, and paper.

This instrument's operation is also dependent on a metal substrate or base. The material needed in this case is normally nonferrous such as aluminum, brass, magnesium, and copper, or respective alloys. Just as with the magnetic induction method, screen printing applications usually require a base under the item being measured.

Standards dealing with eddy current gauges include ISO 2360, DIN 50 984, and ASTM D 1400. Again, more information can be obtained in these sources.

Features

Both types of gauges **(Figure 1)** typically consists of a hand held unit and a probe connected on a flexible cable. Some models have an integral probe built into the main housing of the unit **(Figure 2)**. The instruments usually come with a zeroing base of an appropriate material, several calibration foils, and various probe guides. The main unit has a digital readout display, a control panel with various functions, and a battery compartment. Additional options such as statistical data summaries, printer interface, data interface, and internal data storage memory are also available. Prices range anywhere from $500 to $2100 depending on the manufacturer, model, and probe type. A listing of several manufacturers of these gauges can be found at the end of this bulletin.

These portable devices are designed to reach almost any area of an object, made possible by the separate probe and measurement base. In screen printing applications, this means any given size screen or substrate can be accommodated with ease. Common mechanical thickness measurement devices such as micrometers and calipers have shallow fixed distances to place an object, limiting what can be measured. Therefore, electronic thickness gauges serve a vital function in the screen printing industry.

Probes

Most probes are designed with a spring-loaded gripper which provides consistent contact pressure and positioning on the sample, regardless of the operator using it. Probe guide attachments also assist in taking repeatable readings. The range of thicknesses a gauge can handle will differ with model and probe type. In most cases, the larger the range, the less measurement resolution the instrument will have. Consequently, it is best to select the minimal range that will address all your measurement needs. For the typical screen printer a range of around 0-2000 microns (or 0 to 78 mils) is appropriate. Models with higher and wider thickness ranges are also available. Different probes may have varying ranges, accuracy and limitations that the screen printer should be aware of. The manufacturer should be consulted for this information.

There are a variety of specialized probes available in addition to the general application probe supplied as standard equipment. Most of the specialized probes address measurement tasks in other industries, and are not appropriate for screen printers. However, a new screen printing probe working on magnetic induction (**Figure 3**) was recently introduced by one manufacturer, and is specifically designed for measurements on fabric and stencils.

Many screen printers owning an electronic thickness gauge will find they have a standard probe similar to the one in **Figure 4**, as opposed to a specialized probe. There are important differences between standard probes and the screen printing probe mentioned. Test results from both types will be discussed in a later section.

Calibration

Any type of measuring instrument, be it mechanically or electronically based, needs to be calibrated to function properly. The purpose of calibration is simply to check, adjust or systematically standardize the graduations of a device using a known reference traceable to an accepted source. These "acceptable sources" can be well-established government organizations such as NIST (National Institute of Standards and Technology), or the manufacturers of instrumentation themselves.

Calibration methods for measuring devices vary. Many instruments are calibrated in the manufacturing process and do not require further adjustment. A familiar example of this situation is a common ruler. In some cases instruments requiring calibration will have a standard built into the system that automatically engages itself

Figure 3

A new screen printing probe, working on magnetic induction, was recently introduced by one manufacturer and is specifically designed for measurements on fabric and stencils.

Figure 4

An example of one manufacturer's general purpose probe.

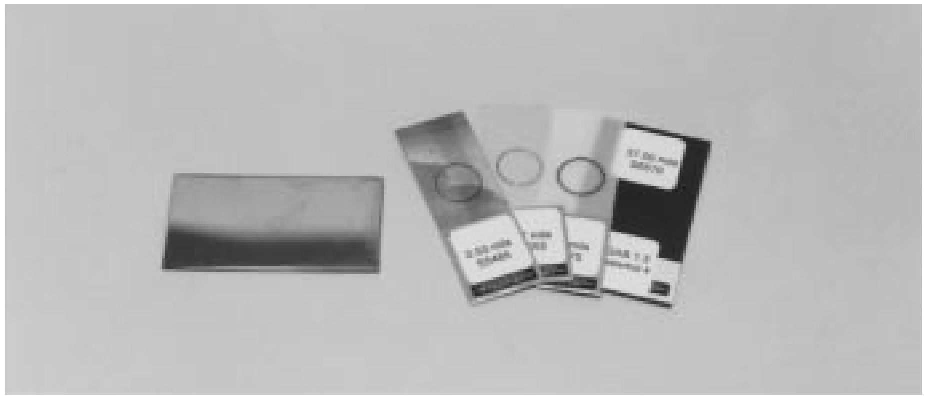
when necessary. In other instances a set of calibration standards are included with the instrument, requiring the operator to perform a calibration procedure as often as the manufacturer recommends. Still other instruments require calibration be carried out at the manufacturer's facilities on a periodic schedule to insure instrument accuracy.

Magnetic induction and eddy current devices have a primary calibration performed by the manufacturer before the instrument is sold, but most also come with a set of calibration "foils" or standards which are made out of a stable plastic material and are different thicknesses (**Figure 5**). Each foil is labeled with its actual thickness by the manufacturer. Anywhere from one to four foils, covering a range of thicknesses, must be used to calibrate these instruments.

The foils are read during the calibration sequence in a prescribed order and the instrument is manually adjusted to recognize the actual thickness of each of the foils. In addition, the base supplied with the instrument is measured alone to establish a zero point. With these reference points, the instrument can accurately extrapolate the correct thickness on any sample introduced to it, provided it is within the range of its measurement ability. Some newer models also offer the ability to store a corrective calibration for specific applications along with a master calibration. These corrective calibrations adjust the instrument to accurately read thickness with different materials. The basic procedure for calibrating both types of instruments is similar, but in all cases the specific instructions recommended by the manufacturer should be followed.

Calibration need not be carried out every time the device is used (if the application remains the same). However, frequent checks with the calibration standards are recommended to determine if significant deviations exist warranting the need for recalibration. Significant deviations are present if readings differ from the actual thickness by more than the stated accuracy of the instrument (please read the *Instrument Accuracy and Resolution* section for more explanation). For added reliability, these gauges can be sent back to the manufacturer periodically (once a year or so) to recalibrate the primary system and to make sure everything is functioning correctly. In addition, calibration foils are easily indented, bent or damaged, and should be replaced frequently.

Figure 5

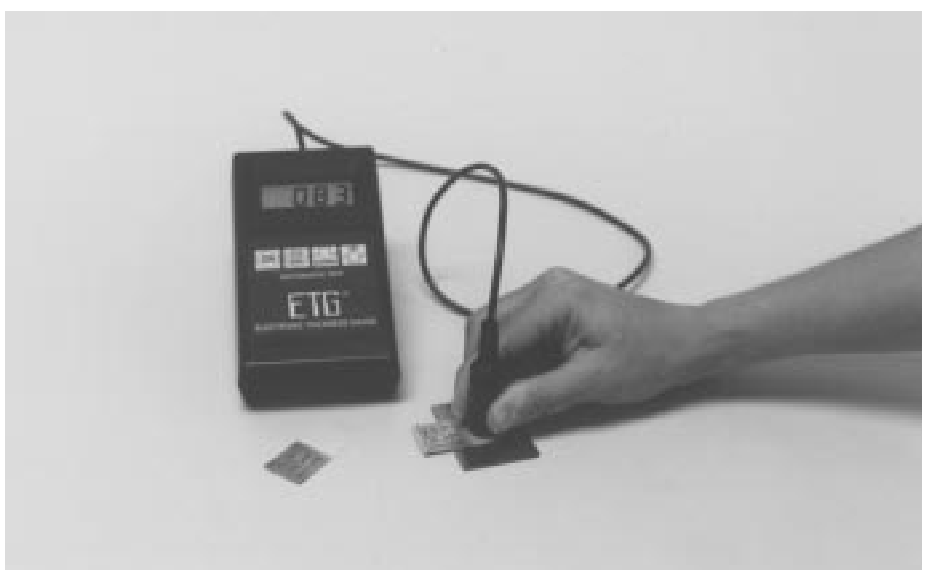


Most magnetic induction and eddy current devices come with a metal base and a set of different thickness calibration "foils" or standards, which are made out of a stable plastic material.

Basic Measurement Procedure

The user can begin making measurements directly after performing the calibration process or after making a quick check with a calibration standard. To take measurements proceed as follows:

Figure 6



When taking a measurement with digital thickness gauges, the test specimen is placed on top of the base (if the coating or object to be measured is not on the proper metal substrate). The probe is then set on the sample at a right angle, and depressed until the spring loaded grip is fully engaged to make the connection.

1. Check that the test specimen and the probe contact areas are clean, dry and free of dirt, dust, and grease. (This is especially important when using the new screen printing probe.) The light spring and wide flat contact area of this probe make it highly sensitive to dirt particles. If dirt is present during measurement the resulting readings will be erratic and higher than the actual thickness.

2. Place the test specimen on top of the base (only use the base if the coating or object to be measured is not the proper metal substrate). Set the probe at a right angle to the test object, making sure that the spring-loaded grip is fully engaged to achieve the connection (**Figure 6**).

3. Once full contact is achieved, hold the probe steady in the perpendicular position until the display registers the thickness. In some instruments an acoustical sound signals the user when the thickness is acquired. Depending on the model's features, readings may be stored internally for statistical evaluation. The readings can also be printed out on a printer if the unit has that option.

4. Raise the probe at least 1 centimeter (1/2 inch) from the surface being measured before taking another reading.

5. Repeat steps 2,3 and 4 until 5 to 10 measurements are acquired across the test surface. If a greater sampling is needed, 20 measurements are generally sufficient. Take readings in all areas where thickness must be guaranteed.

6. If the instrument has a statistics mode, a result key may be pushed when measurements have been completed to display statistical information on the readings collected. Values calculated usually include the mean (or average), minimum thickness, maximum thickness, standard deviation, and total number of measurements.

7. A new measurement series may be started at this point by following manufacturer's instructions.

Conversions

microns x 0.03937 = mils
mils x 0.001 = inches
mils x 25.4 = microns
micron x 0.0001 = centimeters

Important Tips

- If a sample is small, as to only allow one measurement, several samples should be measured.
- Measurements should not be taken near edges, shoulders or material defects.
- Incorrect measurements can occur if the probe is tilted, unstable or influenced by dirt, and should be eliminated from the data set by pressing a delete or clear key on the unit.
- Do not continue to take measurements when the low battery indicator appears on the unit. Replace the battery immediately. Measurements taken with a weak battery will be erratic and unreliable.
- Measurements should not be taken on or around a metal table or other large metal objects to avoid magnetic interference from affecting the readings.

Limitations of the Gauges

Roughness

The roughness of a surface, when over 10% of the total thickness, can cause errors in measurements. The error results from the probe's placement with respect to the peaks and valleys of a surface, affecting the magnetic field measured by the gauge. Roughness becomes a challenge to deal with when measuring screen printing mesh. Errors from the surface roughness of screen printing mesh are explored at length in the Fabric Thickness section of this bulletin. Other surfaces (like substrates and stencils) that are not as rough as screen mesh should simply be measured 10 or more times and averaged to factor out the random error that occurs.

Curved Surfaces

An object with excessive curvature will throw off measurement accuracy. When dealing with contoured surfaces, the manufacturer should be consulted on the acceptable curvature limits tolerated by the instrument, and how to correct for extreme curves.

Fabric Thickness

As its name implies, fabric thickness is the measure of the total thickness of a woven mesh. While mesh manufacturers provide a fabric thickness specification, SPTF research has shown that during the tensioning process the thickness of the mesh changes. Therefore the thickness listed by the manufacturer, which represents untensioned fabric, is generally not applicable to tensioned mesh. The only way to determine the fabric thickness at printing tension is by measuring it on a stretched screen with electronic thickness gauges. The SPTF's research report entitled *Physical Changes in Polyester Mesh During Tensioning* contains more information on the dimensional changes in mesh.

Knowing the actual fabric thickness of a mesh may not seem very valuable, until considering the significant connection it has to the resultant wet ink deposit thickness of a mesh. Discovery of this link came as a direct result of early research conducted by the Screen Printing Technical Foundation. Since then, several formulas have been developed that closely predict a mesh's wet ink deposit. The calculation involves multiplying a factor* by the measured fabric thickness taken at tension. The prediction accuracy from this ink estimate formula is very dependent on the exactness of the fabric thickness measurement.

* There are to date three factors, each addressing three distinct groups of mesh. The appropriate factor must be selected based on the mesh that is being estimated. Please refer to the mentioned practical application bulletin for the factors and an explanation on how to use them.

SPTF's ink deposit estimate method has proven more reliable and accurate than any other well-known formula being used in the industry. Better wet ink predictions can lead to improvements in ink consumption estimates and can be helpful in mesh selection. Full details on this method of estimating ink deposit are in SPTF's Practical Application Bulletin called *Estimating Ink Deposit in Screen Printing: Improving Your Accuracy.*

Another important use for accurate fabric thickness measurements is in determining emulsion over mesh ratios (EMR or EOM) for stencils. The EMR or EOM shows the relationship of the stencil thickness to the mesh thickness. In calculating the ratio, the emulsion thickness is divided by the fabric thickness and then multiplied by 100 to indicate a percentage. Obviously, erroneous fabric thickness values will produce a misleading result.

Measuring Fabric Thickness

Researchers at SPTF have conducted a number of capability studies with magnetic induction and eddy current devices over the years. In the capability study on fabric thickness, a significant error was discovered in the readings obtained from these instruments as compared to measurements taken on proven mechanical systems, including an Electronic Micro Gauge*(EMG) and two micrometers. This data has confirmed that fabric thickness measurements taken with standard probes will be inaccurate unless other methods are used. Fortunately, the error can be corrected by using one of two techniques, making the instrument perfectly useful for measuring fabric thickness.

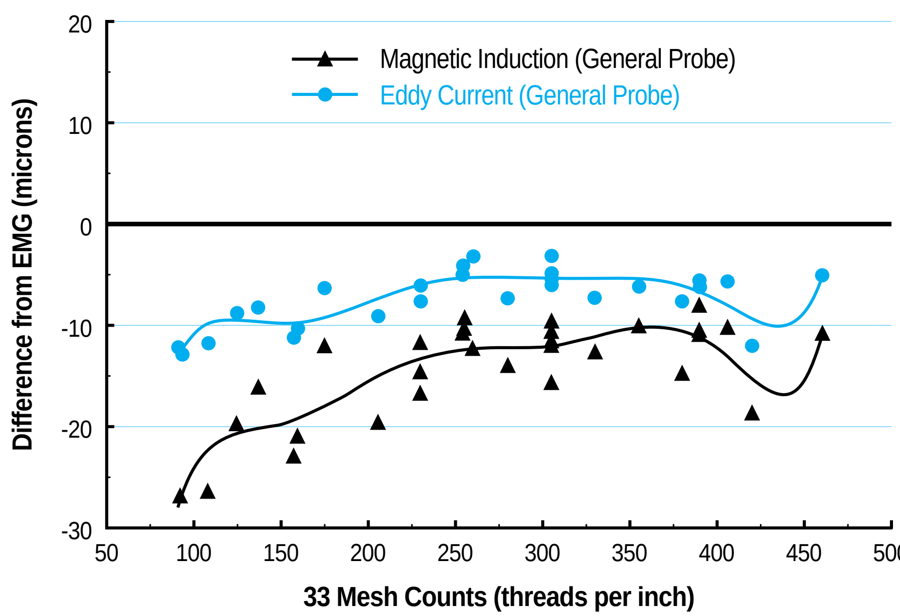
* An Electronic Micro Gauge is a very precise mechanical measurement system, capable of reading both wet and dry thicknesses. A detailed description of this instrument is given in SPTF's technical research report entitled "A Guideline to Wet and Dry Ink Deposit Measurement Methods."

In the first capability study examined, a magnetic induction device (using a general purpose probe) and an eddy current gauge (also using a standard probe) were calibrated according to manufacturer's instructions using the provided foils. Thirty-three meshes were measured ranging from a 35 to a 180 mesh count per centimeter (92 to 460 mesh count per inch), varying in thickness from 53 to 170 microns (2.09 to 6.69 mils). The Foundation's EMG was made the reference instrument, and these reference measurements were subtracted from the readings taken with the magnetic induction and eddy current device. The graphed difference, and can be found in **Figure 7**. The zero line represents the reference instrument, or the true fabric thickness. The other two curves show the error in the readings that results when both the magnetic induction and eddy current systems are calibrated normally. Each point in the graph represents the average of 10 readings on one of the 33 meshes, and the curve fitted lines give an overall view of how each instrument performed.

The error is significant in both sets of data, with the magnetic induction having a difference of -9 to -27 microns, and the eddy current between -3 to -13 microns. These errors are simply unacceptable and produce very misleading fabric thickness values. Notice that the error does not remain constant but increases as the lower mesh counts are measured. The roughness of the mesh is the primary reason for this error, so it is

Figure 7

Error in Fabric Thickness Measurements
Electronic Thickness Gauge Comparison



Error in fabric thickness measurements from both types of digital thickness gauges. The zero line represents the reference instrument, or the true fabric thickness, while the other two curves show the error in the readings that result when both types of gauges are calibrated with the manufacturer supplied foils. Differences in both the individual readings and the curve fitted lines are shown here.

not surprising the lower mesh counts exhibit greater differences. Without a constant offset, using a fixed value to adjust the reading is not effective.

Two different manufacturer's eddy current systems and three different manufacturer's magnetic induction gauges were evaluated, all showing similar errors in fabric thickness measurements with the standard calibration. The effect is therefore not specific to one manufacturer, but rather to the overall measurement principles used by both types.

As previously mentioned, there are two solutions that significantly reduce this error. While both methods work effectively, one may work better than the other in some circumstances. Both are presented here so the screen printer can make an informed decision on which will work best in a given situation.

Method One

The first technique requires a foil or shim having a thickness of around 200-254 microns (7.87 - 10 mils) be placed on top of the fabric during measurement (**Figure 8**). While this adds the shim's thickness to the reading, it also effectively minimizes the effects of the roughness of the fabric, and subsequently the error it creates. The thickness of the foil is subtracted from the readout to identify the fabric thickness value. Measurements on low mesh counts are best taken using this method. Directions for using the shim method can be found in **Table 1**.

Method Two

The second method involves a new calibration technique that adjusts the gauge to read fabric thickness correctly. Simply explained, the revised calibration calls for the user to replace the polyester foils that the manufacturer provides, with samples of screen printing mesh. These replacement "mesh standards" must be pre-measured

Figure 8

One technique to eliminate measurement error on fabric thickness requires a foil or shim having a thickness of around 200-254 microns (7.87 - 10 mils) be placed on top of the fabric during measurement. While this adds the shim's thickness to the reading, it also effectively minimizes the effects of the roughness of the fabric, and subsequently the error it creates. The thickness of the foil is subtracted from the readout to identify the fabric thickness value.

Table 1

Shim Method for Measure Fabric Thickness with Magnetic Induction or Eddy Current

1. Determine if you have the special screen printing probe, or if you are using a standard probe. (There is currently only one manufacturer producing a screen printing probe.) If you have a standard probe you will need to proceed with steps 2-6. If you are using the screen printing probe, no special calibration is required to measure fabric thickness accurately. Measurements may be made after the unit has been calibrated according to the manufacturer's directions.

2. Obtain a plastic shim with a thickness around 200-254 microns. For best results, the shim should have uniform thickness and be made out of a stable material like polyester. One of the easiest things to do is use a foil that came with the instrument, or contact the manufacturer to purchase a foil.

3. Measure the shim with a micrometer to determine its actual thickness. Around 5 to 10 measurements should be made and averaged. Label the shim with the average thickness for reference. A foil from the manufacturer will already have been measured and labeled.

4. Measure and record 5 to 10 fabric thickness readings in various places toward the center of the screen by placing the shim on top of the mesh, and taking the measurement on the shim. Follow the guidelines in the Basic Measurement Procedure section of this bulletin.

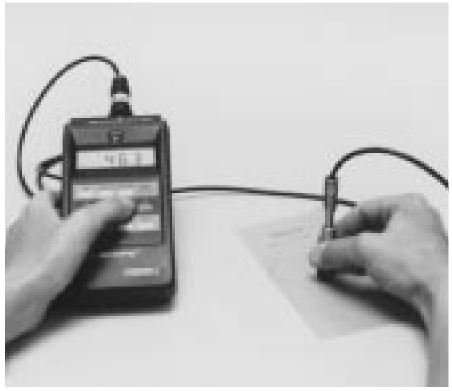
5. Obtain the average of the 5 to 10 numbers from the statistical options of the gauge, or calculate it by adding all the numbers together and dividing by the number of measurements that were taken.

6. Subtract the thickness of the shim from the calculated average to determine the actual fabric thickness of the mesh.

Figure 9

Ten to twenty fabric thickness measurements should be taken with a micrometer when creating a mesh standard for calibrating electronic thickness gauges. The micrometer pictured here has a digital readout and a large diameter anvil which provides a good fabric thickness average on screen printing mesh.

Figure 10



The measured mesh samples will now be used as standards to calibrate both types of thickness gauge so fabric thickness can be read correctly. This can be accomplished by introducing the mesh standards in place of the foils during the calibration process.

Figure 11

Pre-fabricated mesh standards are available from SPTF to simplify electronic thickness gauge calibration for measuring fabric thickness.

Table 2

Mesh Calibration Method for Measure Fabric Thickness with Magnetic Induction or Eddy Current

1. Determine if you have the special screen printing probe, or if you are using a standard probe. (There is currently only one manufacturer producing a screen printing probe.) If you have a standard probe you will need to proceed with steps 2-6. If you are using the screen printing probe, no special calibration is required to measure fabric thickness accurately. Measurements may be made after the unit has been calibrated according to the manufacturer's directions.

2. Select one to three mesh counts (depending on how many calibration points the gauge requires) that represents a cross section of available mesh counts. SPTF strongly suggests the following: For 3 point calibration use 36/100, 90/48, and 150/34 *(English equivalent 92/100, 230/48 and 390/34)*. For 2 point calibration use 43/80 and 150/34 *(English equivalent 110/80, and 390/34)*. For 1 point calibration use 90/48 34 *(English equivalent 230/48)*. SPTF has researched various meshes for calibration purposes and found these to be the best. You may also contact SPTF to purchase mesh calibration standards of these specific mesh counts (eliminating the need to complete steps 3 and 4).

3. Acquire a small sample (6 cm x 8 cm) of each mesh count and take 10 to 20 measurements of fabric thickness in different spots on each sample with a thickness micrometer resolving to 2.54 microns or lower **(Figure 9)**. The micrometer should have a standard or wide surface anvil as opposed to small surface anvils. Light pressure must be used when measuring mesh with a micrometer so it is not crushed. Use the slip ring if it does not apply too much pressure so that your readings will be more consistent. It is also important to turn the anvil slowly when measuring. Turning it fast will apply more pressure.

4. Calculate the average fabric thickness of the 10 to 20 readings for each mesh and label the mesh accordingly. These mesh samples will now be used as standards to calibrate the magnetic induction or eddy current instrument.

5. Calibrate the instrument according to manufacturer's instructions, using the mesh standards in place of the foils **(Figure 10)**. Some of units have a master calibration where you must use the foils, and then have a corrective calibration option where mesh may be introduced to eliminate the error.

6. When the calibration with mesh is complete, you are ready to measure fabric thickness. Measure and record 5 to 10 readings in various places toward the center of the screen. Follow the guidelines in the Basic Measurement Procedure section of this bulletin.

7. Obtain the average of the 5 to 10 numbers from the statistical options of the gauge, or calculate it by adding all the numbers together and dividing by the number of measurements that were taken. Use the average as the fabric thickness of the mesh.

8. The instrument must be recalibrated with the supplied foils if the stencil thickness, substrate or ink deposit is to be measured.

with a reliable instrument, such as a micrometer, so the actual thickness can be entered into the electronic thickness gauge at the time of calibration. A detailed step-by-step procedure describing this new calibration method is outlined in **Table 2**.

Calibration procedures will vary depending on the manufacturer and model. If the unit offers a corrective calibration option, the mesh can be introduced at this point. Other models will allow mesh to be substituted for the foils. What the unit will or will not allow you to do depends on the manufacturer, model, and generation of the unit.

Mesh Calibration Standards

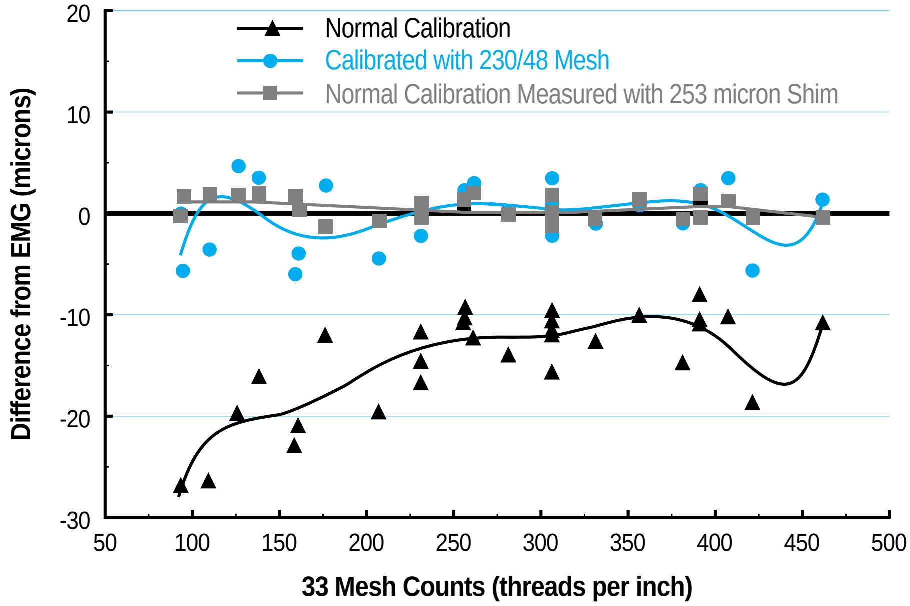
The procedure listed in Table 2 provides instructions for creating a set of mesh calibration standards to use when measuring fabric thickness. For the best possible results, the mesh counts and measuring process specified in these instructions should be used. For those who do not wish to spend the time and trouble of making standards, the SPTF is offering pre-made mesh calibration standards at a minimal cost (**Figure 11**). These mesh standards are constructed and measured at the Foundation with the specific meshes mentioned. Contact the author at SPTF for further ordering information.

The Results

The graphs in Figures 12, 13, 14 illustrate the improved results of the two special techniques just outlined, in both types of instruments. Results from one magnetic induction gauge (with a general probe) are shown in **Figure 12**. Dramatic improvements can be seen from both techniques with this gauge, with the shim method providing the best consistency over the whole range in mesh counts. The first eddy current gauge tested, produced similar results with the two techniques (**Figure 13**). Again,

Figure 12

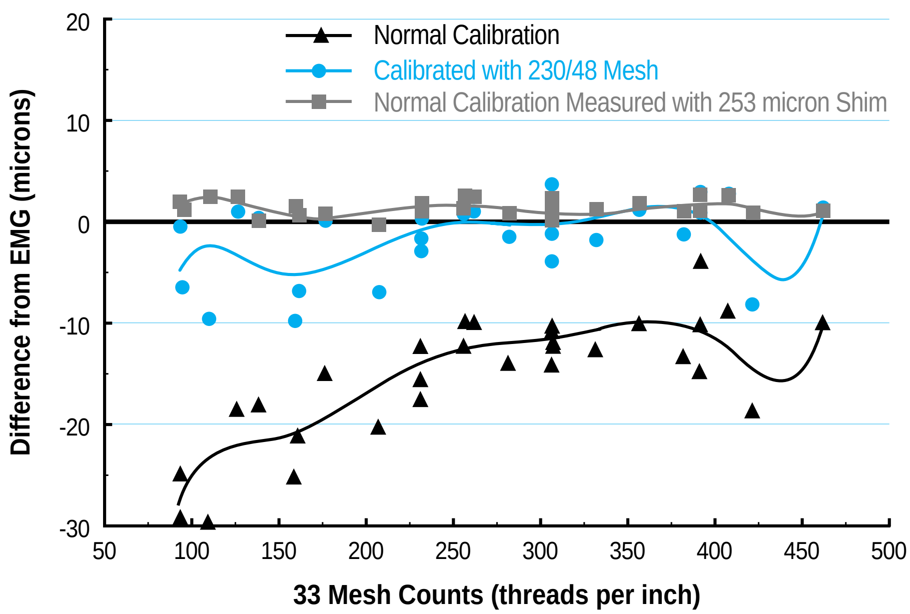
Fabric Thickness Measurement
Magnetic Induction Error Reduction (General Probe)



Fabric thickness error reduction achieved over 33 mesh counts when either of the two techniques are used with a magnetic induction instrument.

Figure 13

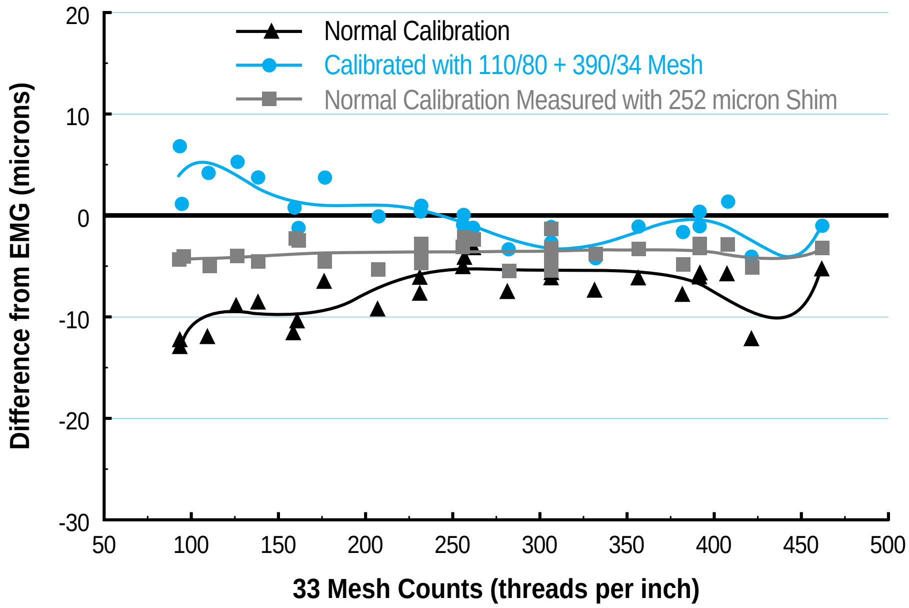
Fabric Thickness Measurement
Eddy Current Error Reduction (General Probe Instrument 1)



Results from an eddy current gauge showed similar improvements from using these two techniques in measuring fabric thickness.

Figure 14

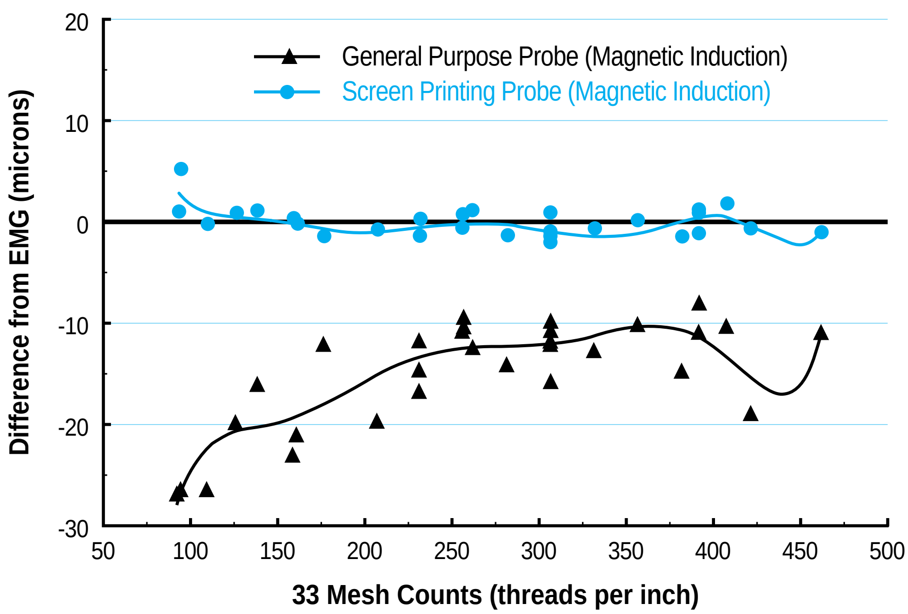
Fabric Thickness Measurement
Eddy Current Error Reduction (General Probe Instrument 2)



Another manufacturer's eddy current gauge did not respond as well with the shim method compared to the unit tested in Figure 13.

Figure 15

Fabric Thickness Measurement
Screen Printing Probe vs. General Purpose Probe



An evaluation of a new probe specifically designed for screen printers found it to work exceptionally well on fabric thickness measurements without any special calibration. Here the screen printing probe results are compared to the standard magnetic induction probe. Both probes were calibrated with the manufacturer foils.

both methods improved the error, but the shim reduced the difference more uniformly than the mesh calibration. However, a different manufacturer's eddy current gauge, shown in **Figure 14**, displayed a slightly different effect with the shim. While it is again more consistent across the range of mesh, is not as accurate to the reference measurements as in Figure 13.

Overall, the shim reduces the error caused from the roughness of the mesh more effectively and consistently, especially in the lower mesh counts. The mesh calibration method also provides and acceptable alternative. One method may be easier to use than another, depending on the application and use of the measurement. Both techniques can be considered legitimate ways of obtaining accurate fabric thickness measurements with electronic thickness gauges.

It becomes apparent that without using one of these two procedures, fabric thickness readings will not be useful in calculating a wet ink deposit estimate with SPTF's formula or the emulsion over mesh ratio. The screen printer using these gauges to measure fabric thickness for any reason must begin to implement one of these methods to get accurate results.

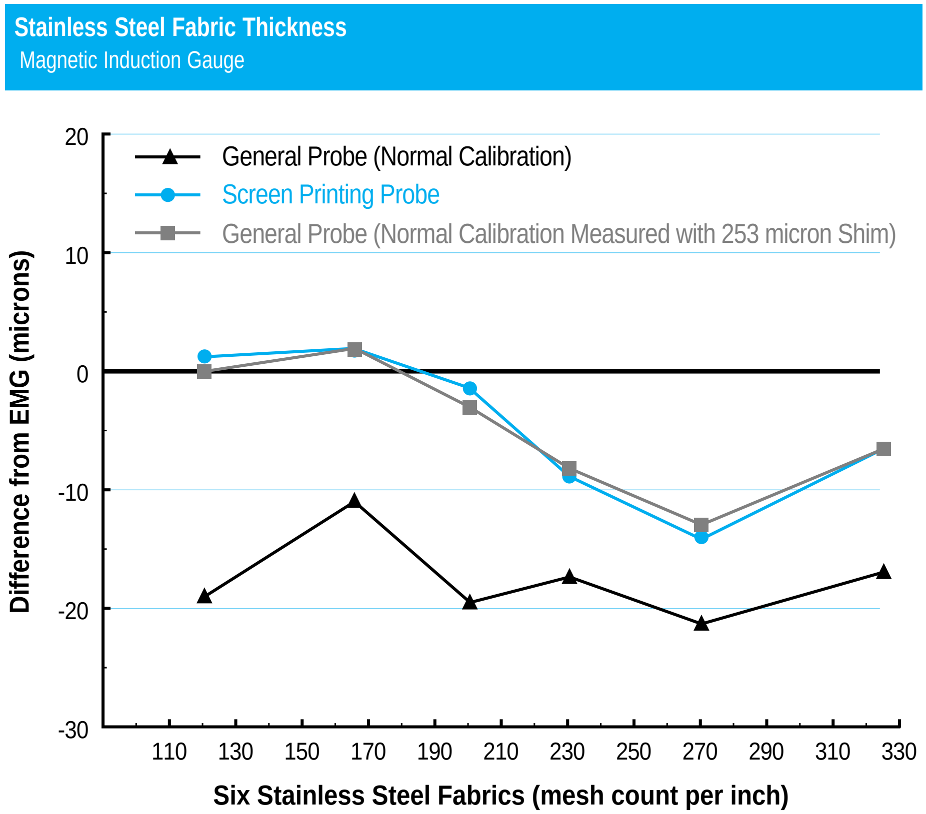
As previously mentioned, one manufacturer introduced a new probe specifically designed for screen printers. SPTF testing found the new probe to work exceptionally well on fabric thickness measurements without any special calibration (**Figure 15**). Notice how closely the readings are to the reference line across the entire range of mesh counts measured. The general probe results are pictured here to show the exceptional improvements this screen printing probe makes in the readings. The new probe also gives more repeatable measurements on stencils. The new screen printing probe is available only on one particular manufacturer's magnetic induction model.

Fabric Thickness on Stainless Steel Mesh

Measuring stainless steel mesh requires the use of a magnetic induction gauge rather than eddy current due to the fact it is non-magnetic and conductive. However, testing at SPTF has established that this gauge produces some sizable differences in fabric thickness readings on some meshes, but can be very accurate on others. While roughness may account for some of this deviation, the properties of the metal also interfere with the electronics to a certain extent, and are thought to be responsible for the error seen here. As seen in **Figure 16**, only the screen printing probe and the general probe with the shim measure close to the actual thickness. It was determined that using the general probe by itself produced very inaccurate results.

These inconsistencies do cast doubt on the reliability of this gauge to give good fabric thickness readings on stainless steel. A more dependable method would be to measure a free piece of the fabric with a micrometer, and assume that since stainless steel changes very little dimensionally during tensioning, this measurement can be considered the general thickness of the mesh.

Figure 16



Magnetic induction gauges do not measure fabric thickness on stainless steel accurately on all mesh counts.

Stencil Thickness

Next on our list of screen printing measurements is the stencil thickness, or more specifically, the thickness of the stencil above the mesh. To calculate stencil thickness, the measurement of the fabric thickness is subtracted from the measurement of the stencil/mesh combination. Other measurements involving the stencil include the total screen thickness (the fabric thickness plus the stencil thickness), and an emulsion over mesh ratio (EMR or EOM). Stencil thickness consistency is a major player in process control for many applications, making its measurement of utmost importance.

Measuring Stencil Thickness

Roughness must again be considered when measuring stencil thickness, and its effects dealt with appropriately. Two different scenarios can be identified with stencil measurements. The first situation involves a rough stencil and the rough mesh, and the second a smooth stencil and the rough mesh. Stencils made with direct emulsion that do not have thick stencil build-ups will generate a fairly rough stencil surface, creating the first situation. Stencils made with capillary film, indirect film, and thick direct emulsion coatings usually produce smooth stencil surfaces, setting the stage for the second scenario presented.

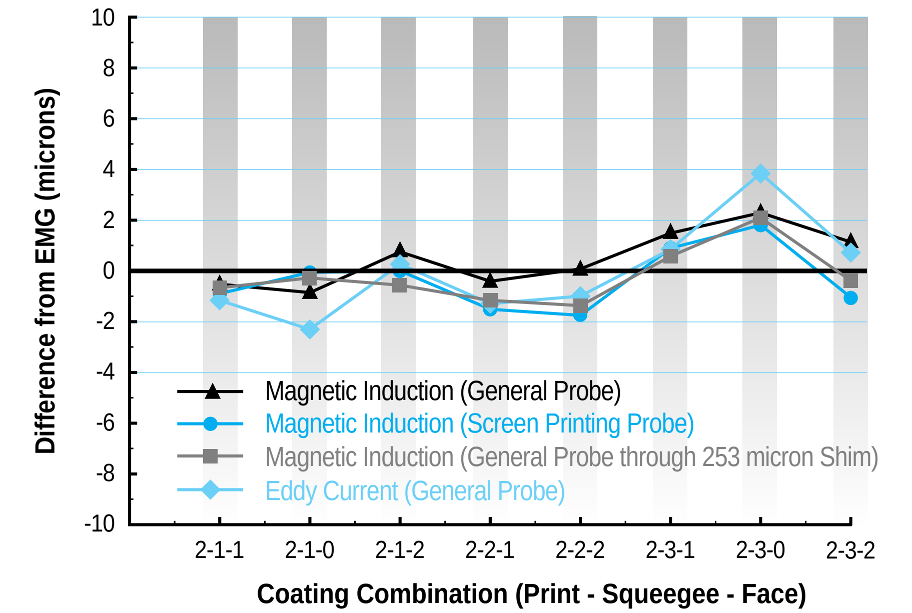
When both the stencil and the mesh have rough surfaces, these gauges will respond approximately the same to each surface. As explained in the fabric thickness section, the general probes under normal calibration give inaccurate readings on rough surfaces like mesh. Since stencil thickness is actually the relative difference between two measurements, those two measurements can be inaccurate and still provide a reliable relative difference, so long as the instrument is consistently reacting the same way. This is the effect that is seen under the conditions of a rough stencil and rough mesh.

In order to get good stencil thickness measurements in this instance, no special techniques or procedures need to be used. Simply take the average of several readings from the mesh and subtract it from the average of several readings from the stencil/mesh combination. As pictured in **Figure 17**, the calculated relative difference is very accurate.

The measurements shown represent an average difference of 10 measurements on the fabric and 10 on the stencil/mesh, for 8 different

Figure 17

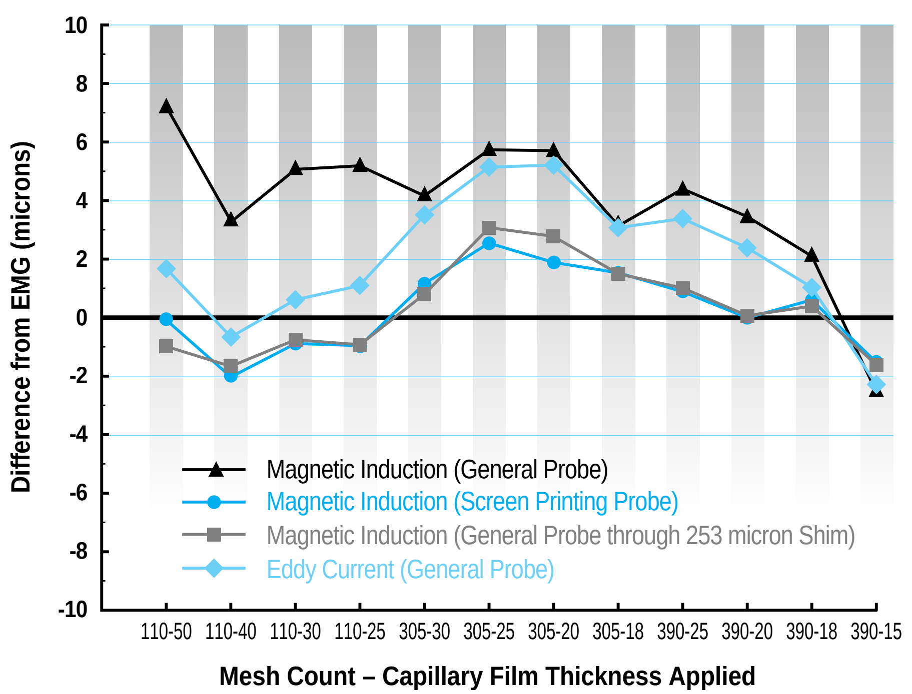
Stencil Thickness of Direct Emulsion
Electronic Thickness Gauge Comparison



Stencil thickness results from eight different direct emulsion coatings show all gauge types and probe types to give accurate values relative to the reference instrument.

Figure 18

Stencil Thickness of Capillary Films
Electronic Thickness Gauge Comparison



Due the the difference in readings from the smooth surfaced stencil and the rough mesh, the calculated stencil thickness is not accurate when using the general probe on capillary film. Both the screen printing probe and the general probe measured through a 253 micron shim improve the accuracy of the stencil thickness measurement on stencils with smooth surfaces.

coatings of a dual cure direct emulsion. The gauges tested were all calibrated using manufacturer foils and procedures. The general probe results from both the magnetic induction and eddy current methods are comparable to the screen printing probe and the shim method. While the new probe and shim eliminate the roughness effect, they do not give improved results over the general probes. However, both of these methods can be used to effectively measure stencil thickness in this situation.

It is extremely important to note that measurements for the fabric thickness and total mesh thickness taken with the general probes will not be accurate, even though their relative difference is. To get an accurate total thickness of the screen either the screen printing probe or the shim method with the general probe should be used. For correct fabric thickness readings, the guidelines already covered in this bulletin should be used.

When the stencil surface is smooth and the mesh rough, as in the second case mentioned, electronic thickness gauges give different responses for each condition. Since rough surfaces cause an inherent error in the measured value, and smooth surfaces eliminate this error, subtracting these two types of readings will not give a good relative difference. Capillary films, thick direct emulsion coatings, and indirect films will all cause this effect to take place. In **Figure 18** showing stencil thickness results for capillary film, the general probes for both magnetic induction and eddy current gauges produce errors in the relative difference. All the points on the graph represent the an average difference of 10 measurements on the fabric and 10 on the stencil/mesh, for 12 different mesh/capillary film combinations. Notice the improvement with the screen printing probe and the general probe measured through a 253 micron shim (for both the mesh and the stencil/mesh area).

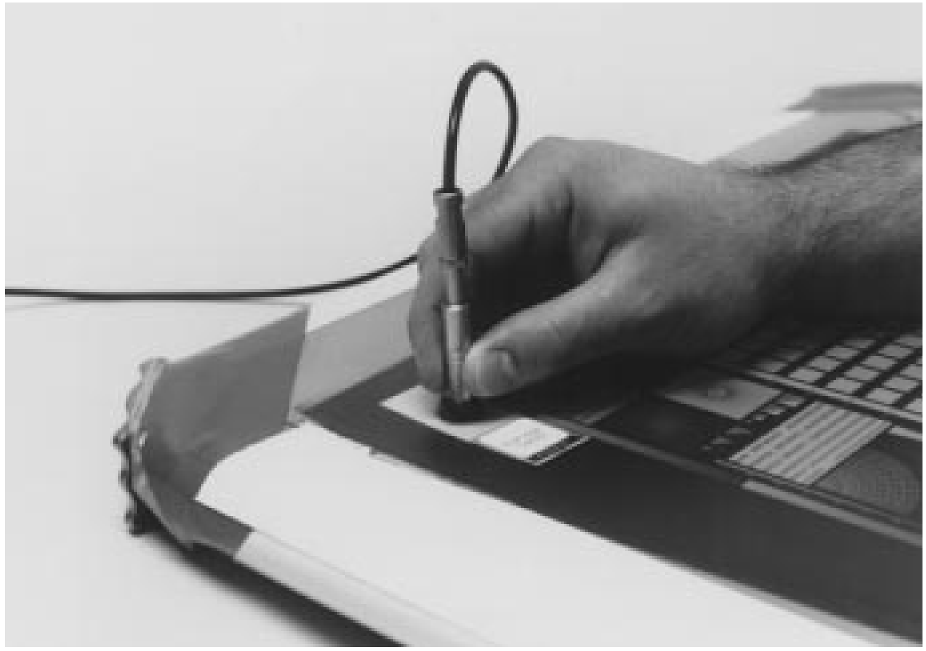
With this information, the recommended methods for measuring smooth stencils is to either measure through a shim for all measurements when using a general probe (**Figure 19**), or use the new screen printing probe. These two options eliminate the different effects from the two types of surfaces, causing the instrument to respond the same to both. The relative difference can then be considered valid. As an added benefit, the fabric thickness number and the total screen thickness number measured with these two methods are also accurate after the value of the shim is subtracted from them.

When making stencil thickness measurements, averages of 5 to 10 measurements should be relied on over single measurements. When reading the mesh, a clear area should be selected that is wider than the probe. It may be necessary to measure the mesh before the blockout is applied if there are no areas on the stencil big enough to measure the mesh by itself. The stencil/mesh area should be measured from the print or substrate side of the screen, avoiding areas with blockout. It is important to measure different areas of the mesh and stencil as thicknesses of both will vary. The list of measurement pointers presented earlier in the bulletin can provide additional guidance when measuring stencil thickness.

Stencil thickness research done on some older models of electronic thickness gauges showed some problems when measuring very thin stencil thicknesses. Older units tend to calculate a negative difference for the stencil, which is simply impossible. The cause can be traced to the older electronic design that had limited calibration capability.

The problem can be solved by measuring through a shim to get both values, as previously described. The object is to bring

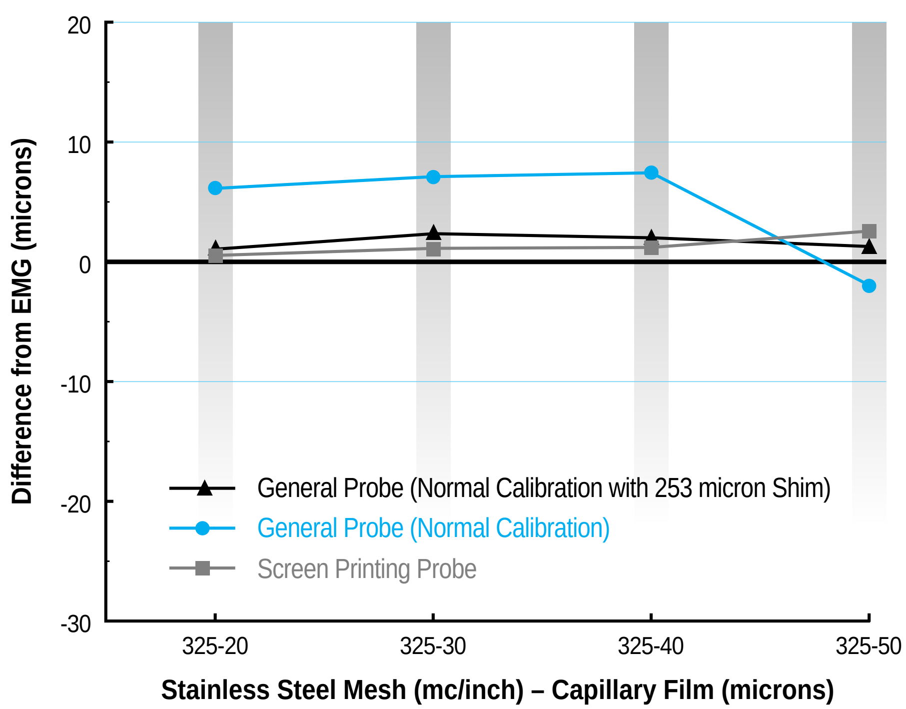
Figure 19



When using a shim to measure stencil thickness, the shim must be used on the mesh measurement as well as on the stencil/mesh combination measurement.

Figure 20

Stainless Steel Stencil Thickness
Magnetic Induction Gauge



A magnetic induction gauge effectively measures the stencil thickness on stainless steel mesh when using either the new screen printing probe or the general probe measured through a shim. Some error will be evident if the general probe is used by itself.

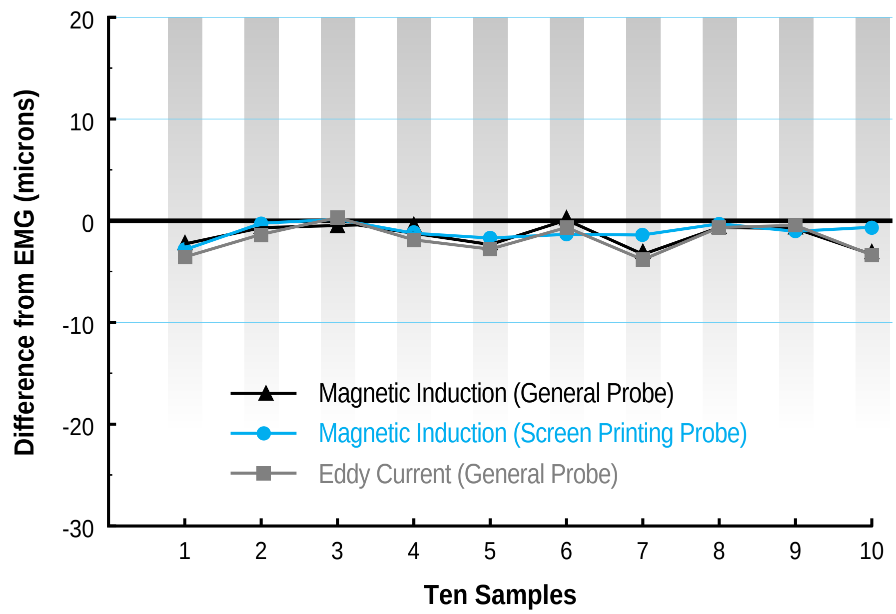
the reading above 100 microns, where these older units are more repeatable. Since a relative difference is needed, the additional thickness of the shim becomes immaterial. The measurements made with a shim eliminate the negative difference, and give an acceptable stencil thickness. If an older model (around 8 years and up) produces this problem, the shim method can again provide a solution.

Stencil Thickness on Stainless Steel

Magnetic induction gauges can be used to read stencil thickness on stainless steel with reasonable effectiveness. However, it is necessary to use either the new screen printing probe or the general probe measured through a 200 to 254 micron shim to get suitable readings (**Figure 20**). This graph also reveals that measurements from a general probe normally calibrated will be in error. A minimum of 10 to 20 measurements should be taken in this application to minimize the variation from the metal and the roughness. As previously stated, eddy current gauges are not appropriate for stainless steel due to its conductive nature.

Figure 21

Dry Ink Deposit on Polycarbonate
Electronic Thickness Gauge Comparison



A comparative graph of a magnetic induction gauge, eddy current gauge, and screen printing probe, shows exceptional results on the dry ink deposit of a UV ink on a polycarbonate substrate. All instruments were calibrated with foils and used normally.

Other Uses in Screen Printing

Dry Ink Deposit

Another extremely useful application for electronic thickness instruments is in the area of measuring dry ink deposit. Ink thickness is an extremely important characteristic to monitor and chart. It is in fact the primary output of all the process variables and can be used to identify resulting changes from them. These gauges are an excellent tool for measuring dry ink deposit for this purpose.

The SPTF report entitled *A Guideline to Wet and Dry Ink Deposit Measurement Methods Part Three* documents an early capability study on measuring dry ink thickness with magnetic induction gauges. The instrument achieved accurate readings when compared to the reference instrument (EMG) used in the project. A comparative graph of the magnetic induction, eddy current and screen printing probe, is shown in **Figure 21**. The readings from all three gauges were taken under normal calibration. Each of the 10 points plotted for each gauge represents an average of 10 measurements taken on one sample, with 10 samples being measured. All three of the pictured devices give very close measurements to the reference instrument. The conclusion can then be made that no matter what the probe type or the measurement principle, these instruments provide accurate measurements using manufacturer recommended calibration procedures with the foil standards.

Along with the accuracy the device provides, it is simple to operate and allows the operator to access any area of a print without cutting it, as would be necessary with a micrometer. In short, electronic thickness gauges are highly recommended for measuring dry ink deposits generated in the screen printing process.

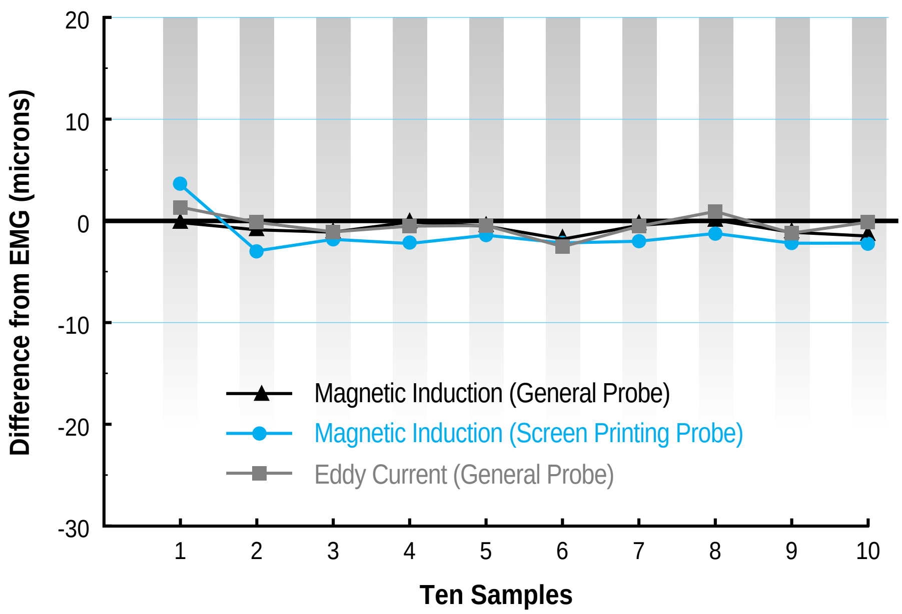
Substrate Thickness

Measuring substrate thickness as an incoming quality control measure is an important practice in some types of printing. Excessive thickness variations in the substrate can create printing problems on the press. Sub-standard substrates will produce sub-standard finished products. To ensure poor substrates are not introduced to the process, a checkpoint must be established for incoming stock. Monitoring substrate thickness should be one of the elements of a quality control inspection.

As with dry ink deposit measurement, electronic thickness gauges are excellent tools for reading substrate thickness. Comparative measurements taken on a 254 micron (10 mil) polycarbonate substrate with magnetic induction, eddy current and

Figure 22

Substrate Thickness of 10 mil Polycarbonate
Electronic Thickness Gauge Comparison



Measurements on 10 mil polycarbonate substrates correlate well to the reference readings for a magnetic induction gauge, eddy current gauge, and screen printing probe. All instruments were calibrated with foils and used normally.

the screen printing probe, are as accurate as readings taken with the reference instrument (**Figure 22**). Normal calibration and procedures are also used in this application. Again, each of the 10 points plotted for each gauge is the average of 10 measurements taken on one sample, with 10 samples being measured. All the probes and gauges tested at SPTF worked equally well on paper and plastic substrates.

Practical Data Translation

Instrument Accuracy and Resolution

The ISO 2178 and the ASTM B499-88 standard for measuring coating thicknesses by the magnetic method requires the device, its calibration, and its operation to measure thickness within ±10% of its true thickness or within ±1.5 µm, whichever is the greater. Eddy current gauges are also required to measure thickness to within ±10% of its true thickness according to ISO 2360 and ASTM D1400-94. While these accuracy ranges seem large, most manufacturers have designed their units to exceed this standard. Of the instruments tested at SPTF, three claim ±1%, and one states ±3%(or ±2.5 micron, whichever is greater).

Differences in individual measurements that are less than the accuracy range specification are not significant and should not be over emphasized. For example, a 70 micron sample can give measurements varying from 72.1 to 67.9 microns (based on ±3% accuracy) simply due to the instrument and not the sample itself. Differences within this range are not attributable to the sample alone and should not be considered significant. To minimize this variation, averages should be compared as opposed to individual measurements. This effectively factors out the instrument variance so the true indication of change can be determined. The defined accuracy must be taken into account when using data obtained on any instrument, so information is put in proper perspective and sound judgments made.

With these accuracy specifications, manufacturers also list the measurement's resolution, or the number of decimal places it measures. The user should take care not to use the instrument to find differences beyond the resolution capability of the gauge.

Documentation

Some mechanism of recording measurements should be put in place. Without documenting the data you took precious time to collect, it will be of little use. A good tool for documentation is a control chart used in statistical process control (SPC). Such a chart will allow the stencil thickness, fabric thickness, etc., to be tracked over time, alerting the printer to significant deviations from normal values. To measure just for the sake of measuring is simply a waste of time. The data should be used to monitor the process and incoming materials to ensure a consistent end product. This will be impossible without consistent documentation.

Conclusion – Measurement for Control

The procedures and techniques outlined in this bulletin are imperative for effectively using electronic thickness gauges to measure fabric thickness, stencil thickness, dry ink deposit and substrate thickness in screen printing. These measurements are some of the most vital that can be made to control and monitor the process. Understanding these gauges and how to use them properly can only lead to a more consistent and repeatable process. Following the recommendations and step-by-step directions contained here will help the screen printer to reach this ultimate goal. ■

References:

ASTM Standard D 1400-87, *Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Non-conductive Coatings Applied to a Nonferrous Metal Base.*

ASTM Standard B 499-87, *Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Non-magnetic Coatings on Magnetic Basis Metals.*

ISO Standard 2178, *Non-magnetic Coatings on Magnetic Substrates - Measurement of Coating Thickness - Magnetic Method.*

ISO Standard 2360, *Non-conductive Coatings on Non-magnetic Basis Metals - Measurement of Coating Thickness - Eddy Current Method.*

Estimating Ink Deposit in Screen Printing: Improving Your Accuracy, SPTF Practical Application Bulletin, Dawn M. Hohl, 1995.

Physical Changes in Polyester Mesh During Tensioning, SPTF Research Report, Dawn M. Hohl and Dennis D. Hunt, 1992.

Sources for ASTM and ISO Standards

ISO Standards available from
American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018
(212) 354-3300

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, PA 19103
(215) 299-5400

Manufacturers of Electronic Thickness Gauges

This list does not claim to be complete and does not include distributors of these instruments

CMI International
2301 Arthur Avenue
Elk Grove Village, IL 60007
Phone: (708) 439-4404
1-800-678-1117
Fax: (708) 439-4425

Elcometer Inc.
1893 Rochester Industrial Drive
Rochester Hills, MI 48309
Phone: (313) 650-0500
1-800-521-0635
Fax: (313) 650-0501

Fischer Technology, Inc.
750 Marshall Phelps Road
Windsor, CT 06095
Phone: (203) 683-0781
Fax: (203) 688-8496

Pro-Motorcar-Products Inc.
1500 Woodward Ave.
Bloomfield Hills, MI 48304
Phone: (810) 646-0666
1-800-334-2843
Fax: (810) 646-2268

R. D. Clark & Associates Inc.
2115 McDonald Ave.
Royal Oak, MI 48073
Phone: (810) 544-9840
1-800-584-3600
Fax: (810) 544-9830