Precision Process Tools for Screen Printers - Part One

Why You Can't Afford Not to Buy Them in the Modern Print Environment

In shops with process tools, troubleshooting begins by asking what specifications are in use and verifying that these tools are still in calibration and used properly.

Of all the different printing methods currently used, screen printing generally has the largest number of critical variables as there are more parameters to measure and keep constant. It's ironic then that as a whole the screen printing industry measures less and owns fewer tools than any other print industry segment. When trying to solve a plant's process issues, you must first measure the existing screen, ink, artwork and press set-up specifications before any changes or improvements can be made.

In shops that use precision process tools, troubleshooting begins by asking what specifications are in use and verifying that the tools used to measure them are still in calibration and being used properly. Troubleshooting is much simpler after you're sure the materials and press settings have not strayed from normal shop specs. In plants that are not well equipped to measure variables, verification of troubleshooting problems becomes trial and error or, in some cases, guesswork.

For most screen printers, the lack of interest in precision tooling often comes down to a combination of two or more viewpoints:

- The tools are too expensive
- We don't need to be that precise
- We don't have time to measure things like that
- We are too small to need tools like that.
- Cost is the major factor in not purchasing these tools.

The Cost of Precision Tooling

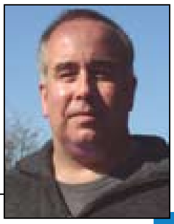
Overall, precision tool costs have dropped in recent years. The tools are more affordable for three reasons. First, new sensor types for electronic tooling are available. This makes some tools cheaper to build, and makes some cheaper type tools repeatable enough to be worth their investment. Secondly, automated manufacturing methods and overseas work forces have revolutionized the affordable precision tool industry. Finally, rising fuel costs for transport created the need to streamline local production through process improvement and standardization.

If the printing of any product becomes more repeatable, higher quality, faster, or improves process control because of these precision tools, you can save money in several areas: Overhead costs, raw material costs, process and print time consumption, defects and waste.

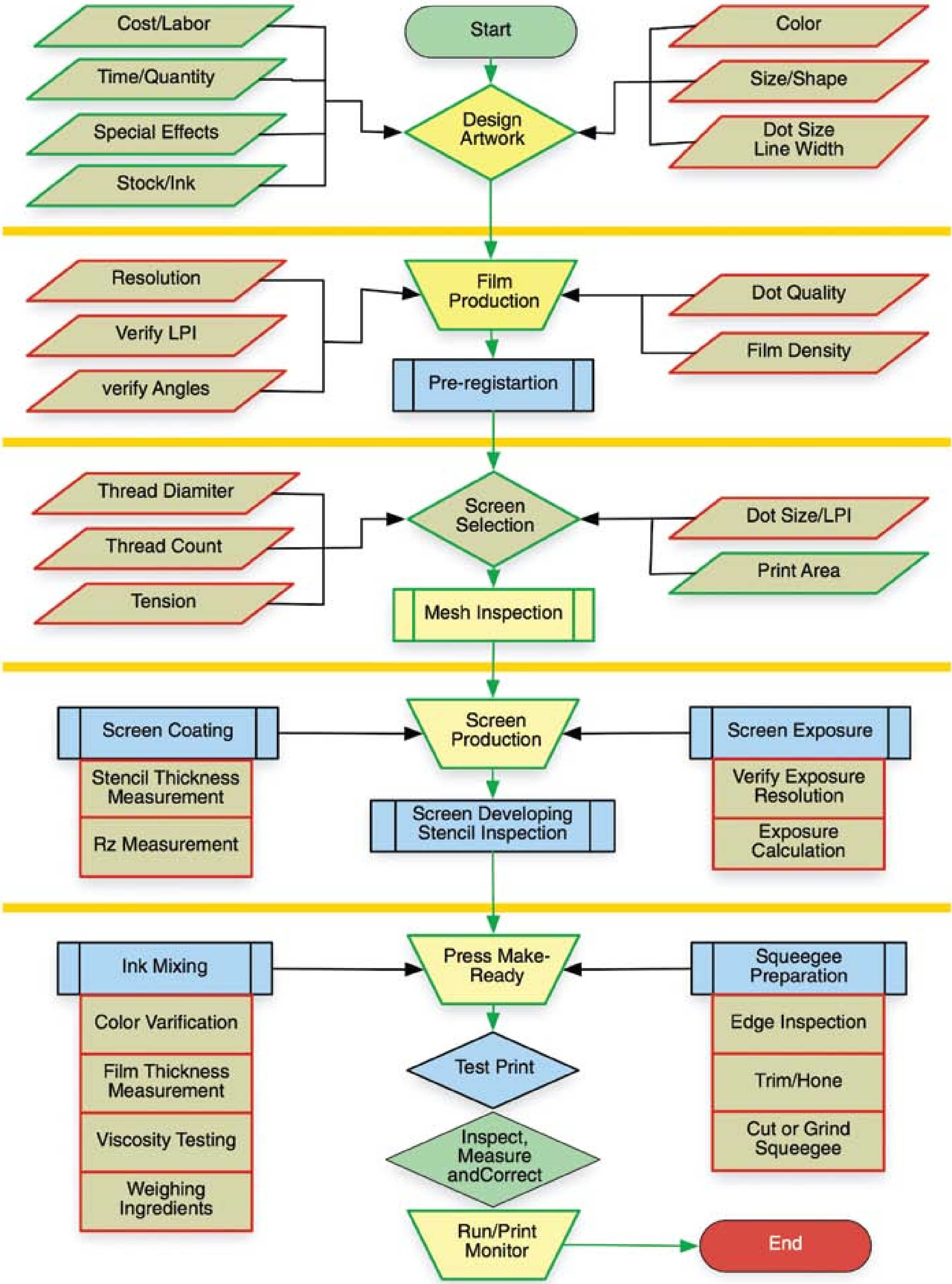
Tool cost, as opposed to utility, is the main reason why printers do not purchase precision tools. This reasoning is faulty in most cases because all but the most rigidly controlled engineering-based facilities rarely take the time to properly research their true and total bottom-line costs. Some costs, such as ink, stock, labor and shipping, are easily calculated, assignable to every item printed and can be passed on to the customer.

Other costs, such as "true" overhead and frictional production losses, are harder to calculate because they are small and cumulative over time. These costs can best be calculated quarterly or seasonally because data on loss per printed unit can be very small. True overhead costs include items such as seasonal peak-load pricing for electricity and gas, which can make summer production costs higher and winter costs lower (or vice-versa) in some regions.

Frictional production losses include long-term material losses of emulsion, adhesives, tape, mesh, block-out materials, chemicals, lamp life, screen making labor or on-press failure time



by Ray Greenwood, Technical Services Associate, SGIA


Cost/Labor
Time/Quantity
Special Effects
Stock/Ink
Start
Design Artwork
Color
Size/Shape
Dot Size Line Width
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Film Production
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Thread Count
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Screen Selection
Mesh Inspection
Dot Size/LPI
Print Area
Screen Coating
Stencil Thickness Measurement
Rz Measurement
Screen Production
Screen Developing Stencil Inspection
Screen Exposure
Verify Exposure Resolution
Exposure Calculation
Ink Mixing
Color Varification
Film Thickness Measurement
Viscosity Testing
Weighing Ingredients
Press Make-Ready
Test Print
Inspect, Measure andCorrect
Run/Print Monitor
End
Squeegee Preparation
Edge Inspection
Trim/Hone
Cut or Grind Squeegee

through inefficient, error-prone or trial-and-error screen making. This loss rate includes discarded squeegees that could be resurfaced or sharpened, and mesh with poor tension, which loses its usefulness too quickly. In short, unseen overhead and material costs generally are more than enough to justify the cost of precision process tools.

All five major factors of process streamlining are interrelated with cost as follows:

Overhead costs

This is the least understood cost factor for most print shops. Higher process or print-time consumption (through slower or problematic print runs) consumes more lights, heat, electrical power, gas and process water. In many cases, labor also is attached to this figure. What should also be included is the cost-per–square-foot usage of floor space of any given machine in the process (in dollars per hour divided by the monthly building rent).

This also should reflect the amortized loan cost of the machines themselves. These turn out to be small numbers (possibly one half of 1 percent per printed piece). But over a year, and thousands or millions of impressions, they become significant. When certain jobs print poorly or require troubleshooting, this overhead cost is higher per printed piece and true costs can be excessive.

Raw material cost

When printing is problematic (e.g., screen issues, make-ready problems and curing problems), it consumes more raw materials than were originally quoted. Many plants quote a "buffer" of raw materials into each job, so true losses are rarely recalculated on a per job basis. In many cases, buffer limits are exceeded and this fact is never known.

This is particularly true when calculating ink consumption. Material calculations usually are exceeded on high-coverage print runs because the ink deposit thickness is unknown. High-ink consumption and uncontrolled deposit thickness commonly use more make-ready stock than what is quoted, leading to more waste. Many large facilities already pay to discard waste. This can be as simple as a dumpster service, or as complex as a chemically safe waste stream disposal incinerator or recovery service. This should be amortized into your per-piece overhead cost.

Print defect

Depending on the company type, printing defects can be called waste, cast-off, spoilage or, in the worst cases, disguised as make-ready or shipped in place of an acceptable product. Print defects are the worst offenders for uncontrolled and hidden production cost. Defects consume overhead cost, labor and raw materials, creating costly waste. More print defects can be prevented by proper process methods, which are backed up and enforced by modern process tools, than by any other method.

Only by calculating your true production costs can you really see how some of these instruments will save you money. But what is meant by precision tools and where do you use them in your process?

Diagram 1 is a basic process model to illustrate what can be monitored or measured. While no two plants' process flow models will look alike, most have the basic processes outlined in the flow chart. In the figure, each process input or sub-process with a "red" highlight ring has critical parameters we can measure and control.

For each main process step (in yellow), we'll cover four main ideas:

- What measurable items are in each process step
- What tools are available that can be used
- What tools can correct or improve the process
- Actual before-and-after print results to illustrate how the tool helps improve print results.

The Printed Images

All of the printed images shown use a common image. Before proceeding, let me explain what test film image was chosen and why. Understanding the precise nature of the chosen images will better illustrate the tools.

Both line and dot images are from an industrial film set used in the circuit industry. They were chosen for their highly technical precision level of film production. The images were produced at 16,800 dpi, with a film density of 5.0. Though this is far beyond the resolution needs of most industrial and circuit screen printers, it is also well above any resolution issues of most emulsions available. This high output rate ensures any edge-definition defects visible in photographs can be properly attributed to the effect being illustrated, and not to the film itself. The difficulty level for printing and imaging the features in this test film is high.

The "line-work" test image will easily show print defects in squeegee or flood pressure settings, off-contact settings, tension levels or squeegee angle or wear. Meanwhile, the "dot"

Print defects are the worst offenders for uncontrolled and hidden production cost. Defects consume overhead cost, labor and raw materials, creating costly waste.

Figure 1: Pantone color matching guide. Old, faded book (right); new book (left).


Figure 2: A reading of the hue variations with a reflectance densitometer.

If the printing of any product becomes more repeatable, of higher quality and faster with better process control because of these precision tools, you can save money.

image immediately will show any defect in stencil thickness, press settings or Rz. This image is sensitive enough that once an ink of a given viscosity is paired to a specific screen and print stock there is only one range of settings to create a defect-free print. A screen change dictates a viscosity change and vice-versa. The image is ideal for demonstrating the failure points of emulsion thickness, screen tension, viscosity and various press settings.

The line work image width on the film is 98.4 X 1/10th of a mil. This is 250 microns. The spacing between those lines is 157.4 X 1/10th of a mil. This is 400 microns. The "dot" images are 250 microns and are approximately equal to a 70-73% shadow dot in 65 line process printing. To make sure we all understand the scale, there are 2.54 microns per 1/1000th of an inch (1/1000th of an inch is one mil.). The use of a shadow dot format, as compared to a highlight dot was chosen because any "tipping" of the dot stencil due to excessive off contact, screen movement, sticking, pressure and speed setting, poor stencil thickness or incorrect Rz will show immediately during printing as a dot diameter and edge clarity loss.

To further prevent skewing print results with unexpected variables, such as stock thickness and press print bed variations, each printed image or photo of a dot or line is the exact same dot or line image from within the same film image, not just a similar dot or line from somewhere else.

Design/Artwork Stage

Measurable Item

Color includes the measurement of client-supplied colors, specification of selected colors or conversion of selected colors to usable mixing formulas.

Process Tools

PMS Guide: The Pantone Matching System (PMS) color chip books are probably the most universal source for communicating color. Surprisingly, many small plants do not use this resource. Matching a custom or created color to a similar or identical color in the PMS guidebook under a standardized light source is still the most effective way to identify a color to all parties and assure the same color we mix ink for and print with is the chosen color. Too many printers and designers do not replace worn or aged Pantone color chip books. Figure 1 shows the color differences in books ranging from old to new. (See Figure 1)

Densitometer and Spectrophotometer: Densitometers are precision measuring devices that utilize internal light sources, of exact intensity and spectrum, that are calibrated to a permanent traceable standard to measure colors and print stock materials and quantify their color numerically. (See Figure 2)

The color-related capabilities of most general purpose densitometers are:

- Color density — how densely a given ink or coating may be applied based upon how much of the visible color it reflects (versus how much of the base stock can be seen).
- Hue — exactly which shade of a particular color we are dealing with. A densitometer can give only numerical coordinates based in RGB or CMYK for hue information.
- Stock gloss subtraction — the true reflected color without interference from light reflected by the materials' gloss.

A spectrophotometer has all functions of a densitometer plus the ability to express colors by coordinates in L.A.B. or C.I.E. color space or in several other color space systems. Both of these tools have numerous dot and resolution functions. (See Figure 3)

Ink Drawdown Equipment for Color-Sampling: As a screen printer, you already have most of what you need for basic color drawdown work. The most accurate use of this method is to have small-scale screens of exact mesh count, thread diameter, tension, open area and stencil thickness as those used in production. After the color is specified in the design phase, ink samples are mixed and printed on job stock using identical squeegee angle, hardness and speed settings. These printed samples are checked for correct ink

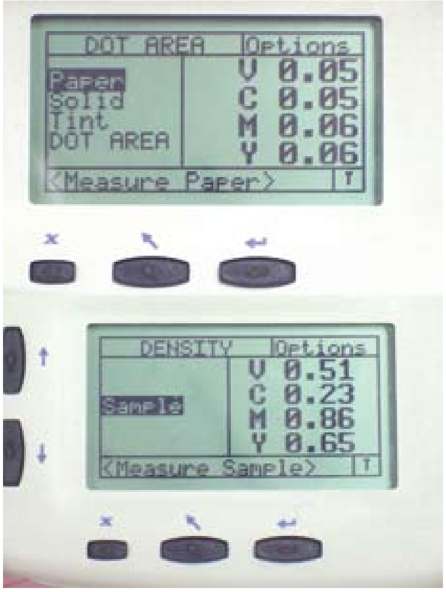


Figure 3A: Densitometer screens show dot function mode for measuring dot loss and gain, as well as half-tone percentage (top) and color-density mode (bottom).

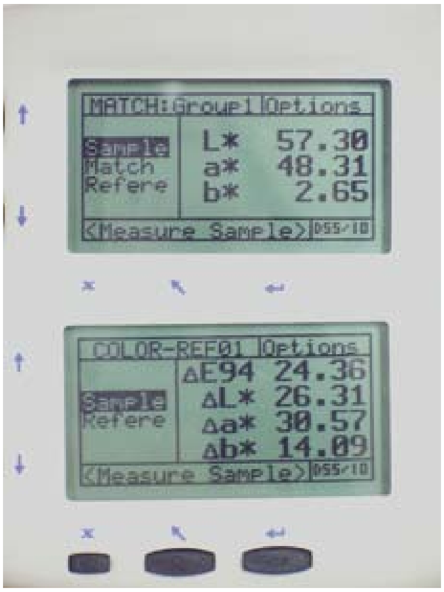


Figure 3B: Spectrodensitometer screens show LAB color mode (top) and absolute color difference mode (bottom).

deposit thickness, dried carefully, dated and presented to customer service for written customer approval. (See Figure 4)

What these Tools Can Do for Your Process

- Correctly quantify and identify the color that a client has chosen.
- Repeatedly mix that color in small or large quantities at different time periods.
- Modify the color to print on differently colored stock, objects and garments.
- Monitor color during the printing process to determine if the actual ink color or method with which it was printed has changed (change in density or dot quality).
- Warrant your colors against possible client dissatisfaction by having a verifiable reference.

Film Production Stage

Measurable Items

Film Resolution: It is important to know how many lines per inch (lpi) of half-tone dot you can produce and what your d-min and d-max (the smallest and largest printable dots the film can resolve accurately) are, as well as the edge resolution of lines and dots in the films as dictated by the dpi or scan rate of your output device. In other words, you may want to know how well your film is rendering shades of gray or if it is accurately producing the specified tonal gradations.

Line Count and Angle Variation: These vary from a simple, film-based tool, showing interference on all but the correct range of line count and angle, to a methodology-based tool that uses protractors and measuring loupes to positively verify line count and angle. The film-based tool is usually accurate within 2 - 4 percent, but takes one minute. In contrast, the protractor method is exact but takes 10 minutes.

Film Density: For most printing plate exposure processes, a minimum film density (opacity) in dark areas of 3.25 to 3.75 is acceptable. Since screen printers may use exceptionally large formats (giving greater lamp distances and longer exposure times) and high-intensity UV-based exposure systems, a more practical film density number is a minimum of 4. In all shops, regardless of the specified film density, having consistent day-to-day density is important.

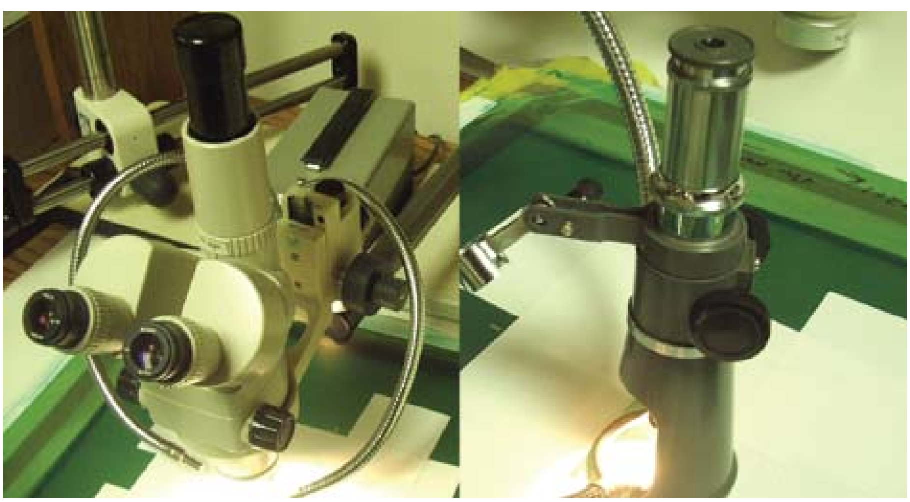
Dot Quality: It's one of the most important control factors in the day-to-day film consistency and standardization of the screen-exposure process. We are well into

Figure 4: An adjustable-drawdown bar for ink film and color density testing.

Figure 5: A bench-top transmission densitometer.

Figure 6: A handheld transmission densitometer.

Figure 7: From the left, an 8 times magnification (8X) folding linen tester, 45X stand microscope, 12X lighted hand loupe, 20X lighted color-correcting loupe.



Figures 8 and 9: Binocular microscope for measuring and high-magnification inspection (more than 100X) and portable stand microscope for 35X to 100X magnification.

Figure 10: Fiber optic lights left, LED light right..

the age of thermally imaged film, advancing rapidly through the inkjet-imaged film age for certain applications and moving toward the age of direct imaging on screen without films. In all instances, the shape and edge definition of imaged dots must be inspected and measured to be controlled.

Process Tools

Transmission Densitometer: Transmission densitometers come in two basic types: Bench top and handheld. The bench top model is more repeatable in its readings than handheld units. These devices tell you the density of both the film base itself and the black areas that block light. *(See Figures 5 and 6)*

They also can read the dot area (spaces between dots relating to whether dots have grown or shrunk) and dot percentage (halftone gradation percentage). Unlike their cousin the reflectance densitometer, used to measure printed color on a solid surface, these models transmit a high-intensity collimated light through the film base and dot/line features and measure what is lost or blocked.

Viewing Loupes: Low-powered, uncorrected, wide field of view (typically 15mm) linen testers and loupes of 10 times to 15 times (10X to 15X) magnification should be standard issue for anyone in a screen printing plant who must look at a print for any reason. Loupes of this power are only really useful for inspecting edge definition in line work and verifying registration marks while stripping films for pre-registration systems (pin registration) or lining up register marks between print layers. *(See Figure 7)*

Higher-powered loupes (20X to 40X maximum), which are generally kept in the production office, are ideal for inspecting dot and line-edge quality and structure when troubleshooting color shifts, poor layer-to-layer printability in four color process and film or screen defects. Loupes (greater than 35X to 40X with magnification) are frequently classified as "microscopes."

The critical differences between loupes and microscopes are generally field of vision (how big an image area can be seen at one time), ability to be focused without rigid mounting (loupes are generally more portable) and the ability to operate with local light sources instead of illumination systems. Knowing when to use a particular magnification of loupe is almost as important as having one in the first place.

Microscopes: If you print four-color process on a regular basis, you should have one microscope in the plant to troubleshoot your film and printed product. The microscope type you need depends on what you print and how much you need to magnify or if you will need to photograph through the eyepiece. In a critical situation where the presses are stopped, a portable microscope pays for itself saving troubleshooting time. *(See Figures 8 and 9)*

For printed circuit, membrane switch, solar and industrial screen print applications, bench top microscopes with measuring stages, reticules, precision light sources, photographic filters and software are almost a requirement. More than just image shape and resolution can be analyzed when you are viewing at higher magnifications than 60 to 200X.

Inspection Light Sources — Backlit: A quality backlit light table for inspecting films and screens will save time, prevent errors and allow you to develop a proper QC program for inspecting films and screens. Film stock defects (thermal, silver-based and inkjet) are common. In inkjet film-positive production, ink supplies and machine defaults are routinely responsible for wide variations in dot density. It is far cheaper to catch this problem on the light table than to wait until screens are burned and product blanks are ruined. This goes for all types of film and screen.

Inspection Lights — Non-Backlit: With the volume of high-intensity LEDs and cheap electronics on the market, it pays to have a few bright, portable inspection lights on hand. Higher-power loupes are almost useless on press without a nearby clean light source. Unlike high-intensity, filament-style bulbs, LEDs give cleaner, brighter light with fewer hot spots, longer life and better ability to illuminate at odd angles. *(See Figure 10)*

Precision Measuring Reticules: A reticule is an insert for a microscope or loupe that has engraved scales for measuring small widths and lengths of the items you view. This is ideal for checking film line counts, measuring a film's actual dot diameter versus the same images exposed to screens to calculate dot or line loss and shrinkage (frequently referred to as generational loss). *(See Figure 11)*

If you are doing industrial, solar or circuit printing, it is worthwhile to invest in a bench-top glass scale reticule for measuring entire screens for shrinkage or distortion. It is cheaper and faster than a microscope with equal screen size capabilities.

Screen and Film Angle Finders: These tools create visible moiré patterns at specific line or thread counts. They are used to quickly identify or grade the actual thread counts of unknown screens, or the true line count of unknown films. With this information, screens or films can be paired properly to avoid moiré and loss of resolution. The accuracy of these tools is directly proportional to their cost of

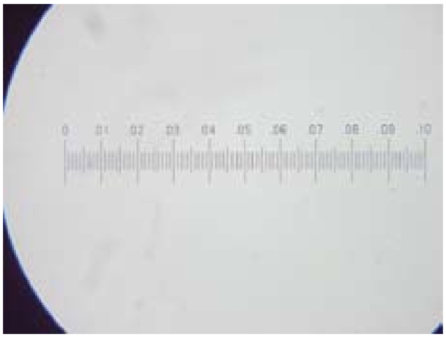


Figure 11: A precision-measuring reticule as seen through a loupe or microscope eyepiece.

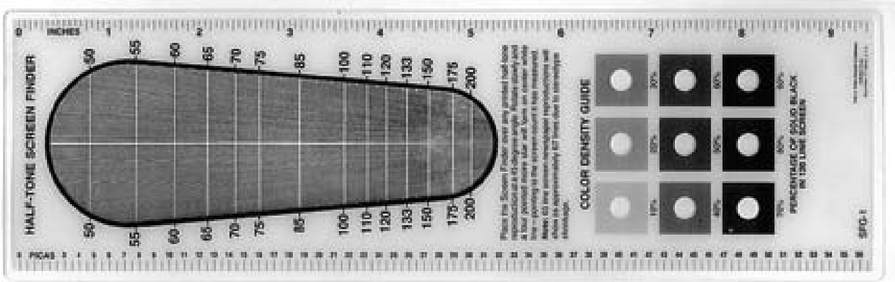


Figure 12: Film type angle finders.

Figure 13: A view through the eyepiece comparision of 60x versus 120x.

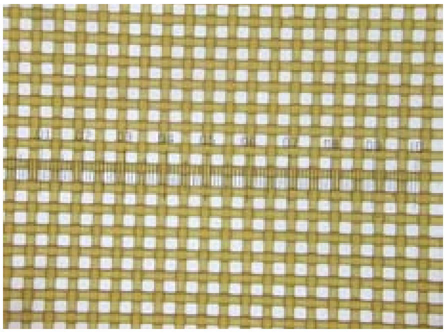


Figure 14: Counting threads with 120x microscope and a 25.4m reticule

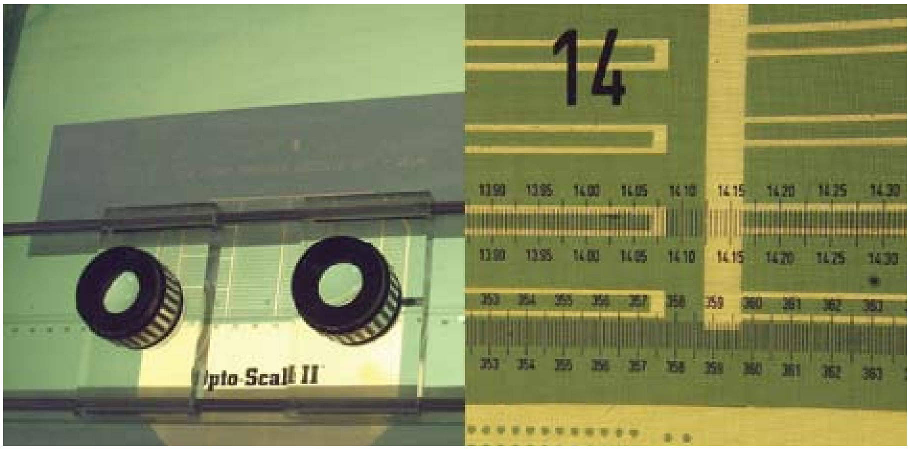


Figure 15: A glass-measuring scale reticule.

Figure 16

production. The higher the line resolution of the output device, the more accurate the tool will be. *(See Figure 12)*

What these Tools Can Do for Your Process

- Control of line count and dot sizes at the film stage will prevent unplanned color shifts during half-tone and four-color process printing.
- By making films more consistent in resolution and density, screen exposure times will be more consistent and the screen lifespan will produce more predictable color transitions on press.
- Consistent film density and resolution will prevent wasted time for excessive exposure testing, improperly exposed screens and excess time for blocking out and pin-holing.
- More consistent films and screens will allow better consistency in color matching and ink mixing which leads to less on-press troubleshooting and less incorrectly mixed ink.

The same tools used to visually inspect films for dot size and resolution also are ideal for inspecting finished stencils to verify proper-edge definition, development and image blockage in areas of highlight dots and fine lines. With these same tools, the vast majority of final troubleshooting can be done before the screen leaves the washout sink. Any screen troubleshooting done beyond film stages or the screen department is always more expensive because of the lost press time.

Screen Selection/Mesh Inspection Stage

Measurable Items

Thread Diameter, Thread Count and Open Area: Knowing what these three measurements are and how much they change from raw mesh off the bolt to a finished, tensioned frame is imperative for four-color process printers, industrial printers and color matching in all screen printing types. These three items are primary controls for ink deposit thickness.

Screen Tension: The tension applied to screen mesh affects all three of the aforementioned measurements. The format size of the screen printing process influences the mesh selection process. The need to keep off-contact (or snap-off heights) low can influence the thread diameter selected. This will have an impact on open area and final thread count.

Mesh Thickness before Coating: Prior to coating, the thickness measurement of the tensioned mesh is the starting point for calculating the required emulsion thickness.

Process Tools

Loupes and Microscopes: A portable or bench microscope is necessary for counting threads and measuring thread diameters. For thread counts of 160 and lower, a loupe or microscope between 45X minimum to 60X average will work; thread counts higher than 160 should use a microscope of no less than 60X. *(See Figure 13)*

Measuring thread diameter as well as the length and width of the open mesh areas requires a 100X microscope or better, with a reticule featuring calibrations of at least two to three increments per thread width. *(See Figure 14)*

For instance, if you know you will be using threads of 34µ, a reticule calibrated a .001" (25µ) per increment will not give an accurate thread-diameter measurement. The alternate method, when correct reticule sizes cannot be found for the more portable microscopes, is to count threads and spaces over a set measuring distance and statistically divide five to 10 sets of readings. This method has some error, but can be a good indicator of thread diameter.

Glass Scales: Common in printed circuit board plants, these devices are affordable, highly accurate and have a large measuring area. They are precision, micro-etched reticules with an attached sliding eyepiece or pair of eyepieces. They are ideally suited for measuring and counting threads, or inspecting films and checking line count. *(See Figure 15)*

Inspection Backlighting: This is described in the previous section, which addresses film production, but is shown here in both portable and stationary formats *(See Figure 16)*

What These Tools Can Do for Your Process

- Find variations or changes in the mesh before they create changes or errors on press.
- Match mesh count and thread diameter more closely to fine-line, half-tone and four-color process films for resolution, pigment particle size and ink deposit.
- Quickly discover if printing or ink-flow difficulties are caused by mesh selection, obstruction or damage.
- Troubleshoot broken screens and immediately find the root cause.

Part two of this article will be included in the first quarter 2009 issue of the SGIA Journal.

Ray Greenwood is SGIA's Technical Services Associate. He is responsible for helping SGIA member companies in all types of imaging-related technical inquiries. Greenwood, who helps the SGIA Digital Lab and SPTF Lab conduct workshops and research projects, has spent the past 20 years of his printing career working with semi-conductors and circuits, as well as textiles and large-format graphics on a variety of substrates.

ray@sgia.org