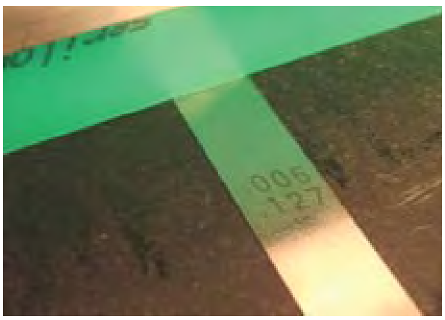
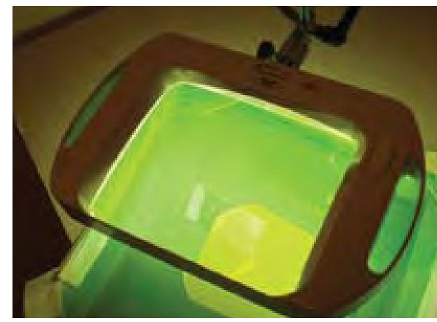
# Precision Process Tools for Screen Printers — Part Two

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

Part one of this article appeared in the fourth quarter 2008 issue of the SGIA Journal.





### Screen Making/Development and Inspection of Screen Stage

*Measurable Items*

**Screen Tension:** This measurable item is the most critical of all screen production parameters. Screen-to-screen tension variations can change the thickness that a standardized coating regime can produce, even with automatic coating systems. Tension affects the ink's shear rate as well as flood-bar speed, squeegee speed, print speed, edge definition and ink deposit thickness.

By making fewer press errors, printing fewer defects and not having to reprint, you save time. Saving time puts money in your pocket.

**Stencil Thickness:** Stencil thickness — along with thread diameter, mesh count, tension and flood-bar speed — is one of the primary methods to control ink deposit. Not only is it important for ink deposit, stencil thickness dictates surface Rz or smoothness. Improper stencil thickness also affects the ability of ink to be properly sheared and discharged from the screen.

**Stencil Surface (Rz):** Rz is a measurement of the "average" smoothness (from the highest peak to the deepest valley of the screen surface at a microscopic level). You can have perfect emulsion thickness and thread count and diameter with which to deliver the correct ink deposit, but still have poor print quality because of a rough or incorrect Rz. Poor Rz equates to a poor "seal" around the perimeter of each feature in your stencil, causing ink to flow out of the image area, creating rough edges and poor resolution.

**Exposure Calculation:** Every change in emulsion thickness, thread color or diameter, distance from the exposure lamp or changes to film density and resolution requires a recalculation or modification to the exposure time in order to keep results consistent.

**Exposure Resolution, Image and Mesh Interference and Stencil Inspection:** Measuring resolution on exposed screens is one of the functions of an exposure calculation. Once the exposure for proper mechanical strength of the emulsion is established, inspection to establish proper "printable" resolution for specifying film changes, requires optical tools. You may have perfect exposure and imaging of all of the features in a film, but find the features are distorted or blocked by threads. Optical inspection of screen and test-print image will determine if you will require change to film image, mesh type or stencil.

**Exposure Lamp Condition and Output:** This is an area that is most often ignored until it has cost large amounts of time and money. Smaller shops with less advanced equipment, lacking light-to-timer integration systems, usually do not know when their lamp is providing reduced spectrum. Better equipped shops, which have light integrator systems in their exposure units, often find themselves doing work that is critical enough that variations in light quality in different

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Figure 17: Digital depth gauge on comparator stand.

Figure 18: Digital induction screen thickness gauge.

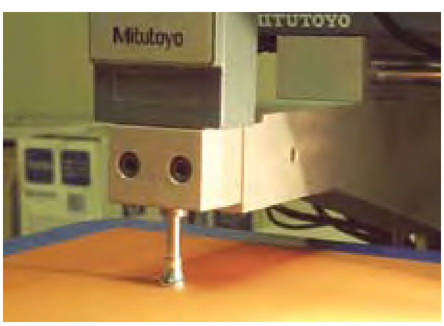


Figure 19: Bench-top comparator system.


Figure 20: Two piece portable RZ gauge (top is infra-red receiver, bottom is skidded probe and sender).

areas of the exposure unit (hot spots and cool spots) can cause problems. Spot measurement of exposure lamp output is ideal for high-precision graphic and industrial printing.

**Stencil Drying Condition:** Shops with fast screen turnover rates (many screens per day), shops with uncontrolled humidity and temperature as well as those with sensitive emulsion systems often have trouble properly drying emulsion before exposure. Improper drying is one of the primary reasons for poor screen life and resolution. The two main courses of action are to create spaces or cabinets and procedures that ensure proper drying (methodology), or buy instrumentation that indicates when emulsion is still too damp for exposure.

## Process Tools

**Stencil Thickness Gauges:** Two common tool types for measuring stencil and mesh thickness are mechanical or digital dial gauges on a comparator stand (See Figure 17) and digital magnetic induction gauges. (See Figure 18)

Both are repeatable to about half a micron. The comparator is the simplest to use, but is the least versatile since most comparators have a short range of screen reach. The longest reach of most affordable comparators is about 45 cm (18 inches) — these are only bench-top tools. (See Figure 19)

If your reach is longer than 45 cm (18 inches), it is more cost-effective to employ other, more accurate machines such as a multi-axis coordinate measuring machine. In most cases, imagers use hand-held, digital magnetic induction gauges. They are portable and capable of readings anywhere on a screen at any angle.

However, body vibration, temperature and humidity changes can cause enough incorrect readings that operators need some training, knowledge of what to expect and correct methodology to achieve the specified repeatability.

**Rz meter:** Of the large range available, the most practical Rz meters are small, hand-held portable models. Industrial instrument companies also sell these devices under the tool name of "perthometer," and there are two basic types:

- The "skidded" probe arm type which refers to the use of a skid or guide plate that keeps the stylus tip from vibrating too hard and creating readings outside of its limits.
- The non-skidded probe arm type which can produce a large range of surface profile readings (e.g., Ra, Rz, Rp, RT, RV, etc.).

The only readings we functionally need are the Rz readings. The non-skidded probe devices typically require three separate calibration strips: one to calibrate the arm balance, one to calibrate for the probe ball condition; and one to calibrate the linearity of the computing device. When shopping for an Rz meter for screen printing, look for a unit that has a probe ball radius of 5μ or larger.

For Ra and other surface measurements, a 2μ radius of ball is typical. Two-part, cordless, non-contact gauges give the most vibration-free readings. (See Figure 20) Bench-top devices for use only in a screen room also are acceptable. (See Figure 21)

**Exposure Calculator:** Every shop should have an exposure calculator. The best ones have at least five neutral density filters (See Figure 22), so you get five or more separate calibrated test exposures with each use. Be sure you select one whose resolution film (the actual part of the film set with letters, words and shapes in black) has a range of features representative of the work you will be printing. Selecting an exposure calculator that is too fine or too coarse will show only how your emulsion exposes at a resolution you are not using. (See Figure 23)

The quality of the stepped-neutral density filters is the most critical part. Along with a commercially made, stepped-exposure calculator, imagers should make a "step-wedge," using their own film and output devices with features that are unique to their shop. Make 10 repeat steps in the film, with space between them for overlap from the masking materials. The commercial film set guarantees you have the ability for a quick everyday check device that can be used on every screen. A careful, self-made film also can be used for fingerprinting presses and in-depth diagnostics of exposure problems.

**UV Radiometer:** This type of radiometer is not to be confused with the UV radiometers that are sent through a UV reactor/dryer. Though they measure the same wavelengths of light, exposure unit UV probes are not filtered for the extreme light intensity, joule levels and heat created by UV curing units. Radiometers for use in exposure units have a maximum energy input of approximately 1,000 W per $cm^2$ (UV-reactor radiometers can endure lamp intensity to 5,000 W per $cm^2$ without sensor damage).

This is not an expression of their operating range. For example, if you use a fluorescent lamp unit, you may want a meter with a range between 0 and 19.99 W per $cm^2$. For a metal halide, you may need something in the 0-199 W per $cm^2$ range. This is not to say that these units cannot record long UV dosage (time spent in the unit), just that the actual lamp intensity should be reduced as compared with a curing unit.

They also should have a temperature range that goes from 110°C to 121.1°C (230°F to 250°F). The photo emulsion we use generally requires the full UV-spectrum of 280nm to 420nm. Be careful as certain filtered industrial probes in the low watts-per-centimeter range have light input of 315nm to 410nm, which is UV-A. (See Figure 24)

**Inspection Loupes:** Exposure loupes and microscopes have a place at almost every stage of screen printing. In screen making, the necessary magnification level is similar to the mesh selection and thread counting stages. Loupes from 20 - 40X work well for inspecting dot and line openings in finished and dried stencils. Basic screen making requires low-power loupes. For actual troubleshooting of why a given dot or line has closed in, you may need higher magnification. (See Figure 25)

**Inspection Light Sources and Stations:** Backlit tables or panels are often ignored because good ones are expensive and working on them with screens requires them to be protected. Too many print shops troubleshoot nearly microscopic stencil features by holding the screen up to the ceiling light. This practice makes it hard to use loupes, microscopes or even block-out brushes. A clean light source with no hot spots and low or adjustable light levels works well. In lieu of large expensive light tables, there are many external light sources like magnifying arm lamps that make screen inspection and critical blockout work simple. (See Figure 26)

**Tension Meter:** There are two basic types: mechanical (See Figure 27, Page 42) and digital (See Figure 28, Page 42). Most have an NIST-traceable standard, but the nature of what is being measured (Newtons per centimeter) and how it is being measured means each and every meter achieves the calibrated measurement effect with its own weight.

Small weight variations mean each meter will meet the National Institute for Standards and Technology (NIST or mil-spec) standards when calibrated, but may not calibrate to each other, even on the same standard. Mechanical gauges are just as accurate as digital gauges, but with fewer numerals below the decimal point in resolution. This is only a factor in the most demanding of printed circuit work and meter calibration procedures. The cost of mechanical meters is a direct reflection of their ruggedness and durability.

**Humidity Meter:** Moisture meters come in three basic types: inductive, capacitive and high-frequency galvanizing or dielectric constant. The inductive meters are some of the most accurate available. However, they are not inherently suitable for screen printing because they use two sharp probe pins to gather data. A few electromagnetically inductive models do not use pins, but their repeatability is difficult because of the thin nature of what we are measuring. (See Figure 29, Page 42)

The capacitive models can use pins or contact pads, but are more easily fooled by high-moisture surroundings in the screen room or galvanic charge differences, which can be water-borne, mineral based or ionic.

A relatively accurate and more expensive system is the high-frequency galvanizing method (sometimes called dielectric constant type). It uses the galvanic charges, which are problematic with the capacitive models as a data source. Galvanic charges change as the water that connects the ions dissipates.

If your screen-room humidity is not well controlled, these tools can work well in place of extreme and expensive measures to control the relative humidity in large spaces. A smaller, well-controlled emulsion drying and staging area, along with good

Figure 21: Bench-top perthometer and Rz meter.


Figure 22: Five step exposure calculator with neutral density filters attached.

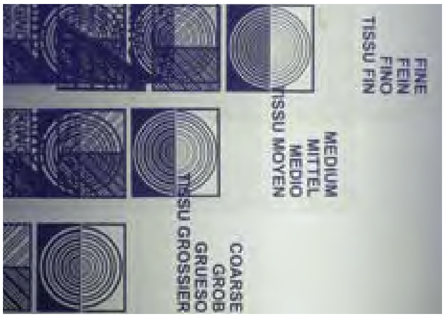


Figure 23: Fine, medium and coarse resolution versions of the same exposure calculator.

Figure 24: UV exposure radiometer and probe.


Figure 25: Selection of basic low power inspection loupes (8-12X).

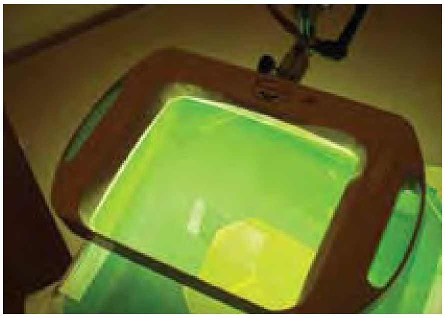

Figure 26: Precision magnifier arm lamp.


Figure 27-28: Mechanical tension meter (left) and Digital tension meter. (right).


Figure 29: Inductive humidity meter (left) probe detail (right).

Figure 30: Screen vacuum (serivac).

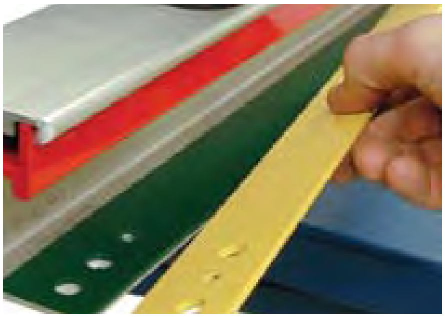

Figure 31: Off-contact shims (M&R Rasta Bars pictured).

Figure 32: Inductive electronic off-contact gauge (DeFelsco).

moisture reading tools, can work wonders in trimming drying time from the process.

**Screen Vacuum:** Workmanship is everything with a screen vacuum. It must be precise and have soft edges. The screen vacuum also can reduce screen drying time by as much as 75 percent. Additionally, it can prevent defects from water spotting and prep stains. (See Figure 30)

## What These Tools Can Do for Your Process

- Ensure consistent screen tension (tension meter). Consistent screen tension can ensure a longer screen life, depending on the mesh used and stretching method. But consistent tension will ensure more consistent emulsion thickness, ink deposit and make-ready times. These in turn will standardize exposure times, print resolution and ink deposit. All of these items reduce raw material use, labor time and costly defects.
- Inspection tools (loupes, backlighting, microscopes, etc.) ensure the standard process is followed. Catching defects or errors before they leave the screen room saves wasted make-ready machine time, make-ready stock, ink and labor. Production time generally is more expensive than screen-room time (in terms of labor cost). When problems arise, the ability to pre-inspect (knowing the screens meet specification) saves troubleshooting time on press because you already know what isn't wrong.
- Exposure calculators, emulsion thickness gauges and Rz meters are pure process tools. They ensure your specifications. Without knowing the emulsion thickness is correct, pre-determined exposure maps will be incorrect. The Rz meter is a tool to verify stencil uniformity in normal printing and a requirement to guarantee edge-definition and ink deposit consistency in high-tolerance printing.

## Press Setup, Test Print Inspection and Print-Run Monitoring Stage

### *Measurable Items*

This is one of the largest continuous process steps. Test printing is an active part of press set up or make-ready. If the result of test printing is correct, the transition into the press run is seamless. Some of the process tools shown in this section are the same as those used in various other process steps. In this section, we will explore how these tools affect the actual print.

### *Process Tools*

**Off-Contact Gauge:** Off-contact gauges can be as simple as numbered shims (See Figure 31), or as complex as electronic induction gauges (See Figure 32) and dial indicator and clamp systems. (See Figure 33). Some of the best and most user-friendly gauges are somewhere in between, such as an LOC gauge. (See Figure 34) In production, they are used for quick off-contact changes, off-contact verification and in normal press maintenance for leveling and parallelism.

**Squeegee Sharpener:** The tools range from manually operated grinders (See Figure 35) and knife cutting systems, to automated grinders and knife cutting systems. (See Figure 36) The only squeegee blades, which cannot benefit from a pass with a diamond hone (See Figure 37), are molded-edge blades. Even molded-edge blades will need to be resurfaced after use.

**Edge-Inspection Tools:** These tools use loupes, light and a flat surface of at least 30 cm to 45 cm (12 inches to 18 inches). The machined-steel stock or granite plates are quite affordable. (See Figure 38, Page 44)

**Ink-Film Thickness (Wet):** This can be measured by simple tools — ranging from "comb"-style gauges that are pulled through a wet print (See Figure 39, Page 44), coil and roll-type gauges that are rolled through a test patch (See Figure 40, Page 44) to optical surface tension gauges such as the "Pfund" gauge.

**Ink Viscosity and Viscometers:** The need for basic viscosity testing is primarily in graphic printing, while precision viscosity testing is necessary for industrial printing. The tools range from basic Zhan cups (See Figure 41, Page 46) and calibrated oils — Ford (automotive), Parlin (DuPont), DIN and ISO cups for various specific ranges of inks and coatings — to advanced spindle and cone-plate type digital viscometers.

The basic viscosity range, normal known variance of your inks and the cost or loss potential of the materials you print on will dictate which system you need. Electronic cup and cone systems will determine not only the viscosity but the shear point. These are ideal in electronic and specialty graphic shops for proper mixing of exotic specialty inks and selecting mesh and emulsion combinations that can print them. (See Figure 42, Page 45)

**Ink Mixers:** There are basic hand tools that improve and simplify what you can do manually, such as specially shaped bucket wall and side-scraping, chemically resistant spatulas. Semi-automated motorized stirring units have a large range of impellors, each capable of operating on coatings and inks in a specific viscosity and volatility. (See Figure 43, Page 45) There are blade-type ink shearing units, which mix and pre-shear inks to a print-ready state (See Figure 44, Page 45), and shaker systems, which can accomplish a fair portion of what all of these tools do in a short time amount.

**Scale and software products for mixing ink recipes:** Products range from a basic digital scale to one with software to match the ink system. Most ink manufacturers provide scales and software that have built-in density and colorimetric knowledge of the inks you use.

**Adhesion Testing:** The range of adhesion testers for cured inks (UV, plastisol and solvent) is large. In most screen printing applications, the precision scoring blade tester is the most commonly used. (See Figures 45A, B & C, Page 45) In the industrial, "removable" adhesive arena, surface-cleanliness adhesion testers are used. They are available for most surface and coating types.

**Dyne-Level Testing:** In cost and result reliability, the range of dyne-level test materials includes felt-tip pens, flow tip liquid pens and liquid sample with swabs. If you are a plastic, metal or glass printer, you should have some kind of Dyne-level test kit.

The accuracy, range and repeatability of the kit you require will be dictated by the type and cost of inks, coatings and materials you use. If you require daily dyne-level testing, you print on materials with low-surface energy. You should have a dyne set with a range that extends at least three levels above and below the minimum and maximum levels recommended for your material. (See Figure 46, Page 45)

**UV Radiometer for Curing Units:** There are many forms of UV radiometers, from wired probes and wands for specialty object printers, to armored "pucks" that move on the conveyor belt. (See Figure 47, Page 45)

**Temperature Probes for Thermal Curing:** These probes range from wired probes (See Figure 48, Page 45) and non-contact laser temperature guns (See Figure 49, Page 45) to disposable-heat change tapes. (See Figure 50, Page 47) They all work well within a tolerance. The one you'll need depends upon volume, equipment configuration and accuracy tolerance of the materials and coatings you use.

## What These Tools Can Do for Your Process

Tools that aid in the uniformity of inks, screens, films and squeegees help to ensure the press settings will be the same on each job. Most presses require little if any changes or troubleshooting if these items remain uniform.

- Consistency in ink viscosity (using viscometers and Zhan cups) and ink color repeatability (mixing scale, software, densitometer and PMS book). Make sure that there is no requirement to make changes to the screen or film parameters to correct color on press. Keeping screen tension and emulsion coatings uniform and consistent (tension meter, Rz meter, exposure calculator, thread counting loupe and emulsion thickness gauge) will allow you to produce repeatable work with few if any changes to ink viscosity, color recipe or film work.
- Even subtle changes in one parameter (such as screen tension or emulsion thickness) can require a change in ink, film or press speed in order to set up a press or finish a job in the allotted time. It also may also produce unacceptable results, making daily work repeatability difficult.
- Once an initial test print or image strike-off after the setup has been accomplished and signed-off by the customer, the right inspection tools (loupes, densitometers, etc.) ensure color and registration stay true throughout the print run. This reduces waste and defects, guaranteeing printed pieces cost the same or less than what was quoted. This saves time and money.

## Time Savings

Saving time is what process tools are all


Figure 33: Dial indicator and clamp.


Figure 34: Dedicated head-size-specific, off-contact gauge (LOC gauge, SDI inc.).


Figure 35: Diamond wheel squeegee grinder (Fimor).


Figure 36: Rotary knife squeegee cutter (Theime).


Figure 37: Diamond squeegee edge hone (Fimor).

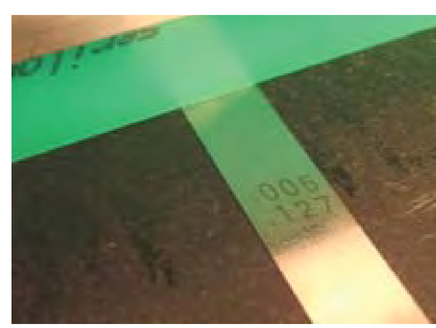
Figure 38A: Brand new blade showing uneven .005" (125µ)gap on granite surface plate.


Figure 38(B): Initial diamond wheel contact mark illustrating the curvature of a new un-cut/un-ground blade.

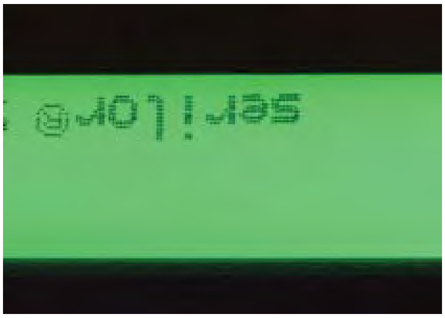

Figure 38(C): Backlit edge inspection on granite surface plate showing no unevenness after grinding/cutting.

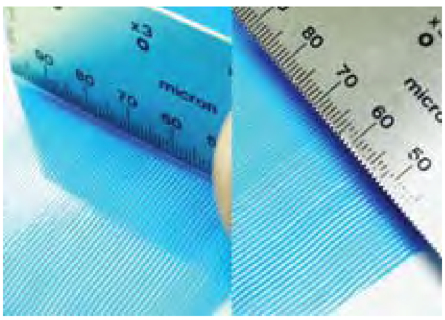

Figure 39: "Comb" style wet ink film thickness gauge (Gardco).

Figure 40: "Coil" or "wheel" type wet ink film thickness gauges (Gardco).

Figure 41: Zahn viscosity testing cups (Gardco).

about, whether you save time by setting up the press faster, running the press faster or making the screens faster. By making fewer press errors, printing fewer defects and not having to reprint, you save time.

You save time by not remaking screens that were incorrect; preventing screens from reaching the print floor when they are incorrectly made; and catching film errors before they leave the art department. Saving time puts money in your pocket, and reduces overhead costs and labor. But how much time can you save? How much saved time will you require to get a return on your investment?

## Return on Investment (ROI)

Anyone who wants to help you calculate your ROI, but isn't an employee with your business, cannot do this accurately without spending time in your plant. Let's look at a calculation for a specific real operation to illustrate real world loss rates from an imprecise process. Because we are capturing the "true" process cost by knowing all of the components that go into that cost (not just the obvious ones), we can make a very quick and accurate assessment of how much money per hour, minute or printed piece the company may save.

This will show how fast my ROI on the new tool will be and when it starts making money. When you do your homework on your own plant, the savings for your investment become obvious.

## Example process:

### *Screen Making for Semi-Conductor Work (Three Presses)*

- Proposed new tools: Rz meter and emulsion thickness gauge.
- Original ROI time frame on main equipment and room cost: Four years at 248 production days of 10 hours each = 9,920 hours of production to amortize costs.
- Labor cost (two employees constant): Hourly rate of $13.50 each x 2 = $27-per-hour labor cost x 9,920 hours = $267,840 labor.
- Production load annually: 1,000 impressions per hour (three press combined capability) x 9,920 hours = 9,920,000 impressions maximum potential.
- Frame size and type: 30.4-cm-by-30.4-cm (12-inch-by-12-inch) cast aluminum.
- Screen frame costs: $42 each. Lifespan estimate four years because of milling to strip mesh with a total of 44 stripping and milling cycles per year. This includes 44 annual re-mesh cycles per frame.
- Service costs: Adhesive ($1.18 per screen), mesh ($12 per screen), reclaim chemicals ($1.85 per screen), emulsion (57 cents per screen), block-out (2.5 cents per screen) and tape (95 cents per screen).
- Total screen cost: $16.57 + $42 = $58.57 per complete and brand-new screen.
- Reclaim, recoat and material costs per screen: $16.575 + $3.25 (sandblasting outsourced) = $19.82 per screen.
- Total screens used in ROI cycle: 248 days x 4 = 992 days at 12 frames per day = 11,904 screens in ROI cycle.
- Total screen cost per ROI cycle (48 frame loop): Initial 48 frames ($2,811.36). Remaining screens (11,904 minus 48 initial = 11,856 screens). 11,856 divided by 12 screens per day = 154.6 reclaim cycles at $16.575 each = ($2,562.495). 44 re-mesh cycles x four years = 176 cycles x 48 frames = 8,448 x $19.825 = $167,481.60.
- Grand total screen cost per ROI: $170,044.09 materials, $267,840 labor = $437,884.09

**Equipment Overhead:** Exposure unit ($7,500), washout sinks ($5,200), pressure washer($2,300), light table($1,100), exposure calculator ($89), serivac ($250), measuring loupe ($725), frame racks ($850), frame carts ($675), drying cabinet ($3,200), mixing scale for adhesive ($1,800), screen stretching unit ($11,000) (six frames up) and small tool set ($185). Total: $34,874/992 days = $35.15 per day in equipment costs (don't forget interest on your bank loans).

**Facility Overhead:** Square foot rental cost (45 cents per square foot x 1,100 square feet = $495 per month for this room). This overhead will depend on monthly lease or rent cost divided by total square footage to get cost per square foot per month. Multiply this cost per square foot by number of square feet in the production space in the ROI. You now know what this screen room costs in rent per month.

**Process Consumables:** Water at 500 gpd average x 992 days = 496,000 gals. At $42 per 3,500 gals = $5,951.99. Electricity: 7 kw per hour X 10 = 70 kwh per day x 992 day = 69,440 kwh at 12 cents per Kilowatt hour (peak load) = $8,332.80. Total: $14,284.79.

**Total Facility and Overhead Cost for This ROI:** 48 months X $495 (rent) = $23,760+$5,951.99 (w) + $8,332.80 (E) = $38,044.79.

**Grand total of Combined Costs:** $514,802.88.

Divide this by 9,920,000 impressions at current maximum potential = .05189 cents per printed unit.

There always are some costs that aren't captured. For example, I purposely left out consumable items, such as wiper towels. At an average cost of about 6 cents each with a daily use of about 100 in a screen room, these can be $5,952 of this screen room's total ROI cost. Small things add up quickly.

Our two new pieces of equipment for this sample screen room are an Rz meter ($2,100) and emulsion thickness gauge ($1,250) for a total of $3,350. When this $3,350 is added for a total cost of $41,035.36, it seems to be a significant portion of the investment.

This is where homework, process timing and modeling are important. The history in this example shop is that three of the screens used each day on average were short-lived failures because of variations in screen thickness. They bled too much or lost parts of the image during the printing process. This production facility can actually operate on only eight screens per day, producing a maximum 1,000 impressions per hour.

This is a total of 992 days multiplied by four screens equals 3,968 screens that would otherwise not have been made. The total savings in screen reclaim materials will be: $3.395 X 3,968 = $13,471.36. Add to this $178.50 for electricity over four years (about 1.5 Kwh per day not used for exposure or pressure washer) and $488 worth of water.

What also wasn't captured here are the 18 minutes of set-up time for each of the 3,968 screens that would not have to have been used (1,190.4 hours). The press operator pay rate in this plant is $22 per hour. That is a savings of $26,188.80.

The grand total of savings that these two tools brought to this shop is $39,886.66 for an investment of only $3,350 in process tools. These are tools you cannot afford not to buy.

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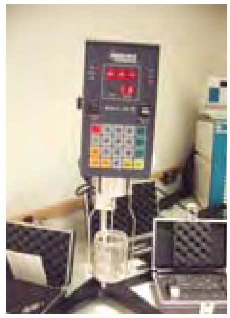
Figure 42: Digital, temperature controlled cup and cone viscometer (Brookfield).

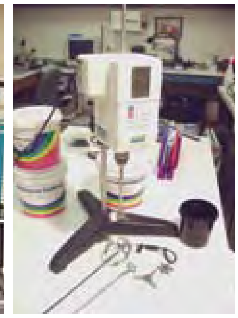
Figure 43: Programmable ink stirring motor/mixer with attachments.


Figure 47: Radiometer for UV curing units.


Figure 44: Stationary blade type mixer.


Figure 45A: ASTM certified cross-cut adhesion test kit.


Figure 48: Hardwired temperature probe.

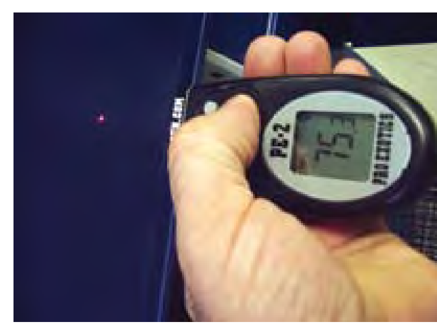
Figure 49: Laser temperature probe.


Figure 45B: Detail of cutter head.

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface of cross-cut area from which flaking has occured. (Example for six parallel cuts) | NONE | | | | | GREATER THAN 65% |
| CLASSIFICATION | 5 | 4 | 3 | 2 | 1 | 0 |

Figure 45C: Detail of cross-cut test patch.


Figure 46: Dyne level test kit.

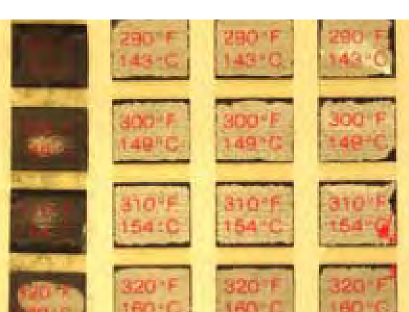
Figure 50: Temperature indicating tape strips.