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Optimizing Stencils for High-Resolution Graphics

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The greatest challenge producing high-resolution prints is defining the 'optimal' stencil and tailoring its characteristics to the printing application. Due to the wide range of applications and printing environments, an 'optimal' stencil for one application may be inappropriate for another. Each print shop must define the optimal stencil for their specific application and environment. This article provides an overview of stencil parameters relative to printing requirements.

The Starting Point

There are 3 main types of stencil systems: indirect film, capillary film, and direct emulsion. Indirect film is a dried, photosensitive coating on a polyester carrier that is exposed and developed before application to the mesh. Capillary films and direct emulsions - chemically similar, are both applied to the mesh then exposed and developed. A capillary film is a direct emulsion coated to a specific thickness onto a carrier, dried, and packaged into rolls or cut into sheets. Capillary film is applied to a wet screen; the water then pulls the film into the mesh. A direct emulsion is a liquid coated onto the mesh and then dried. The table below provides a general comparison of the stencil systems.

	Indirect Film	**Capillary Film**	**Direct Emulsion**
Advantages	• Very fast processing. • Highest resolution. • Very fast exposure.	• Fast processing. • Defined thickness & stencil smoothness, leading to application consistency.	• Highest chemically/mechanical resistance. • Wide latitude for adjusting stencil thickness & stencil smoothness. • Relatively inexpensive.
Disadvantages	• Low chemical/mechanical resistance, used for very short print runs. • Narrow processing latitude. • Requires chemical processing. • Narrow exposure latitude.	• Limited shelf life. • Less mechanically resistant than direct emulsions. • Relatively expensive.	• Longer processing time.

Most printing shops today use either capillary film or direct emulsion. Both offer very repeatable results and have specific characteristics that lend themselves to a range of printing applications. The choice of one product over the other depends on the print requirements and the ability of the screen maker to optimize the stencil's inherent properties. When printing high resolution images day-after-day, exploiting and maintaining the stencil characteristics becomes increasingly important.

Environmental Control

A clean environment and clean screens are essential for any printing shop. A contaminated screen in a dirty screen room limits the possibility to optimize the stencil. Each limitation imposed on the screen maker decreases the processing latitude to build the 'optimal' stencil and risks poor, inconsistent printing. This includes the suitability of the screen making equipment. Equipment specifically designed for the screen making process increases the latitude to optimize stencil production.

Control tools and documented procedures need to be established to achieve consistent stencil making. Tools such as a tension meter and thickness gauge help to establish tolerances and monitor stencil production. Any control placed on the stencil making process provides a means to evaluate every stencil and determines its suitability for the printing application <u>before</u> it goes to press. Any screen not held within established tolerances before going to press risks press downtime; every minute the press is not running... (the fighting begins between printer and screen maker).

There are several criteria for defining the 'optimal' stencil, but the three main criteria are:

- **Resistance properties**
- **Copying properties**
- **Ink transfer properties**

Stencil Resistance

There are two types of resistance: chemical and mechanical. Chemical resistance is the stencil's ability to remain consistent throughout a print run in spite of the inks and press ink cleaners. When UV-curable, solvent-based, and plastisol inks are used, the stencil needs to be resistant to not only the ink, but also the solvent press cleaners. For these applications, use a solvent resistant stencil product. For water-based inks, the stencil needs to be water resistant. Some capillary films and direct emulsions offer both solvent and water resistance. The thing to keep in mind is that each stencil product has a certain level of solvent/water resistance. Optimizing chemical resistance requires proper application, thorough drying, and complete exposure.

Mechanical resistance refers to the stencil's durability when subjected to physical stresses during printing. The required amount of mechanical resistance, again, depends on the printing application. The mechanical resistance is inherently higher with direct emulsion because emulsion fully encapsulates the mesh; the stencil holds onto the mesh better. The mechanical resistance of capillary film is improved by adhering with sensitized emulsion rather than water. Optimal mechanical resistance for both stencil systems is achieved through complete drying, exposure, and developing.

Copying Properties

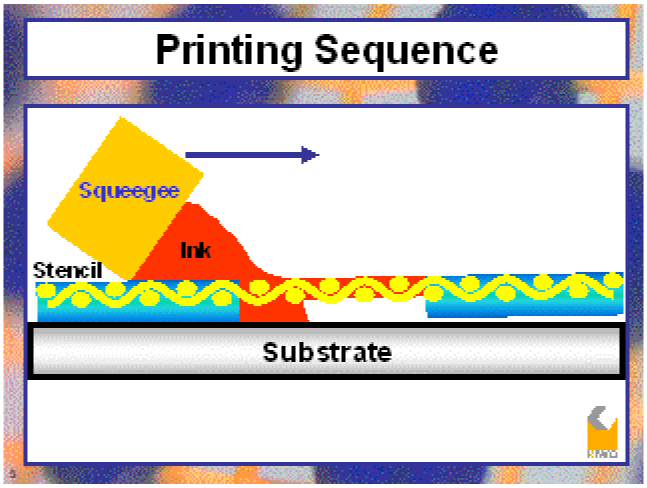
Copying properties is the ability of the stencil to reproduce detail. Those copying properties are directly related to the inherent quality of the product, and differences become apparent when higher tolerances are demanded.

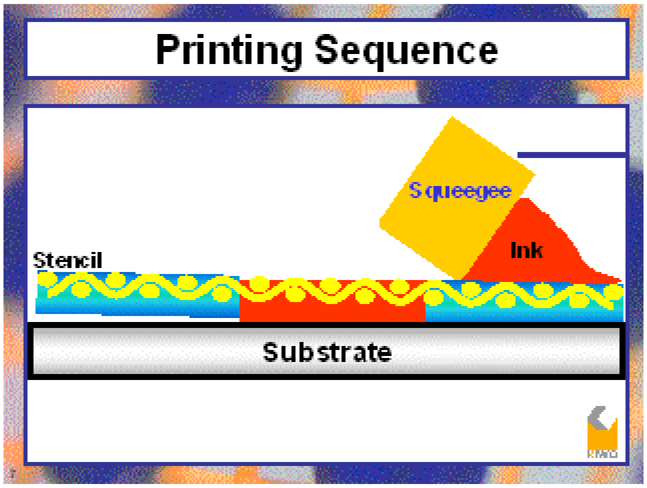
High resolution stencil products must resolve and maintain detail even when screen making parameters change. A good stencil system needs to handle a wide latitude of processing requirements and maintain the required copying properties. The major screen making parameters that influence the consistency of achievable detail includes:

- **Dryness of the coated screen**
- **Environmental cleanliness**
- **Stencil application**
- **Spectral output, duration, and degree of exposure**
- **Quality of exposure lamp/system**
- **Quality and use of screen making products**
- **Quality and density of artwork/film positives**
- **Developing pressure, thoroughness, and duration**

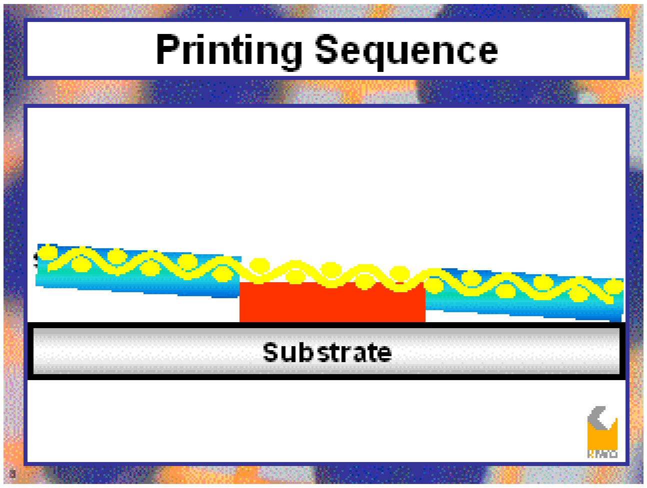
Ink Transfer

Ink transfer refers to the drawing of the ink by the substrate from the stencil to accurately reproduce detail. The squeegee performs two jobs during printing: (1) it fills the open areas of the stencil with ink and (2) contacts the screen to the substrate. The actual printing or ink transfer happens as the stencil lifts from the substrate; the ink adheres to the substrate better than to the stencil. With minimal stencil surface for the ink to hold onto, the ink easily 'slides out'. Defining the 'optimal' stencil would include increasing the ease of ink transfer.





Printing Sequence

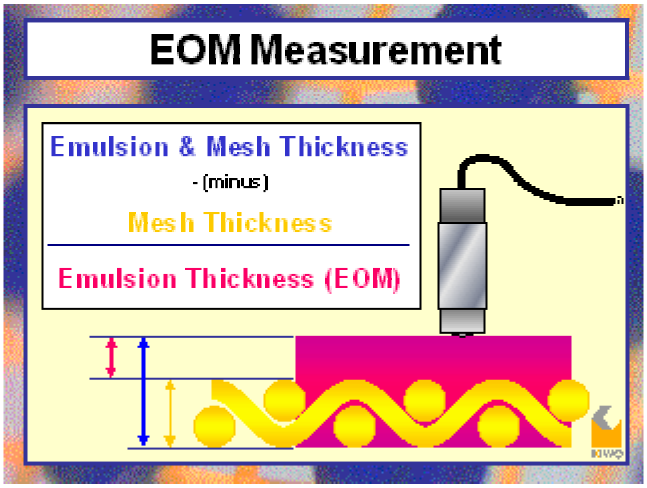


Printing Sequence

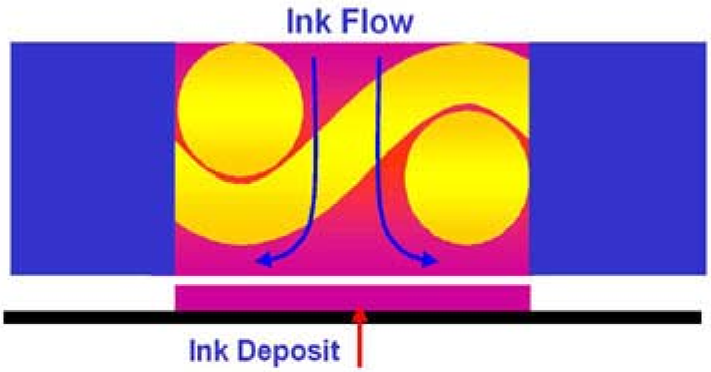
Ink transfer also includes accurately reproducing the stencil image on the substrate - to print the stencil image true in shape and size. Two major stencil parameters are critical to accurate ink transfer: emulsion build up and stencil smoothness.

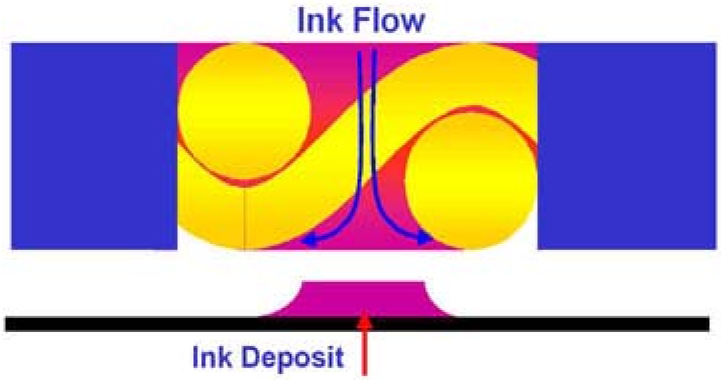
Emulsion Build Up

Emulsion build up, also referred to as Emulsion Over Mesh (EOM), is the total stencil thickness minus the mesh thickness. A thickness gauge is used to obtain measurements in microns or mils.



In general, the emulsion build up is only on the substrate side of the screen. The build up provides a support structure to hold mesh knuckles away from the substrate during printing. Ink then flows under and around the thread fibers to the edges of the stencil. The transferred ink from the stencil to the substrate is truer in shape and size.

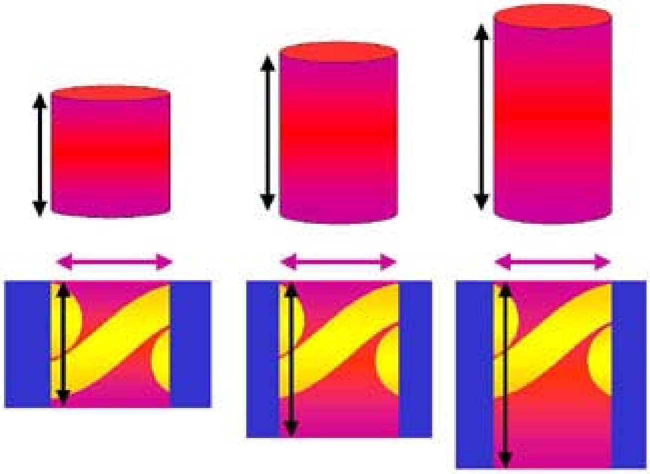




With little or no stencil build up, the knuckles of the mesh contact the substrate during printing causing a pattern of voids in print. The ink cannot flow to the edges of the stencil and does not reproduce the stencil detail accurately in print.

A thin build up is also a weak stencil. The stencil spanning the mesh openings needs to be strong enough to resist mechanical forces during developing and printing or it could break away in the mesh openings. In weak stencils, the emulsion could break away in the mesh openings causing a stair-step or saw-tooth pattern in print.

A thicker EOM up provides greater support for the stencil image; however printing fine detail becomes more difficult. The contact area the of ink to the substrate should be greater than the ink to the stencil wall. As the total height of the stencil increases, so does the surface area within the stencil. Printing a tall and narrow column of ink is very difficult, if not impossible. A wide, short column of ink has more relative contact area to the substrate than to the stencil– ink transfer is easier. Printing fine detail requires the total stencil thickness to be as thin as possible.



The EOM compromise: The stencil needs to be thick enough to hold the mesh off of the substrate during printing and provide stencil strength, but thin enough for easy and accurate ink transfer. The best EOM compromise depends on the print application. General guidelines are provided in Table 1.

Emulsion Over Mesh (EOM) = total stencil thickness minus (-) the mesh thickness.

Emulsion Over Mesh Ratio (E/M R) = emulsion build up thickness divided by (÷) the mesh thickness.

Guidelines for 305 tpi and above:

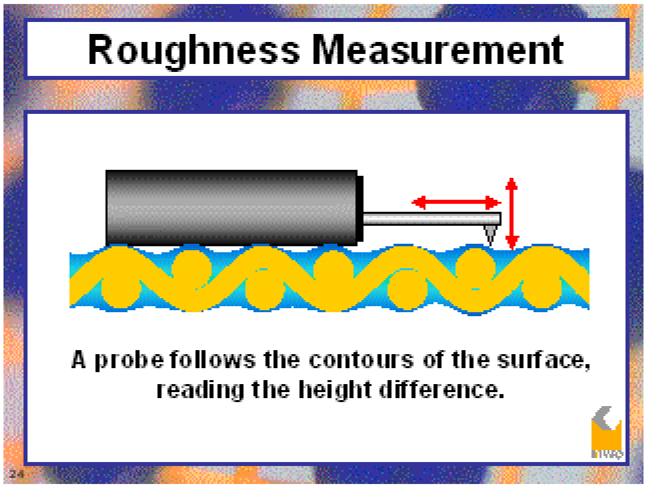
Fine detail: EOM = 5-7 microns (E/M R=10%-15%)

Medium detail: EOM = 7-10 microns (E/M R=15%-20%)

Stencil Smoothness

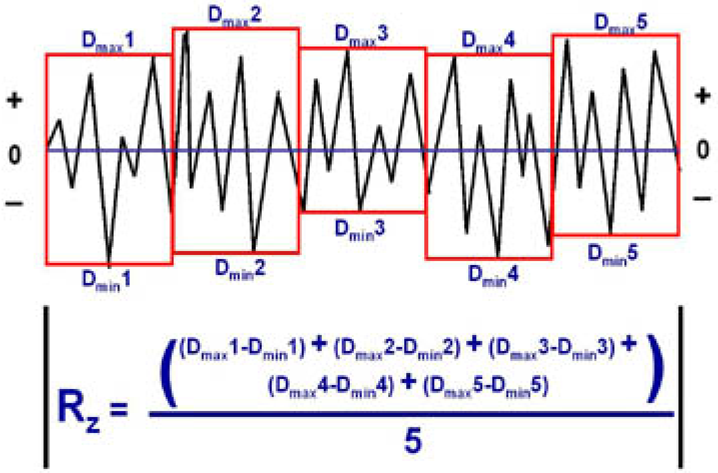
The surface smoothness or R_z value is the second stencil parameter to be defined and built into the stencil. The R_z value, like EOM, is a measurable stencil characteristic and, in part, determines the quality of the print.

An instrument known as a Profilometer or R_z meter measures the stencil roughness/smoothness in microns. A diamond point secured to a probe is placed on the stencil and pulled across the surface. The maximum height (Dmax) and minimum height (Dmin) is measured for 5 sections. The *total height difference* between the Dmax and Dmin for each section is calculated. The section values are averaged to find the R_z value. The smoother the stencil, the lower the R_z.



Roughness Measurement

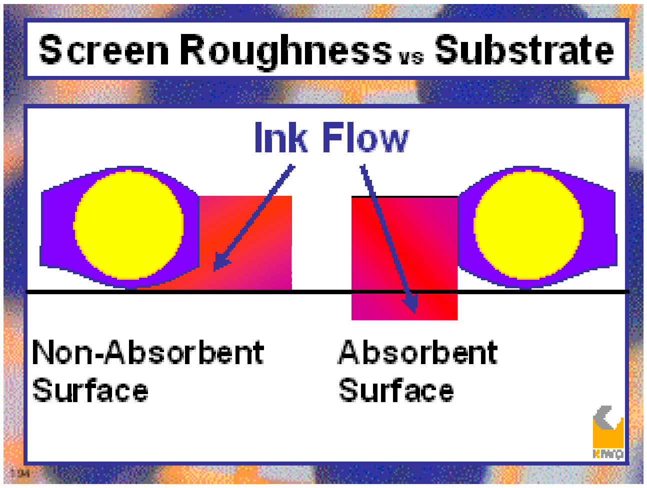
A probe follows the contours of the surface, reading the height difference.



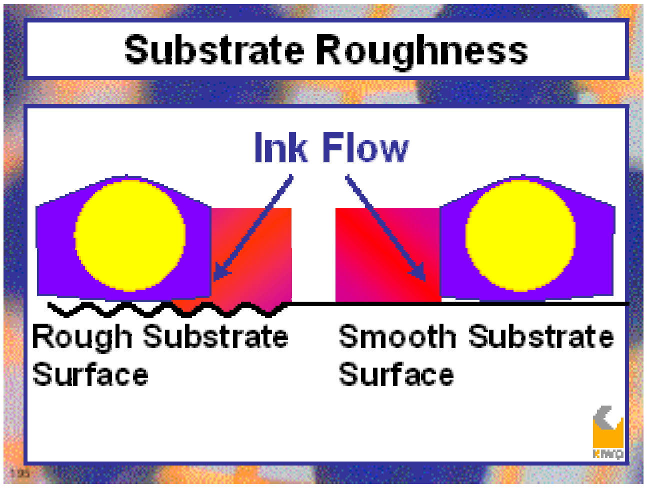
$$R_z = \frac{\left((D_{max}1-D_{min}1) + (D_{max}2-D_{min}2) + (D_{max}3-D_{min}3) + (D_{max}4-D_{min}4) + (D_{max}5-D_{min}5) \right)}{5}$$

Let's look at R_z in relation to printing. Ink is filled into the stencil openings flowing to the stencil edge. If the stencil edge does not make complete contact to the substrate, ink continues to flow. Wherever contact is not complete along a stencil edge, the printed edge distorts; the stencil image does not reproduce accurately in print.

By building a smooth stencil (low R_z), a complete gasket of the stencil edge forms to the substrate; the gasket stops the ink from flowing under the stencil edge. In general, the smoother the stencil - the better. However, there are exceptions.



Screen Roughness vs Substrate



Substrate Roughness

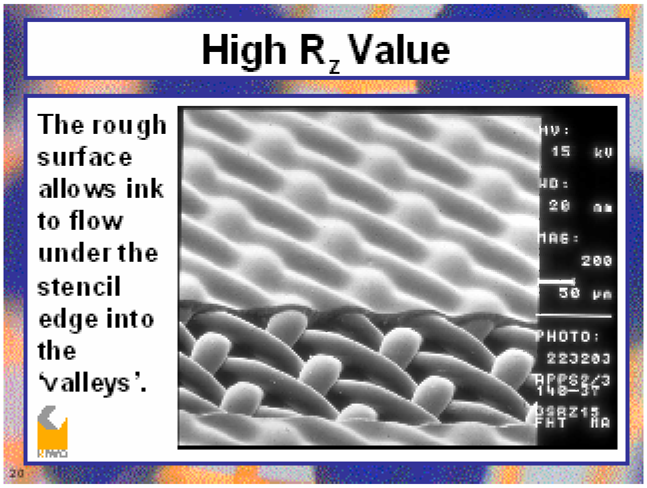
If the substrate itself has a rough surface, a stencil can only contact the raised areas. The low areas may allow ink to flow under the stencil edge; a low R_z stencil reduces this. Conversely if both the stencil and the substrate have low R_z values, the effect during printing would be as if a piece of glass was covered with plastic wrap. The extreme smoothness of both surfaces makes it very difficult to separate them and static electricity is generated upon separation. In this case, a rougher stencil is required.

As a general rule, the sum R_z of substrate and stencil should equal 12 to 14 microns. A rough substrate is paired with a smooth stencil and vice versa. This guideline should be considered as a starting point to test R_z in relation to printing results.

Capillary films can produce smooth stencils with initial application. It is coated onto a polyester backing, mounted on the mesh and dried. Before exposure, the carrier is removed from the substrate side of the screen. The resulting stencil surface is very smooth. For some printing

applications, this smooth surface is ideal. The downside is that it normally produces only a smooth stencil surface. The R_z can not be easily adjusted to fit applications requiring a high R_z.

When a direct emulsion is coated, most of the product evaporates. The dried coating takes on the surface structure of the mesh. The stencil surface becomes rough and has a pattern of hills (knuckles) and valleys (mesh openings). Additional coats are applied to the substrate side of the coated and dried screen to reduce the R_z.



High R_z Value

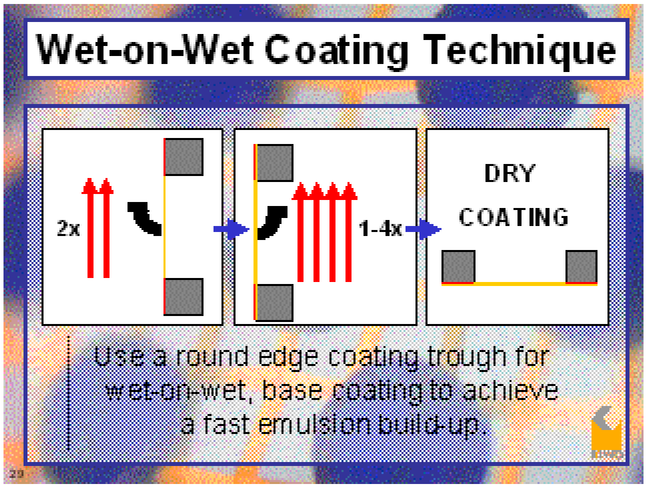
The rough surface allows ink to flow under the stencil edge into the 'valleys'.

Direct emulsions may require additional coating to achieve a smoother stencil surface, but the coating technique can be altered to achieve the 'optimal' R_z value to fit the printing application.

Base and Face Coating

The resulting EOM and R_z for capillary film is determined by film thickness and application. For direct emulsion, EOM and R_z are controlled through coating. In general, the initial base coating builds the emulsion thickness; the additional coating smoothes out the stencil surface.

Base or wet-on-wet coating is the initial application of emulsion to a clean screen. Starting on the substrate side, apply emulsion using a round edge trough. Coat as many passes as it takes to completely flow emulsion from the substrate side to the squeegee side. Continue until a glossy sheen appears on the squeegee side of the screen. At this point, turn the screen around (either vertically or horizontally) and coat as many passes as it takes to build the stencil to the required emulsion build up. Testing determines the number of squeegee passes. The coating ends on the squeegee side so the emulsion build up is on the substrate side. The screen is dried substrate side down to maintain the coating on this side.



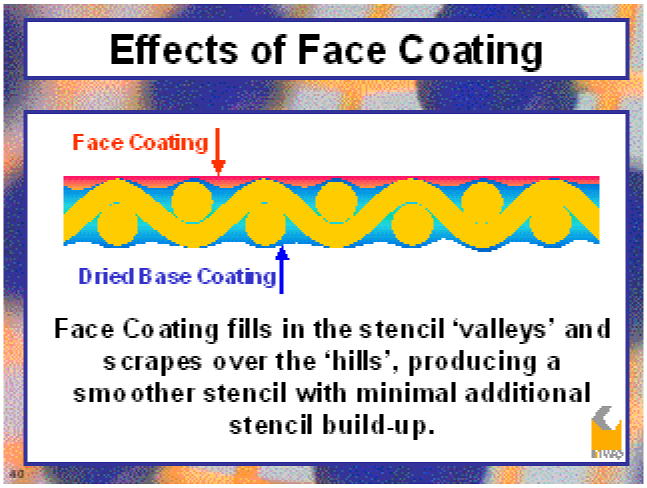
Wet-on-Wet Coating Technique

Use a round edge coating trough for wet-on-wet, base coating to achieve a fast emulsion build-up.

The initial base coat should be somewhat thick since 50% to 75% of the coating evaporates. A round edge trough makes base coating quick and efficient. A sharp edge coating trough deposits much less emulsion, requiring more coating passes to achieve the 'optimal' thickness.

Finer mesh counts have a lot more mesh mass (threads) and less open mesh area prohibiting/metering emulsion from flowing through the mesh. High mesh counts require more coating passes to achieve the minimum emulsion thickness. Thinner thread diameter for a given mesh count provides more open area also allowing more emulsion to flow through the mesh. A change in mesh count or thread diameter produces different EOM and R_z values and must be tested.

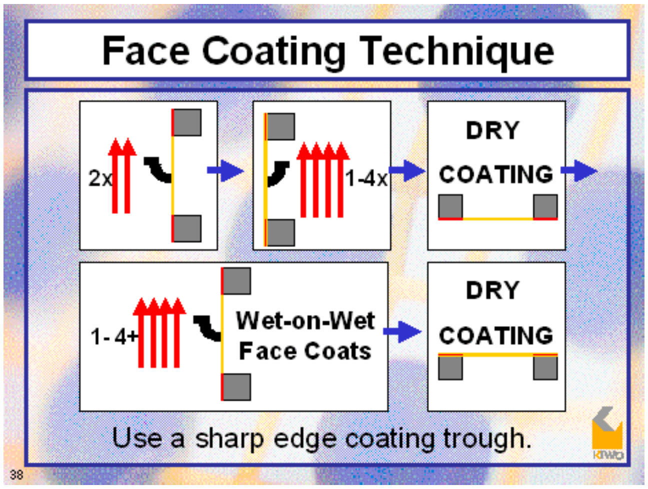
To reduce the R_z of the base coat use a technique known as face coating – an additional coating with a sharp edge trough depositing emulsion in the 'valleys' and scraping over the 'hills' of the stencil on the substrate side of the dried screen. The stencil becomes smoother with minimal additional build up.



Effects of Face Coating

Face Coating fills in the stencil 'valleys' and scrapes over the 'hills', producing a smoother stencil with minimal additional stencil build-up.

Traditionally, face coating is dried between each application; the first face coat re-wets the surface of the initial base coating causing it to become slightly tacky. Successive face coats could become difficult to apply. However, the emulsion deposit is minimal. By the time the second face coat is applied, the first face coat may already be dry enabling face coats to be applied one right after the other - successfully.



Face Coating Technique

2x

1-4x

DRY COATING

1-4+

Wet-on-Wet Face Coats

DRY COATING

Use a sharp edge coating trough.

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Capillary film provides standard thicknesses and smooth R_z values immediately ‘off the roll’; direct emulsion provides adjustability to ‘dial in’ the required EOM and R_z. For both systems, mesh count, thread diameter, and application affects the resulting EOM and R_z value. The stencil system used, again, is based on the printing requirements and defined through testing by you.

Cap Film Testing

To test capillary film with varying EOM and Rz values with respect to printing results, obtain several thicknesses of capillary film of a given product. For fine detail printing, obtain various film thicknesses ranging from 10 to 25 microns. Pre-size the films to allow all samples to fit on one test screen. Prepare and wet the screen of a given mesh type and apply films in rapid succession. Process the screen and compare the printed images of each area. (See the section ‘Evaluating the Print’)

Direct Emulsion Testing

A *step-coating* is used to test resulting EOM and R_z values for direct emulsion. With a given mesh type and emulsion product, coat as many passes on the substrate side of the screen as necessary to completely push/flow emulsion through the mesh and produce a ‘glossy sheen’ on the squeegee side. (Click here for figures.)

Turn the screen around and apply one coating pass from the bottom to the top of the screen; apply a second pass starting 1/3 the way up from the bottom; and a third pass starting 2/3 the way up from the bottom. The screen should have 3 different coatings varying in emulsion deposit thickness. Dry the screen.

Then turn the dried screen clockwise 90° from the initial base coating direction. On the substrate side of the screen with a sharp edge trough, apply the one face coat starting ¼ the way from the bottom. Apply the second face starting ½ way from the bottom; and apply the third face starting ¾ the way from the bottom. Either dry the screen between each application or coat all face coats at once. The drying procedures follow procedures used in production.

Evaluating the Print

To find the best capillary film thickness or direct emulsion coating technique(s) for a given application, expose each area to repeated artwork containing detail typical in production. Expose thinner thickness areas to less UV-light. Expose thicker areas to more UV-light. Develop, dry, and

prepare the test screen for printing. Use the test screen to print all substrate/ink combinations that would use the same mesh and detail parameters.

The proof is in the print - evaluate each of the printed areas with at least a 30 power magnification microscope. Compare the image sharpness quality and the reproduction size and shape accuracy. The area(s) producing the best printed image provide the technique(s) to use for the specific printing application. Ideally, a stencil thickness gauge and R_z meter are used to measure the area(s) producing the optimum printed image. The measurements are used to establish and maintain EOM and R_z value standards and tolerances.

Keep Searching

The general EOM and R_z parameters have been stated, but these values are only a starting point. Testing provides concrete screen making tolerances to optimize the stencil to the printing application taking into account the best stencil compromises and adjustments.

Each print application requires different stencil characteristics. Whether using capillary film or direct emulsion, the ‘optimal’ stencil is found through defining the print requirements, testing and establishing standards. Tolerances are then maintained from screen to screen using the established procedures and measuring controls.

The ‘optimal’ stencil is one that can be produced consistently and achieve predictable print results. Once the print becomes predictable, finer and finer adjustments can be made within the screen making and printing process to increase quality and efficiency. This article only offers a brief look into effects of the stencil in print. Much more investigation and comparison needs to be continued through testing and evaluation. The ‘optimal’ stencil can be defined and built.