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# **Getting the Most out of Direct-Emulsion Stencils**

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For screen printers, screenmaking remains the number one problem area of the printing process, despite the vast number of training seminars offered by distributors, manufacturers, trade associations, and schools. We still struggle with pinpointing exposure times and selecting the right coating techniques for the specific jobs we have to print.

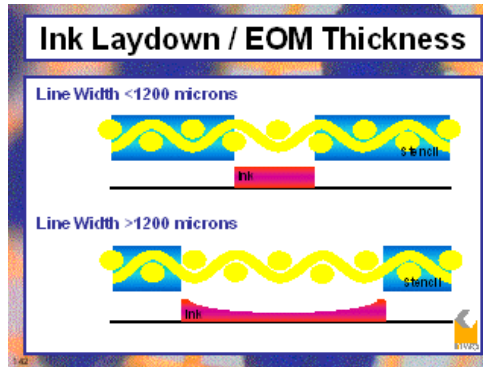
Unfortunately, exposure times and coating procedures go hand in hand, so you have to deal with the combined problems. On top of that, you have to consider the ink and press characteristics and their relationship to stencil profiles. This article investigates what the optimum stencil looks like and what you must do to produce that "perfect" stencil on a daily basis.

Due to the range of applications in screen printing, with its variety of substrates and ink systems, no single method exists for coating a screen "right." The prescription for a perfect stencil not only satisfies a certain emulsion-over-mesh ratio and roughness range, but also dictates the careful balance you must create among ink characteristics, press parameters, substrate characteristics, and the stencil. In achieving this balance, you may discover that a screen for printing a specific job is compatible with a specific ink from a particular supplier. Such discoveries are what make screen printing such an interesting, yet nerve-racking, process.

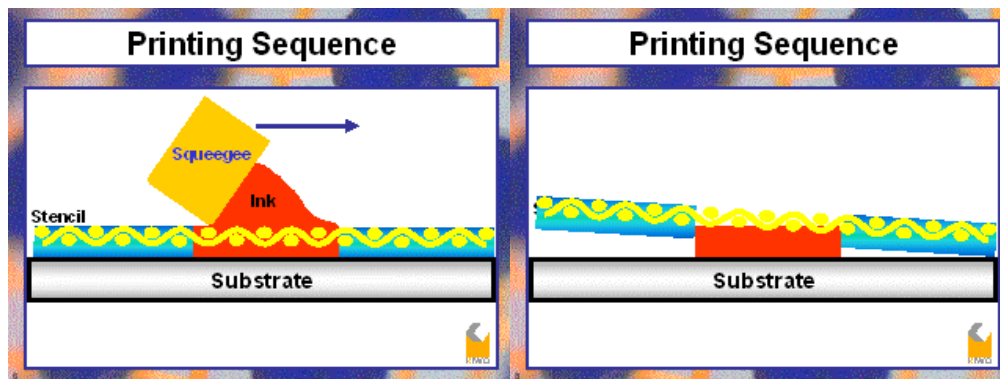
## **How does a stencil work?**

Before you can create perfect stencils, you must understand how a stencil works and what it must provide in terms of durability, resolution, and ink-transfer capability. Other than being the image carrier, the stencil is also a device for controlling the amount of ink deposited onto the substrate. This function has led to the variety of mesh counts and coating techniques we use today. While each mesh count holds a different amount of ink, stencil thickness can also influence the total amount of ink that transfers to the substrate by increasing the amount of ink the mesh can hold and supporting the mesh above the substrate during printing.

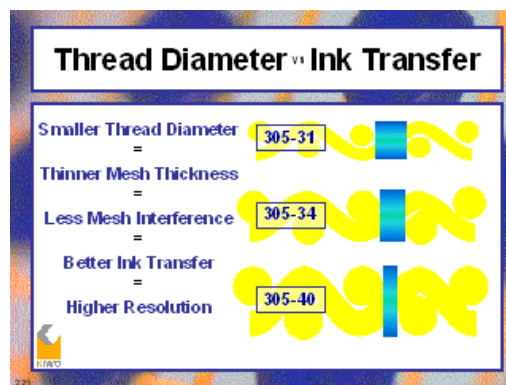
However, when the size of open image areas becomes too large, the stencil supports the mesh only at the image edge. This means that the stencil only affects ink-deposit thickness at the edge of the open area. In such situations, the stencil can lead to irregular ink laydown and cause a dark "outline" around the printed image, particularly with translucent or transparent inks. The maximum size of the open area that a stencil will support depends on the stencil thickness, squeegee pressure, mesh tension, and many other variables.



During printing, ink is transferred to the substrate. Contrary to common belief, ink transfer is not caused by the squeegee pushing the ink through the stencil, but by the interaction of two physical properties--cohesion and adhesion. The squeegee only fills the stencil with ink and cuts excessive ink away from the top of the stencil. Once the squeegee has passed over the image, the stencil lifts off the substrate due to off-contact distance. The ink transfers by adhering better to the substrate than to the stencil when the screen snaps. But the ink will only transfer correctly if it is cohesive enough to hold together well and can "slide" out of the stencil without much resistance.



The ratio of the ink's contact area in the stencil, which includes the stencil walls and the thread surface, versus its contact area on the substrate is important for fine-detail printing. The more contact area in the stencil, the more difficult the ink transfer will be. Because of these simple physical laws, fine detail is more difficult to print with a thick stencil than with a thin one. Choosing the proper mesh count, thread diameter, and stencil thickness is critical for achieving proper ink transfer and a quality printed image.



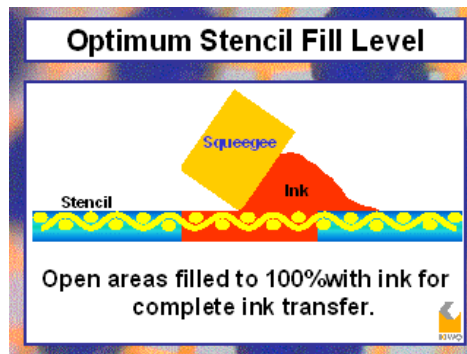
## What does the perfect stencil look like?

A perfect stencil transfers ink easily, has the resolution required for the image, and holds up on press under all conditions. However, a perfect stencil does not necessarily have the same physical properties for the same image if other printing parameters change. For example, printing a fine-detail image with a low-viscosity UV ink requires a different stencil profile than needed for printing the same image with water-based ink.

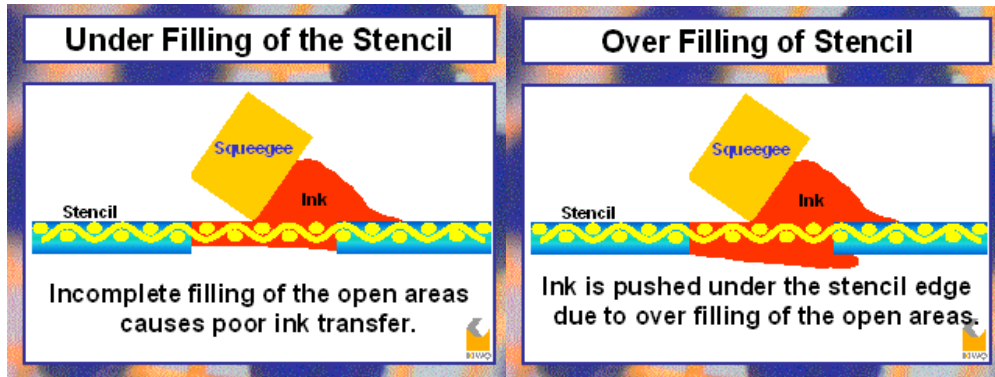
Stencils can counteract or complement a given printing environment. If your press does not support squeegee-angle adjustments and has only one squeegee speed, you can still print well, provided that the stencil is made specifically for the press and the ink you plan to use. To explain this in more detail, let's say that you're using printing a solvent-based ink on paper stock, using a long-stroke, flatbed press with no squeegee adjustments whatsoever. Due to the preset squeegee/floodbar speed, squeegee/floodbar angle, and ink viscosity, the amount of ink that fills the stencil is always the same with a given mesh. The floodbar will fill the stencil with a certain amount of ink, the squeegee will push a certain amount of ink into the stencil, and the ink will flow at a given rate through the stencil. You can't change the press settings, and let's assume that you cannot change the flow properties of the ink. In this example, you have only one option for influencing the printed result: You can vary the stencil profile.

## How do you match the stencil to other printing parameters?

Ideally, the amount of ink that fills a stencil exactly matches the total thickness of the stencil. In other words, the open areas of the stencil completely fill with ink from the base to the shoulder of the stencil. With this optimal "fill volume," the ink will be in contact with the substrate across the entire image area during the print stroke and will slide out of the stencil when the screen snaps off the substrate.



If a stencil is made correctly but creates prints of poor quality, it could point to two other problems: overfilling or underfilling the stencil with. In the case of underfilling, the ink does not fill the entire stencil and does not make contact with the substrate in open areas. Without contact to the substrate, the ink is likely to stay in the screen and not transfer to the substrate, causing voids in the print. If the stencil is overfilled, the excess ink will have no where else to go but underneath the stencil edge during the squeegee stroke. This will cause smearing at the image edge and result in a muddy print or severe dot gain in process-color printing.



In either case, you can simply create a thicker or thinner emulsion buildup to match ink-fill characteristics, as long as the stencil still provides good ink transfer. Ideally, however, you should avoid adjusting stencil thickness and, instead, adjust press settings to match the ink fill to the stencil.

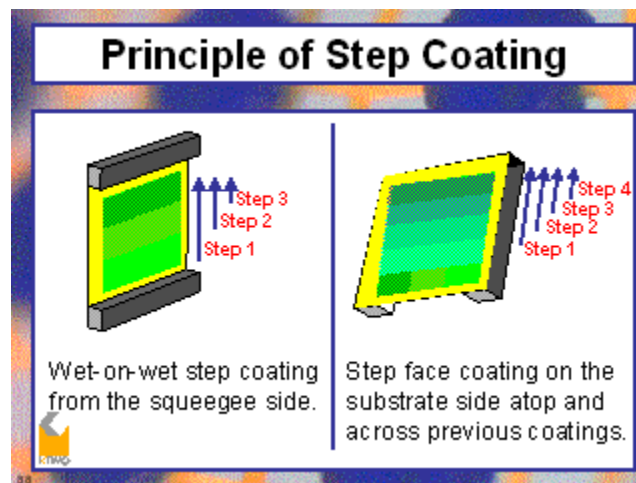
### Is there an optimal stencil, regardless of the application?

If you could apply a general rule to stencilmaking, screen printing would be much easier and more controllable. Unfortunately, different applications require different stencil characteristics, so specific parameters such as thickness and roughness cannot be set. However, to make printing easier, you can apply the general information shown below in "Stencilmaking Guidelines."

These guidelines are based on physical laws that affect the way the ink flows into the screen, transfers to the substrate, and slides out of the stencil. It may not be possible to adhere to these guidelines in all applications, but the closer you can follow them, the easier printing will become and the better your prints will look.

### How can you determine the optimal stencil for any application?

With all of the variables involved in screen printing, predicting the performance of a stencil with 100% certainty is impossible. To assess the influences of substrate surface, press adjustments, and ink rheology on the stencil, you must create a test screen and generate some test prints. The following simple test-coating technique provides information about how a stencil with a specific geometry reacts with your ink and press settings.



Start with one or several coats of emulsion on the substrate side of the screen to completely fill the mesh with emulsion. Apply a single coating to the entire squeegee side, followed by another wet-on-wet coat that covers only 2/3 of the screen. Then add another wet coat that covers only 1/3 of the screen. The result is a different emulsion thickness for each 1/3 of the screen.

Now dry the stencil in a horizontal position with the print side down. Once it is dry, coat the substrate side of the screen using a sharp-edged coater (or a round-edge coater for mechanical coating), covering 2/3 of the screen perpendicular to the coating direction used on the other side. Finally, apply another coat to the substrate side and cover only 1/3 of the screen.

The resulting screen has a total of nine different emulsion thicknesses. Now, expose this test screen with a pattern that covers all nine fields. When exposing the screen, use an exposure time appropriate for the center field to accommodate the different emulsion thicknesses.

When printing with this screen, you will see how each field produces a different print quality with a given press setup. This makes it easy to pinpoint the coating technique that produces the best results for your application.

## How can you produce quality screens every time?

Once you establish the coating technique required for each application, you have to set stencil tolerances and determine the accuracy required to repeat the coating process. For forgiving applications where stencil thickness and roughness is of little importance, such as coarse graphics on garments, set tolerances within a range that does not affect the exposure time of the screens. A tolerance of  $\pm 3$  microns in stencil thickness should be fine. Other applications where the stencil thickness is an integral part of controlling the ink laydown, as in four-color-process printing with UV ink, require much closer tolerances in both stencil thickness and Rz value. For these applications, tolerances of  $\pm 1$  micron for stencil thickness and Rz value are required.

To achieve target tolerances with manual coating, you have to follow a few rules. Ideally, only one person should coat the screens and should produce them in batches. Careful preparation of the screen, including haze removing and degreasing, prior to coating will decrease the chance of problems such as pinholing and fisheyes. The coating trough should be kept clean and should be washed out at least once each day. Emulsion that thickens in the trough needs to be discarded or used as blockout. The trough should also have a large fill volume and provide both a sharp and a round edge. The round edge should be used for wet-on-wet coating; the sharp side for face coats (wet-on-dry coats applied to the substrate side of the screen). The main parameters that influence coating results are as follows:

- trough pressure
- trough fill level
- coating speed
- trough angle
- coating sequence
- number of coats
- drying position

Any one of these variables can influence coating quality. The actual outcome depends on the percentage of open area in the mesh, the mesh thickness, and the coating thickness. Meshes with large openings, such as coarse mesh counts, are more likely to be affected by these variables. Fine mesh counts and meshes with smaller openings are more forgiving and will not exhibit the same sensitivity.

During coating, the emulsion is transferred into and through the mesh by the combined pushing action of the coating-trough edge and flowing of the liquid emulsion due to gravity. Let's see how each of the previous variables affects the final outcome.

## Coating-trough pressure

The pressure of the trough against the screen needs to be strong enough to maintain a close contact between mesh and coater edge. Too much pressure does not bear any positive results, but too little pressure will most likely produce a thicker emulsion deposit in the center of the screen, where the counter-tension of the mesh is the smallest. Uneven emulsion thickness will also result if the pressure from one end of the trough to the other is unequal.

## Trough fill level

The fill level of the coating trough influences the amount of emulsion that can flow into the mesh. The greater the fill level, the more emulsion that will contact the mesh during coating. Similar to the pressure that builds up behind a water dam, the more liquid emulsion that pushes against the mesh, the higher the hydrostatic pressure. A low fill level results in lower emulsion buildup because less pressure builds against the screen; a higher fill level will result in a greater emulsion buildup on the opposite side of the screen. Keeping the fill level as constant as possible greatly improves repeatability and helps avoid uneven coating thickness from the bottom of the screen to the top.

## Coating speed

The coating speed influences the amount of time the emulsion has to flow into the mesh during the coating stroke. With a slower coating speed, the column of emulsion standing against the mesh has more time to flow than during a fast coating pass. The influence of coating speed is also affected by the fill level, since gravity is the driving force behind both variables.

## Trough angle

The coating trough angle is also important since a change in angle typically changes the amount of emulsion contacting the mesh. Most coating troughs have end caps that are shaped so that they provide a certain angle with the mesh when tilted forward. This angle needs to be constant during the entire length of the stroke and should be repeated from coating to coating. The most critical point in the coating process is the upper end of the coating stroke, where we tend to tilt the coating trough back in order to cut off the emulsion.

## Coating sequence

The sequence for wet-on-wet coating always starts on the substrate side of the screen with enough coats to fill the mesh completely with emulsion. Apply subsequent coats to the squeegee side of the screen to allow the emulsion to flow through the mesh and accumulate on the substrate side, where you require the emulsion buildup. After the wet-on-wet coatings have dried, apply additional coats only to the substrate side. These wet-on-dry coats, with intermediate drying, should not add much emulsion buildup, but should provide a smoother stencil surface, which ensures a better seal between the substrate and stencil.

## Number of coats

Increasing the number of wet-on-wet coats on the squeegee side will result in a thicker emulsion deposit on the substrate side. Adding more wet-on-dry coats will primarily lower the stencil

roughness and add very little to the emulsion thickness. However, proper wet-on-dry coating depends on using good coating pressure and a sharp-edged coater. The sharp edge will cut away any excessive emulsion from the top of the stencil and will only fill depressions on the surface.

## **Drying position**

Drying position is important, especially for screens with thicker emulsion buildup and large mesh openings. Once again, gravity does its duty by pulling the emulsion downwards. You should dry coated screens with the substrate side facing down to keep the emulsion on the substrate side. If you dry the screen with the substrate side facing up, the emulsion will flow back through the mesh and end up on the squeegee side.

Taking these parameters into consideration helps to increase the repeatability and tolerance in manual screen coating. And the ability to vary any of these adjustments makes it possible for us to create a broad range of stencil profiles.

Manual coating for high-tolerance printing applications requires a different coating technique. This is particularly true for process-color printing, where a change in stencil thickness of only 3 microns can change the colors visibly. With manual coating, high-tolerance stencils can be achieved by using smaller frames and applying a thin base coating followed by several face coats with intermediate drying in between. This allows you to measure the stencil thickness after each coat and add as many coats as needed to build up the stencil to the desired thickness.

However, the best option for achieving close-tolerance stencils is to use automatic coating equipment. Coating machines are available for less than \$20,000, and the improved repeatability they provide is drastic. Tolerances of  $\pm 0.5$  micron are possible, and the same result can easily be repeated.

Higher-priced models include features for automatically applying face coats with integrated drying between coatings. Those machines also offer storage programs to record and save all coating parameters, including the number of coats, coating speed, drying times, and face coats. The ability to fine-tune these coating parameters enables you to optimize the stencil for a given environment and press. By choosing different emulsions with various solids contents, flow characteristics, and resolution capabilities, you can create any kind of stencil on any given day. Coating machines not only take the human error out of the coating process, but they also allow untrained personnel to produce close-tolerance screens on a consistent basis.

## **Control is the key to quality screens**

Mastering stencilmaking with liquid direct emulsions can be difficult, if not impossible, unless you understand the function of the stencil in screen printing and the variables that affect stencil performance. To produce high-quality screens for a broad range of applications, you have to select the right mesh and emulsion, create test screens to determine the best coating procedure for each application, and employ the correct techniques in manual or mechanical coating.

Experience leads to consistency, and if you follow the guidelines I've provided below for every project you print, perfect screens will be your reward. Don't let stencilmaking determine the quality of your images. Decide on the quality you want, and then create stencils to achieve the results you expect.

## STENCILMAKING GUIDELINES

Guideline	Possible consequences if guideline is not followed	Applicable areas
For a particular mesh, the finest detail in the image should be no smaller in width than 2 x mesh opening + 2 x thread diameter.	Finer detail may result in blocking of the open stencil areas by mesh threads.	This is important when printing fine halftones, text, and line art.
The total stencil thickness (mesh + emulsion) should be no greater than 2 x width of finest image detail.	Greater stencil thickness will create a tunnel-like stencil opening where the amount of surface area in the stencil opening is greater than the contact area between the ink and substrate, resulting in insufficient ink release.	Affects fine-detail areas and image edge definition.
Reduce the amount of contact area in the stencil opening to improve ink release. Use thin thread meshes and emulsions with small particle size in combination with thin emulsion buildup to reduce the total area.	Has the same effect as thick emulsion buildup. Can also be caused by using a mesh with thick threads or a calendered mesh.	Affects process-color printing and fine-detail printing by influencing ink-deposit.
The stencil surface on the substrate side of the screen should be smooth enough to create a gasket-like seal between the stencil and substrate, which prevents ink from flowing underneath the stencil edge.	An insufficient seal between the substrate and stencil results in ink smearing, which causes unsharp images, sawtoothing, and dot gain.	Any type of application may suffer in quality, with the exception of prints on highly absorbent materials.
The lower the viscosity of the ink and the smaller its pigment particle size, the smoother the stencil surface needs to be.	When using inks with high flow, a rough stencil surface can lead to ink flowing beneath stencil edges.	Printing with glossy inks on nonabsorbent substrates, such as CDs.
The combined roughness (Rz value) of the substrate + the stencil should not exceed 15 microns.	A rough surface creates a poor seal between the stencil and substrate, which results in ink flowing underneath the stencil.	Printing on any nonabsorbent substrates, especially when using inks with high flow characteristics.
A matte-finish, thixotropic ink is likely to produce a better print because it doesn't flow after it has been transferred to the substrate.	Inks that tend to flow out after printing can lead to reduced print sharpness.	Any application that requires printing of halftones.