

Understanding Mesh Geometry, Stencil Resolution, and Measuring Systems for Quality Control

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Measuring Systems for Stencil Quality

Would you run a bakery without teaspoons and measuring cups? Here are five basic tools for measuring and controlling stencil quality in the screen room.

Quality Control Starts with Basic Tools

In the stenciling process, you need to measure and control five variables for consistency in order to obtain repeatable stencil quality:

1. **Moisture in the stencil during exposure**
2. **Thickness of the coating**
3. **Smoothness of the coating**
4. **Complete hardening of the stencil**
5. **Stencil resolution, mesh bridging and edge definition**

For each of the five variables, we have a specific tool with which to measure them: a humidity and temperature gauge, a thickness gauge, a profilometer, an exposure calculator and a microscope.



Measuring Humidity and Temperature

The humidity and temperature gauge, or hygrometer/thermometer, is a basic tool that is used in screen drying and storage rooms to measure relative humidity (RH) and temperature. Since typical stencil systems are affected by both humidity and temperature, this tool is essential for every screen department.

To achieve full performance potential of the stencil, the coated, but not exposed, screen should be dried in an environment with an RH below 50 percent and a temperature around 100 degrees Fahrenheit (F). If the use of drying cabinets is not an option at least raise the temperature of the room. Warm air can hold more moisture than the same volume of cool air. This will help to draw the water out of the coating. Use of heaters and dehumidifiers will help obtain an ideal balance of RH and temperature.

Considering the low cost for this measuring instrument, about \$45 purchased from a supply catalog, you have no excuse for not having a hygrometer/thermometer in the screen room.

Monitoring Stencil Thickness

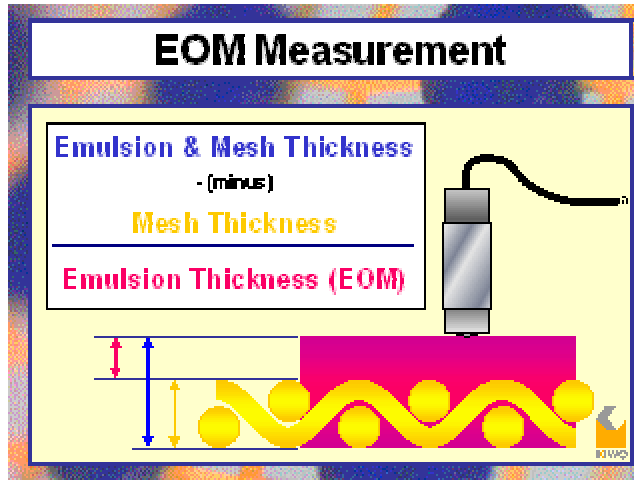
Variances in stencil thickness affect print quality considerably. You should check stencil thickness regularly unless you are using an automatic coating machine and have established coating techniques for a specific machine, emulsion, and mesh configuration. For shops that manually coat their screens, a measuring device such as a thickness gauge is a major element in controlling stencil quality.

Time and experience have given us two basic recommendations for the emulsion build-up in relation to mesh thickness. Using these thicknesses in approximate applications should provide good print quality:

1. For general printing; that is non-ultraviolet (UV) ink applications and jobs that do not require extreme detail. An emulsion build up of approximately 20 percent of the mesh thickness usually provides excellent print resolution and edge definition.

For example: if the mesh thickness is 50 microns, the emulsion build-up above mesh should be 10 microns. A measurement of 20 percent EMR (emulsion over mesh ratio) provides enough emulsion build-up on the print side to effectively lift the threads off the surface of the substrate at the shoulder of the print. This will help reduce any loss of printed image by allowing the ink to fill the entire image area. Edge definition will be greatly improved. A minimum of 10 microns is usually recommended.

2. Applications involving fine detail, halftone/4 color process and UV printing require thinner overall stencil thickness. Approximately 10 percent EMR is recommended, or a minimum of four to five microns emulsion over mesh (EOM). Using this target thickness will give the stencil just enough relief from the mesh on the substrate side, as mentioned earlier, but will reduce total screen thickness (mesh plus emulsion) so very fine detail can release from it without bleeding.



The following applies to both rules: If the emulsion coating is too thin, it will not provide a proper gasket seal. The ink will bleed underneath the stencil. This will cause the print to have rough looking edges (saw-toothing). Other symptoms of inadequate emulsion thickness include smeared images, dot loss in the highlights and dot gain in the shadows.

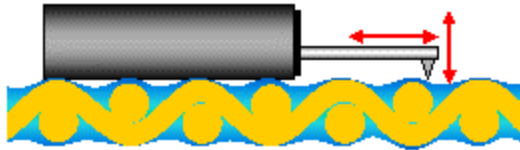
In the case of too high emulsion build-up, the print shoulder will have too high of a vertical wall or column, and the ink may or may not completely fill into this area. If the ink doesn't fill the area, the resulting print will show voids. If the ink does actually fill the column it may not release properly during printing. Even when the ink does release, too much ink may deposit into the image.

In any case, emulsion thickness is a critical factor in maintaining good stencil quality and represents an area that needs to be controlled. Changes in thickness may lead to color shifting, poor edge definition, smearing and many other problems on the press.

Smo-o-o-thing Out the Rough Edges

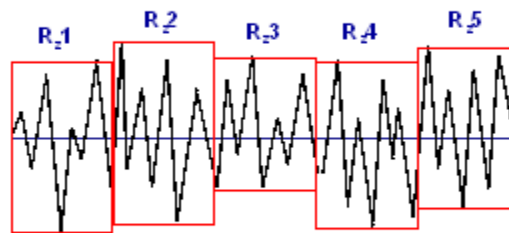
A profilometer measures the roughness of the dried emulsion surface on the substrate side of the screen. The instrument displays the average of the difference between the five highest and the five lowest points measured. This is called Rz. It can also print out a profile of this measurement. A smooth emulsion surface is preferred to provide the best possible gasket seal between substrate and stencil. A good seal will produce a very sharp printed image with the most uniform ink deposit. Additionally, a profilometer can be used to measure the roughness on non-textile substrates.

Roughness Measurement



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

Definition of R_z Value



$$R_z = \frac{(R_{z1} + R_{z2} + R_{z3} + R_{z4} + R_{z5})}{5}$$

To obtain the sharpest printed image, a roughness (R_z) value of less than 10 microns is desirable for the stencil. More specifically, when combining the R_z value of the stencil and the R_z of the substrate, a value of 12 to 15 microns or less is ideal. If the R_z value is higher or the stencil rougher, the ink is likely to flow underneath the stencil edge, causing saw-toothing and smearing the print.

Typically the R_z value changes with emulsion build-up. The thicker the stencil the smoother the surface, or the lower the R_z . The challenge is to reach target smoothness without making the emulsion build-up too thick.

Some applications such as fine detail, UV or four-color process printing, require very low emulsion build up but do need smoothness to achieve a sharp print. In these applications a profilometer is a very valuable tool. Once you establish a coating technique, you need to frequently measure the thickness of the coating and occasionally check the R_z value.

Determining the Right Exposure

A large percentage of screen printing problems are caused by wrong exposure of the stencil. A valuable tool for calculating and establishing proper exposure times is an exposure calculator.

Because they are so inexpensive you have absolutely no excuse for not having an exposure calculator or a similar test film in house.

Several types of exposure calculators are available. Most are film positives that have five or six elements of the same image. Each element has the same image so you can evaluate and compare at different exposure times.

Usually, all but one segment is covered with successively increasing filter densities to simulate different exposure times. This allows the operator to make a test screen using one long exposure (usually double the amount of time estimated to be the correct exposure) and still be able to see representations of six different exposure times.

For example: if we exposed a screen with an exposure calculator for six minutes, developed the screen and evaluated the stencil after drying, the segment identified by the number 0.5 would represent an exposure time of three minutes ($6 \text{ minutes} \times 0.5 = 3 \text{ minutes}$). The operator determines the correct exposure time by examining the different segments. Occasionally, the correct exposure time is a compromise between complete crosslinking of the emulsion (maximum durability) and maximum resolution.

Check the exposure time frequently, even if your exposure unit has an integrator. Considering the high percentage of problems that are caused by wrong exposure, an exposure-calculator is probably the most important one in the screen room.

Taking a Closer Look

A microscope is a magnification tool. Specifically, you want to use this tool to inspect the stencil at close range for the characteristics of an emulsion. A 50-60 power microscope works best for distinguishing and evaluating stencil resolution, mesh bridging and edge definition. Stencil resolution is the emulsion's ability to reproduce the finest detail correctly in size with the film positive. Resolution depends on the color and thickness of the mesh, the quality of the emulsion, and the quality of the light source. You can evaluate stencil resolution most accurately by using the microscope in conjunction with the fine detail of the exposure calculator. Mesh bridging is the emulsion's ability to reproduce the shape of an image correctly. You will be comparing the final shape with the shape of the image on the film positive. When the edge of an image travels close to the threads in the mesh, the emulsion has a tendency to jump over to the thread instead of maintaining the shape of the image on the film positive. If an emulsion has excellent mesh bridging characteristics, the image on the screen will stay true to the shape of the artwork.

Note: that we are talking about shape, not size. For example, an operator might produce a 10-point text that is correct in size, but fail to reproduce accurately the shape of the letter "O." A microscope will tell you that while the height of the letter and width of the line may be correct, the circle is distorted and the mesh bridging is substandard.

Edge definition describes how defined, smooth and perpendicular the printing edge of the stencil shoulder or wall is. While this characteristic is rather subtle, it is no less important than the other two. For this reason a 50-60 power magnification may be required to evaluate its quality accurately. Poor edge definition will adversely effect resolution and ink release or ink transfer. Emulsions with excellent edge definition will illustrate a clean, sharp edge at the print shoulder or stencil wall.

Tool Time

Five Tools can be used to measure and control the five variables that influence overall stencil quality. Some of those, the microscope, the hygrometer/thermometer and the exposure calculator are inexpensive and control the causes of many screen room problems.

Others such as the thickness gauge, for measuring stencil thickness, and profilometer, for measuring stencil smoothness, are more expensive but increase the level of control considerably. Specifically the thickness gauge is highly recommended when you ask for repeatable stencil quality.

Understanding Mesh Geometry and Stencil Resolution

To understand mesh geometry and stencil resolution, first we must understand that the mesh and stencil must work in unison in order to print with the highest quality resolution; and second, they each have a unique function. Sometimes we get confused as to which role each is playing and how they may influence the printed product. Let's first take a look at each one separately, and then we will look at how the two relate.

Mesh Geometry

Mesh geometry is simply the three dimensional composition or structure of the mesh. There are two specific characteristics which influence the geometry of the mesh: mesh count (threads per inch) and thread diameter. This could also be called fabric mass. Spacing and diameter of threads also determine size of the mesh opening, mesh thickness, percentage of open area, and fabric pitch (crimp angle of the thread). The reason for selection-specific mesh count goes beyond how much ink you want to deposit onto the substrate.

To provide screen printers with the widest selection of mesh choices to satisfy virtually any printing requirement, mesh manufacturers can provide a variety of thread diameters per each mesh count. Too many choices may confuse a printer trying to select the correct mesh for the job.

Stencil Resolution

Resolution can be classified three ways:

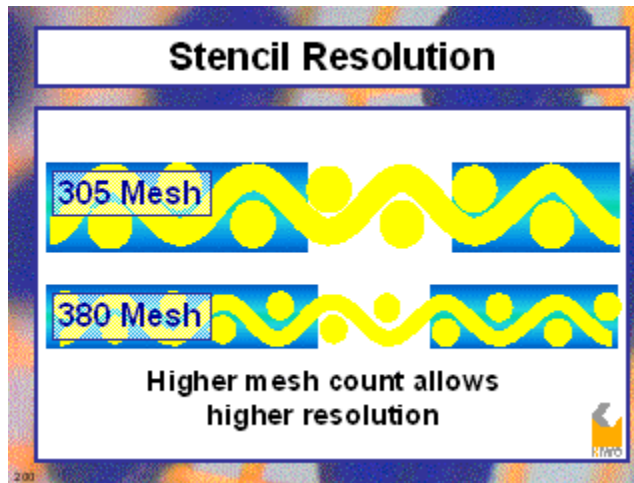
1. **Chemical resolution** is the ability of the photographic emulsion to reproduce fine lines usually represented by the width of the finest positive and negative lines it can resolve.
2. **Stencil resolution** is the ability to accurately reproduce fine detail correct in size on the exposed screen.
3. **Printed resolution** is the ability to reproduce fine detail correct in size on the substrate.

Today's technology gives quality emulsions the ability to resolve lines as small as 4 microns. This would be the chemical resolution of a particular emulsion. Chemical resolution is the only classification that is not influenced by mesh, but by chemistry of the emulsion and its particle size. Chemical resolution is evaluated by exposing an emulsion film, similar to exposing an indirect film prior to mounting the film onto the mesh. The mesh directly influences the other two classifications.

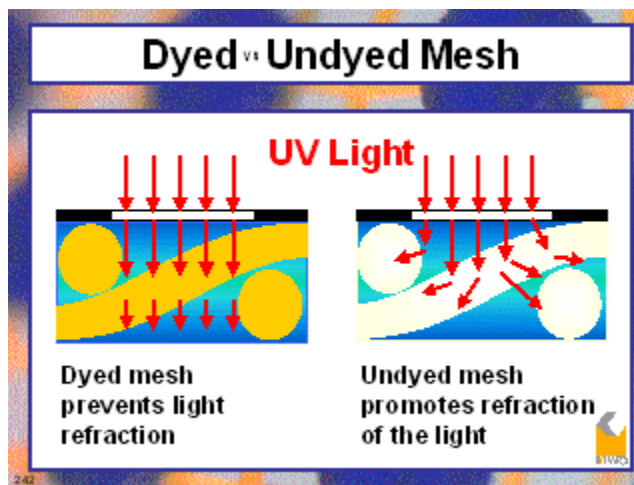
Relation Between Mesh and Resolution

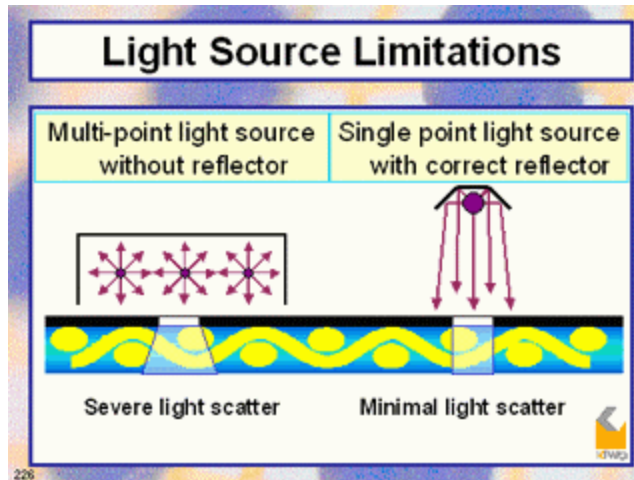
Mesh adds thickness and light refraction to the equation. Mesh thickness, mass and color, can limit the ability of the emulsion to resolve fine lines. The thicker the mesh, the thicker the emulsion

coating required to encapsulate the mesh and form a stencil with a smooth stencil surface (Rz-value). Thinner mesh is usually easier to coat, and provides a smoother stencil at a given thickness. The thicker the total stencil thickness, the greater the chance for light refraction within the stencil, which closes in the fine detail.



Light refraction and reflection within the mesh is influenced by mesh mass, mesh color and the angle at which light falls onto the screen during exposure. A white mesh reflects light and can never produce the same resolution as dyed fabric, which adsorbs reflected light, thus increasing stencil resolution. Higher thread mass also means increased light reflection leading to less resolution. The exposure unit itself can further limit stencil resolution through diffuse light output. On one hand, mesh interferes with stencil resolution as mentioned above and by the threads blocking very fine detail or causing the stencil to inaccurately reproduce the desired image.





On the other hand, we need a relatively high number of threads in the mesh to be able to support very small emulsion dots and fine lines. If the dots are smaller than the mesh opening, some of them will simply fall through the mesh. Conversely, threads can block the negative dot if it is too small.

This is where having a choice of thread diameters becomes important. Selecting a mesh with the thinnest available thread for that particular mesh count will provide the best chance of achieving the finest possible resolution. A thinner thread will reduce fabric thickness and thread interference without jeopardizing opacity and ink transfer. In fact, ink transfer is improved. A thinner thread increases the mesh opening and percentage of open area.

For example, 380-mesh count with a standard thread diameter of 34 microns has a fabric thickness of 55 microns, a mesh opening of 23 microns, and 12.1 percent open area. A 380 mesh with a thinner thread diameter of 31 microns has a fabric thickness of 49 microns (a 10.9 percent reduction), a mesh opening of 32 microns (a 28 percent increase), and a 23.3 percent open area (a 92.6 percent increase). These specifications are for PeCap LE meshes. Other mesh manufacturers may vary slightly. The 380-31 mesh will hold more ink despite being a thinner mesh and having a lower profile.

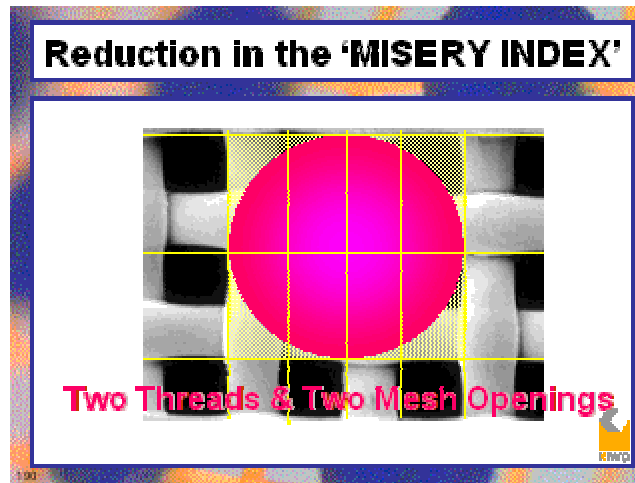
Recommendations

Using plain weave, low elongation mesh with the thinnest thread diameters will enable you to achieve the finest possible stencil resolution. This recommendation offers these distinct advantages:

1. a smoother surface structure which provides for a smoother stencil and easier coating techniques to achieve that smooth stencil,
2. reduced thread mass and increased open area which means less mesh interference to disturb or distort the image, and
3. thinner fabric thickness which makes printing easier because it allows ink to release from the screen easier and with more efficient ink transfer. Be aware you do sacrifice fabric strength for resolution. When opting for thinner threads, low elongation fabrics should be used, as they can hold higher tension values and have higher fabric strength.

If possible, the finest line or smallest dot printed should be as large as two mesh openings plus two thread diameters combined, or have a width twice the size of the total screen thickness (mesh and stencil). That will improve ink transfer to the substrate, as the ink can attach to a larger surface area

on the substrate, and that attachment pulls it free from the stencil. If the smallest detail is smaller than this, the ink sits in a high column similar to a tunnel, clinging to a large surface area.



A thicker stencil not only increases the surface area in the stencil, but large particles in the emulsion increase the surface area in the ink tunnel. This increases friction on ink flow. You will see easier ink release from the stencil if the emulsion has small particle size, allowing higher print resolution.

Choose a mesh that allows a thin overall screen and an emulsion with small particle size and a chemistry that allows high resolution. This combination, coated correctly and exposed with a high-resolution lamp will provide the best possible printed detail.

Conclusion

When striving to achieve the highest possible resolution you must consider all aspects of stencil making. This includes chemistry of the emulsion, type of screen room equipment and mesh characteristics. You cannot expect the emulsion to perform to its full potential if the mesh or equipment is limiting.