Intermediate

by Dave Dennings

Calculate Exposure

The compromise between resistance and resolution

Proper stencil exposure can be described as the point at which the emulsion reaches a synergistic balance between resistance and resolution. Proper exposure is dynamic in nature, as it fluctuates with printing requirements, and the quality and consistency not only of the artwork and screen, but also of the equipment used to generate the art and the screen. Environmental conditions constitute another dynamic force in play. Understanding how each of these variables impact proper exposure helps establish mechanisms for controlling them. Likewise, this improves the ability to tighten production parameters, leading to higher-quality and more consistent product reliability. Properly-cured emulsion also solves common stencil-related problems like excessive pinholes, stencil breakdown, reclaiming difficulties and emulsion stains.

Since proper exposure is predicated on dynamic variables, it stands to reason that frequent exposure calibrations are required to maintain exposure control and to assure quality control. They should be done for each mesh count and whenever changing mesh, emulsion, coating technique, exposure lamps and distance. Moreover, proper exposure plays an important role in one's ability to print with challenging media, such as aggressive printable adhesives and solvent-based inks, abrasive ceramic and glass frit inks, as well as water-based and discharge inks. This report will look at the best way to determine proper exposure and some pitfalls to avoid when doing so.

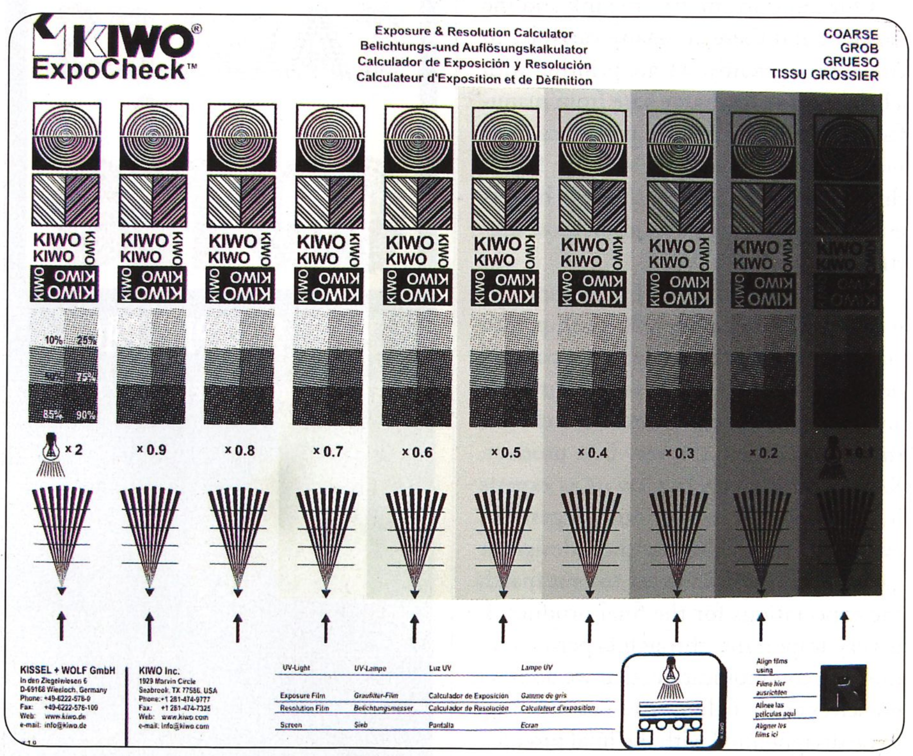

Figure 1: Exposure calculators consist of a resolution film—a test pattern comprised of concentric circles, horizontal and vertical lines, halftones and text. This pattern is repeated up to 10 times so objective observation can be made between the series of exposures. Each repeated pattern is referred to as an exposure step. Overlaying each exposure step is the exposure test film, comprised of a series of filters progressing in density that effectively provide a series of exposures. (All images courtesy the author)

Determining proper exposure involves evaluating stencils created using a series of varying exposure times, which provides the ability to determine the best balance between its hardness (durability) and its copying properties (resolution, mesh bridging and edge definition). Using commercially-available exposure calculators is the easiest way to do this.

Exposure calculators consist of two primary components: a resolution film and an exposure test film. The resolution film incorporates common test pattern images comprised of concentric circles, horizontal and vertical lines, halftones and text. This pattern is *stepped* (repeated) up to 10 times in order to make an objective observation between the series of exposures.

The beauty of the calculator is it eliminates the need to make a series of exposures; instead only one very long exposure is made and the calculator takes care of the rest. Each repeated pattern is referred to as an exposure step. The exposure test film, comprised of a series of filters progressing in density (see **Fig. 1**), overlays each exposure step. These filters effectively provide a series of exposures.

Determining the exposure time to use for the test exposure is critical to using an exposure calculator correctly. The test exposure time should be twice the expected exposure. Expected exposure time could be that already employed, an estimate of the anticipated exposure based on experience, or exposure data obtained from the emulsion manufacturer.

The reason the expected exposure time needs to be doubled is because several exposure steps ranging from under- to overexposure are needed to properly identify

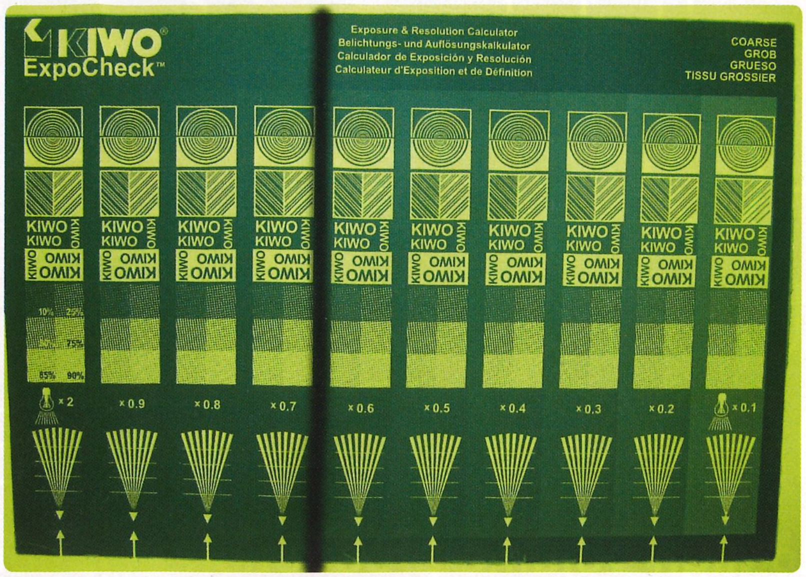

Figure 2: This exposure test shows a black line at the point where there is no rectangular filter covering the emulsion. All exposure steps left of the black line show no color variation between the facing arrows along the bottom of the stencil, while exposure steps right of the line do.

the step where no visible color variation is seen between adjoining steps or between adjacent filtered and unfiltered portions of the calculator. In other words, look at which step shows no visible appearance of the rectangular filter covering the emulsion (see **Fig. 2**). This completes step one of the two-step process of determining proper stencil exposure.

Color change controversy

There is a common misconception in the industry that color variation, or the point of "no color change," can only be used to gauge expose times of diazo-sensitized emulsions, but not pre-sensitized SBQ

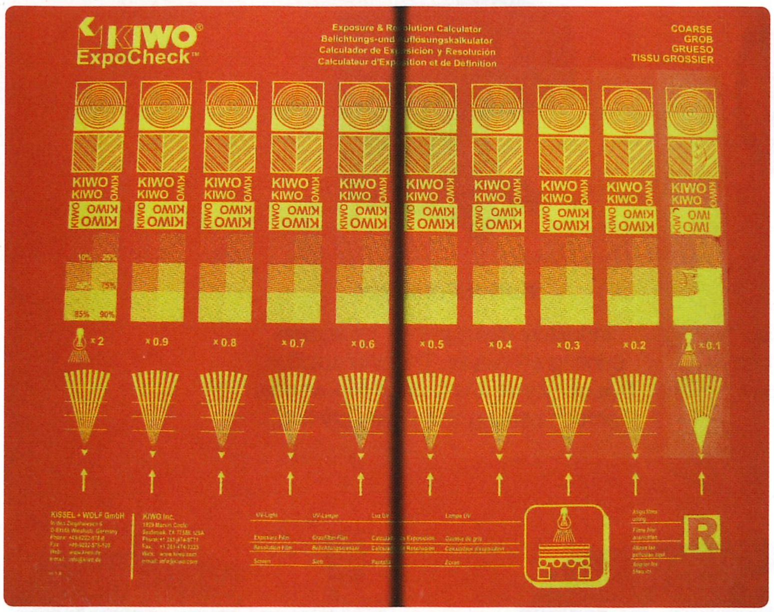

Figure 3: SBQ emulsions are more difficult to gauge because they are comprised of only one color. But there is a color shift attributed to density. Illustrated here in a red-pigmented SBQ emulsion; notice the changes from step to step as viewed from right to left.

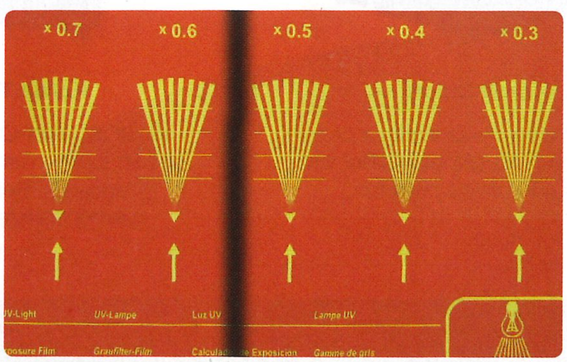

Figure 4: Each step has an associated number, seen here, that is used as the multiplier for calculating the representative exposure for that step. This number is multiplied by the time used to expose the calculator.

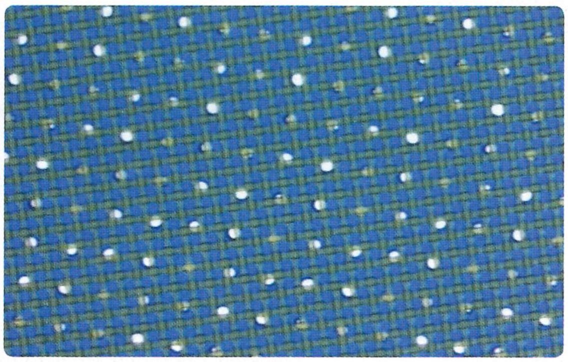

Figure 5: In this stenciled image of fine highlight dots, the emulsion resolved the dots. However, it doesn't look like it because the dots are too small to print properly; more than half of the dots are fully or partially blocked by the threads. Only the dots positioned directly over the mesh openings will print. This is a leading cause of regional moiré in highlight areas of the print.

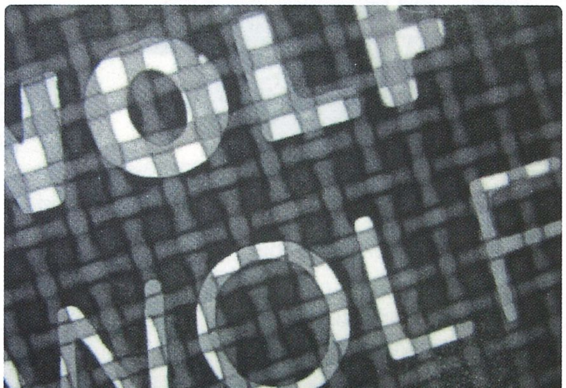

Figure 6: This is another example of poor art-to-mesh relationship as it relates to text. The letter F, although fully resolved by the emulsion, falls directly on a thread, while the letter L luckily falls between the threads. This case illustrates how choosing the wrong mesh count also causes problems. The mesh count here is a 156-64, which clearly is unable to support this fine detail. This artwork requires a much finer mesh count.

emulsions (a.k.a. pure photopolymers). This originates from the fact diazo-sensitized emulsions consist of two colors; yellow (the color of diazo) and whatever pigment is used to color the emulsion (blue, red, violet, etc.). As these emulsions cure, the yellow cast from the diazo wanes as it nears full exposure, thus the color change. Although SBQ emulsions are more difficult to gauge because they are comprised of only one color (and, technically speaking, there cannot be a "color" change if only one color is present), there is a color shift attributed to density (see **Fig. 3**). The color changes because emulsion washes away from the squeegee side of the screen when developing the under-exposed steps, leaving a thin, lighter-colored stencil. When the color stops changing, the emulsion is adequately cured (because no emulsion washes away).

Step two

Regardless, each step has an associated number (see **Fig. 4**) that is used as the multiplier for calculating the exposure for that step. Multiply this number by the time used to expose the calculator. For example, if 60 seconds represents the time used to expose the calculator and 0.6 represents the point of no color change, then 36 seconds (60 x 0.6) represents the exposure time of that step. The result is the recommended exposure time to properly harden the emulsion and achieve very good resistance.

Identifying where no color change occurs can be done immediately after developing the screen while it is wet or after the screen dries. More steps of visible color change occur when evaluating a damp screen, thus reflecting a longer exposure time. Fewer steps of visible color change occur when viewing a dry screen. The difference between a wet and a dry screen in terms of calculation is that a wet screen is slightly swollen from absorbing water, which makes observing slight color variations easier.

Arguments can be made supporting both methods. The size of the job and/or how detailed the artwork is may help determine the method to use. However, the type of ink required for the job is the clear determining factor for me. When the job calls for characteristically-challenging or aggressive inks, I use a wet screen to select and calculate exposures. Textile printers using water-based and discharge inks, for example, should choose their exposure times from a wet screen to enhance screen longevity. Longer exposure times offer extra insurance especially for long runs.

Expose in terms of production requirements

As mentioned earlier, determining the point of no color change is just the first step of a two-step process for calibrating proper exposure. Step two is determining whether the stencil's copying properties (resolution, mesh bridging and edge definition) meet or exceed production requirements. Make sure to evaluate the appropriate exposure step through the first part of this process.

A common mistake in evaluating copying properties, especially resolution, is making an assessment based on whether or not the finest details of the exposure calculator are open. Use this as a gauge only if art details are as fine. Do not sacrifice the stencil's durability by selecting a step with a shorter exposure time in order to capture details you will not print in production.

Another common mistake is trying to capture details that are not even printable. Much of the halftone artwork I see today contains some highlight and shadow dots that are too small to be printed successfully. You may be able to resolve most of them in the screen; even so, they will not print properly, if at all. Unknowingly, but innocently, the screen department adjusts exposure times lower in an effort to open up every highlight dot on the film positive. This is one of the root causes why the vast majority of screen printers under expose screens, then suffer from the consequences.

Underexposure Exposed

Far too often printers err on the side of shorter exposures; not always because they are pressed for time. Often times it is attributed to one or more of the following:

- Film positives lack density (poor D-max)
- Using inappropriate mesh count for the detail involved
- Using stencils that are too thick
- Printing halftones or process color from linearly-output film
- Using exposure units with poor vacuum drawdown
- Starting exposure before adequate vacuum is reached
- Using poorly designed exposure systems

Get these variables under control and you will be amazed by the amount of processing latitude you have and how forgiving the process becomes.

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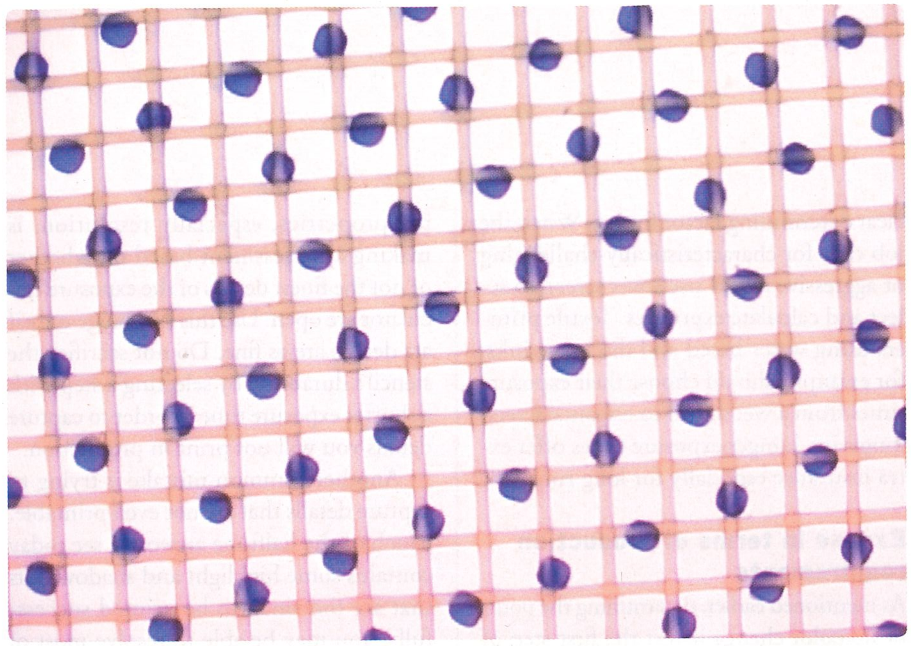

Figure 7: This example shows where the emulsion resolved the shadow dots. However, because the dots are so small, the print from this stencil will result in solid 100 percent coverage as a result of dot gain once the ink levels out, leaving no shadow detail.

Theory in action

Take, for example, the stenciled image of fine highlight dots in **Fig. 5**. The emulsion resolved the dots, but it doesn't appear that way because the dots are too small to print properly. More than half of the dots are fully or partially blocked by the threads. Only the dots positioned directly over the mesh openings will print. This is a leading cause of regional moiré in highlight areas of the print.

Fig. 6 shows poor art-to-mesh relationship as it relates to text. In this example, you see that the letter F, although fully resolved by the emulsion, falls directly on a thread. The letter L luckily falls in between the threads. This case illustrates how choosing the wrong mesh count also causes problems. The mesh count used is a 156-64, which clearly is unable to support this fine detail. This artwork requires a much finer mesh count.

It is in situations such as in **Fig. 5** that throws off the balance between stencil durability and resolution. It becomes skewed towards the resolution side, unjustly sacrificing durability. What can we do to circumvent this from happening?

To help avoid falling into the trap of under-exposing screens and suffering from printing inconsistencies, control the artwork so the finest detail width is equal to the width of at least two mesh openings plus one thread; or twice the screen thickness (mesh + emulsion). Of course this is not always possible, but the closer you adhere to this rule, the less likely you will be to encounter printing problems caused by underexposed screens.

Understanding the art-to-mesh relationship and how it impacts not only printing but also your process.

Now take a look at another example in **Fig. 7**, this time looking at shadow dots where the emulsion, again, resolved the dots. Because the dots are so small, the print from this stencil will result in solid 100 percent coverage caused by dot gain once the ink levels-out, leaving no shadow detail.

Understanding the art-to-mesh relationship and how it impacts not only printing but also your process. This knowledge aids in making more informed decisions as they relate to artwork limitations, mesh selection and screen making. PW