UNDERSTANDING EMULSIONS AND STENCIL EXPOSURE

(OR OPTIMIZING EXPOSURE OF DIRECT STENCILS)

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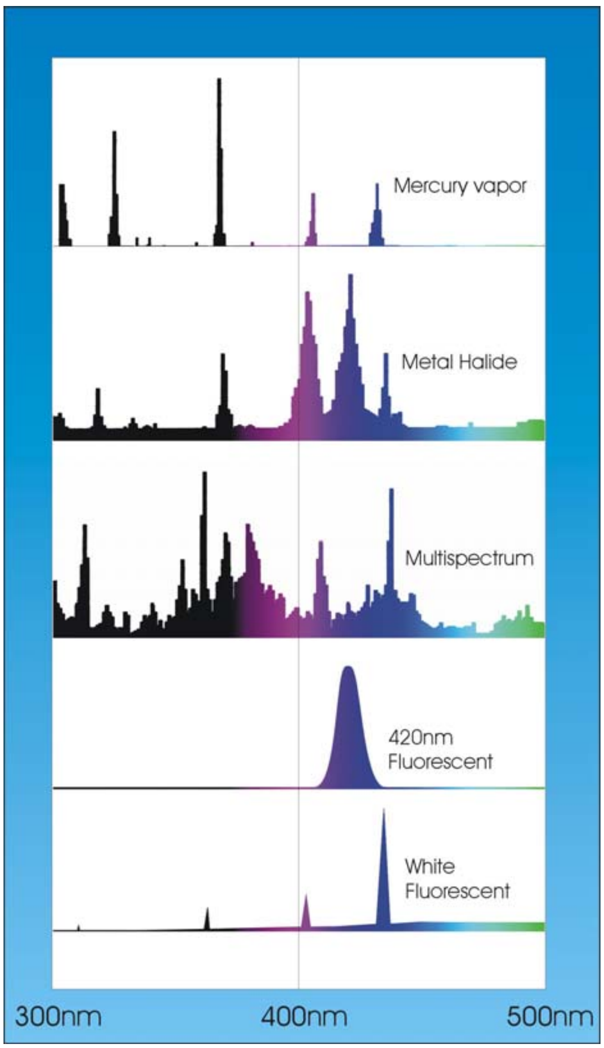
Understanding emulsions and stencil exposure (or optimizing exposure of direct stencils).

Up front, I have to admit that my motives for writing this article are purely selfish. As someone who toils daily in the manufacture of stencil systems, it is in my best interests to ensure that anyone who makes screens for a living is highly trained, knowledgeable, and best of all, qualified to troubleshoot problems. So, the aim of this article is to focus on some key variables that affect the correct exposure of direct emulsions and capillary films and to explain their influence. Then we will consider how to best evaluate optimum exposure for the different types of formulation that are used to manufacture these stencil systems. Finally we will touch upon some of the more practical aspects that are involved with producing quality screens on a daily basis.

Exposure lamps of many types are used to make screens and they exist with a wide variety of spectral output, geometry of light delivery and power. The first thing that must be established is how much of the useful spectral output falls in a range that is used by the stencil material being exposed. Only a fraction of the rated input power of a lamp is converted into output with the correct wavelengths that can harden a stencil. This is known as actinic light, with wavelengths corresponding to blue, violet and ultraviolet. As can be seen in Figure 1, metal halide, multispectrum and certain specialty fluorescent tubes produce light very rich in these wavelengths. Other types of bulb are not suitable for high quality stencil production.

Figure 1



If we consider the light sensitive chemistry that is used in direct emulsions and capillary films, then we have to deal with two categories. Diazo and dual-cure types can be grouped together, as it is the diazo sensitizer that mainly determines the length of exposure and the degree of latitude. Photopolymer emulsions and films employ a different sensitizer referred to as SBQ that will react much faster than diazo when exposed with the correct type of lamp and will therefore be treated separately.

Figure 2 shows the light absorption spectrum for diazo sensitizer, with its peak in the UV at 373nm, overlaid on the output spectrum for a metal halide bulb. Also shown is the sensitivity curve for diazo. As can be seen, the peak in sensitivity corresponds to the tail of absorption where light is still absorbed, but less strongly and is therefore more penetrating. More on this later when we examine optimum exposures and degree of latitude, but in short, metal halide bulbs, sometimes referred to as diazo or gallium lamps with their peak output in the 390-420 nanometer violet/blue range are the best choice for optimizing exposure of diazo or dual-cure emulsions and films.

Figure 3 shows the analogous situation when photopolymer products are exposed. In this case the maximum of the absorption peak is at a shorter UV wavelength of 342nm. This shifts the peak of sensitivity into the 360-390 nanometer UV range where multispectrum bulbs, also referred to as trimetal halide or sometimes as iron lamps have their strongest output. The result is that multispectrum bulbs are the best choice for optimizing exposure of photopolymer emulsions and films.

Figure 2

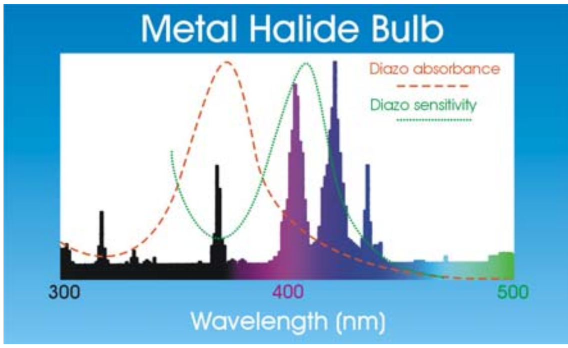
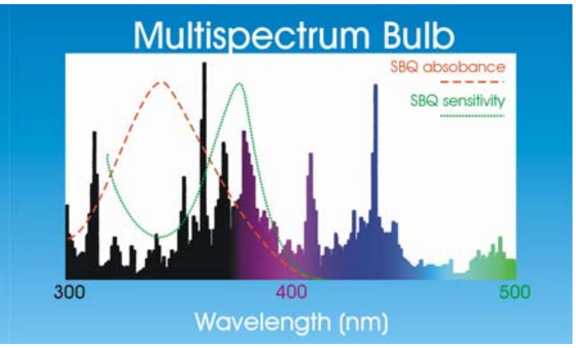


Figure 3



This wavelength dependence of sensitivity of the two types of photosensitive systems results in a somewhat complicated relationship in their relative photographic speeds. As an example, take a photopolymer emulsion that requires only 20% of the exposure time of a diazo or dual-cure if used on an exposure system with a multispectrum bulb.

With a metal halide bulb, the photopolymer is less sensitive and slows down so that it now requires approximately 50% of the dual-cure exposure time. With 420nm fluorescent blue tubes, the longer wavelength output is so weakly absorbed by the photopolymer, that most of the light leaks right through and out the backside of the coating, with the result that the fast exposing photopolymer now requires about 75% of the dual-cure exposure time. White fluorescent tubes, with their very low UV output cause photopolymers to actually expose slower than most diazo or dual-cure products.

Don’t be fooled by a lack of resolution, under these or any other circumstances, into thinking that a stencil is well exposed or even overexposed. Image resolution is affected by too many other factors to be used as a guide for determining exposure time. For instance, a poor vacuum caused by a leaking seal or rip in the blanket can kill resolution, even at a fraction of the correct exposure time. Similarly, incompatible combinations, such as photopolymer emulsion, coated on white mesh, and exposed with a fluorescent tube exposure system should be avoided. Combining any two of these variables can yield acceptable results, but all three things together is a recipe for very low-resolution stencils.

Optimum exposure time is only determined by depth of cure of the stencil. Depending on the printing application, the required thickness for a stencil, meaning mesh plus emulsion, can range from tens to hundreds of microns. In order to minimize pinholes, premature stencil breakdown, soapy scum during developing that bleeds, dries in and can block the image, or at least worsens reclaiming, the stencil has to be fully cured through its full thickness.

There are various techniques that can be used to determine optimum exposure and perhaps the most well known is the use of an exposure calculator. A typical example is shown in Figure 4. It utilizes a series of increasingly dark neutral density filters, overlaid on a repeating design, and allows multiple simultaneous exposures to be simulated, usually 100%, 70%, 50%, 33% and 25%.

After processing, the finished stencil has to be evaluated in a backlit environment by the color change method, and not for resolution. As can be seen in Figure 5, residual unused diazo shows up as a strong yellow undertone in the color of the stencil. The correct exposure is determined as the time taken for the diazo sensitizer, a yellow dye, to be completely bleached out. In a test situation, no yellow undertone should be seen on one of the middle sections of the calculator image. Once this has been achieved, the exposure factor for that part of the calculator is multiplied into the test exposure time, in order to find the optimum time. In an underexposure situation, the 100% exposure, or Factor 1, always looks correct, and the only thing this means is that another test with double the exposure time is needed in order to move the first completely bleached out section into the middle of the calculator.

Figure 4

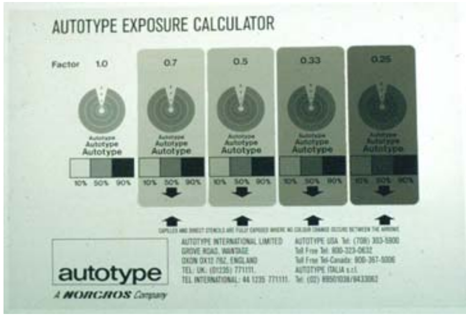
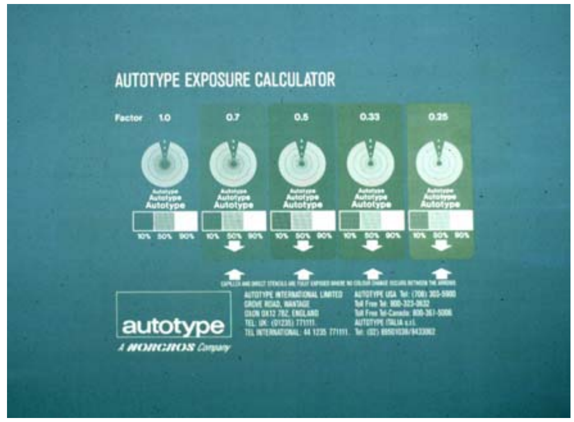


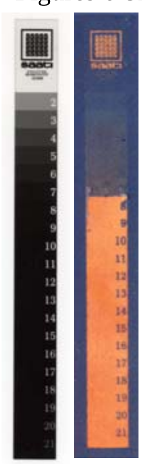
Figure 5



This type of exposure calculator works perfectly only for diazo emulsions. With dual-cures, there are often two separate color changes happening simultaneously, but with the extra dual-cure component color change being fainter but more persistent. The trick then becomes determining just when exactly did the diazo part stop changing color. With photopolymer stencils there is no color change, and although this type of exposure calculator may be useful for determining the degree of resolution available at several different exposure levels, it does not indicate the extent of cure.

An alternative method is the use of a grayscale sensitivity guide, an example of which is shown in Figure 6.

Figures 6 & 7



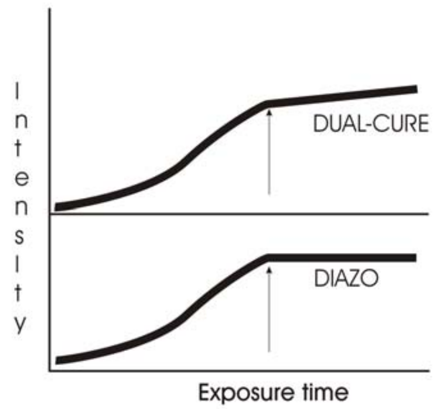
In this case there are 21 continuous tone steps, with a density increase of 0.15 between successive steps. It is not a halftone dot pattern. Interestingly, this 0.15 density increment is the same as that employed for the series of filters used on the traditional exposure calculator mentioned previously. With longer exposure times, higher numbers of steps are successfully hardened into the finished stencil, and if used correctly, this technique can be can be used to determine the optimum exposure with only one test.

In almost all cases, a solid step 7 after development indicates a correctly exposed stencil, as is shown in Figure 7.

If the initial test yields only five steps, then the exposure needs to be doubled. Six steps require an increase of 40% in exposure time. Eight steps indicates an overexposure situation and possible loss of detail in the stencil, although no doubt fewer pinholes due to scratches, dust etc. Exposure time should be reduced to 70% of the original. Nine steps indicate a double overexposure. The biggest advantage of this method is that it can be used to control the degree of cure of any type of stencil, diazo, dual-cure or photopolymer.

The last recommended method does not use a test film at all, instead it employs a digital radiometer to determine the point at which all the sensitizer in the coating has been used up. It works like this, the photocell with a 365nm filter is placed in the vacuum frame, behind the emulsion coating, and the exposure is started. At the beginning, due to the extremely high absorbance of the sensitizer, no light is able to reach the photocell and the radiometer registers a reading of zero. During the exposure, as sensitizer is used up, an increasing amount of light is measured that gradually levels off. This information can be displayed in a graph, and the optimum exposure is indicated by a rollover in the gradient that shows the increase in light intensity measured behind the stencil. An example of this is shown in Figure 8.

Figure 8



Diazo emulsions finish flat, but dual-cures display a lesser and longer lived gradient, due to the additional photochemistry that also complicates evaluations during the color change method. Unfortunately, this method does not work with photopolymer products. This is due to high absorption even at the end of the exposure process caused by residual sensitizer. More on this later when we discuss post exposure effects.

Now comes the tough part. In the real world, most of the time, it is impossible to create a perfectly exposed screen like the example shown in Figure 9. The main reason is that light intensity is not even over the whole screen. With a typical point light source, that is best for reproducing good detail, unless the lamp is pulled back very far from the vacuum frame, then the intensity of the light in the corners of the screen will be significantly less than in the center. This leads to the cure profile shown in Figure 10. There are two scenarios shown here for the underexposed regions of the screen. In one case a bad bulb was used and the underexposure is concentrated at the foundation of the stencil where it adheres to the fabric. In the second case, although the stencil is equally underexposed, increased penetration by the light has resulted in a more even cure. One result of using a good bulb is a stencil with much wider exposure latitude that is evidenced by fewer pinholes and less scumming during development. It should be noted at this point, that when a doped bulb such as metal halide gets old and weak, then its spectrum gets closer to that of a mercury vapor bulb. The longer wavelength intensity drops, while the UV output remains relatively constant.

Figure 9

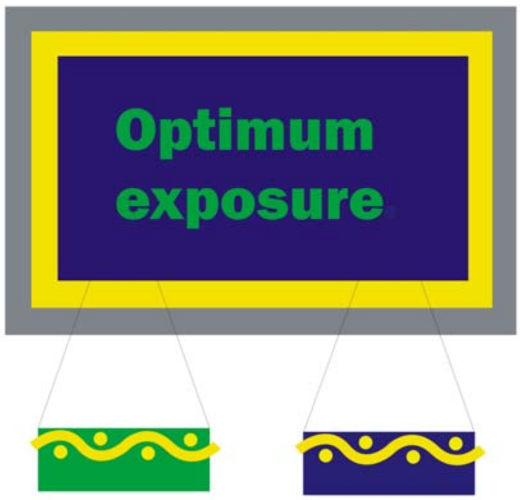
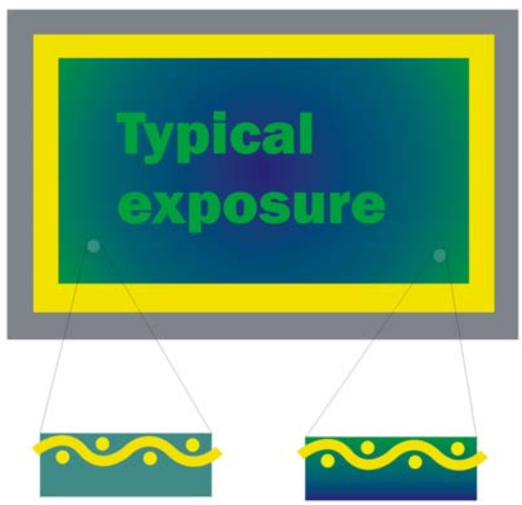
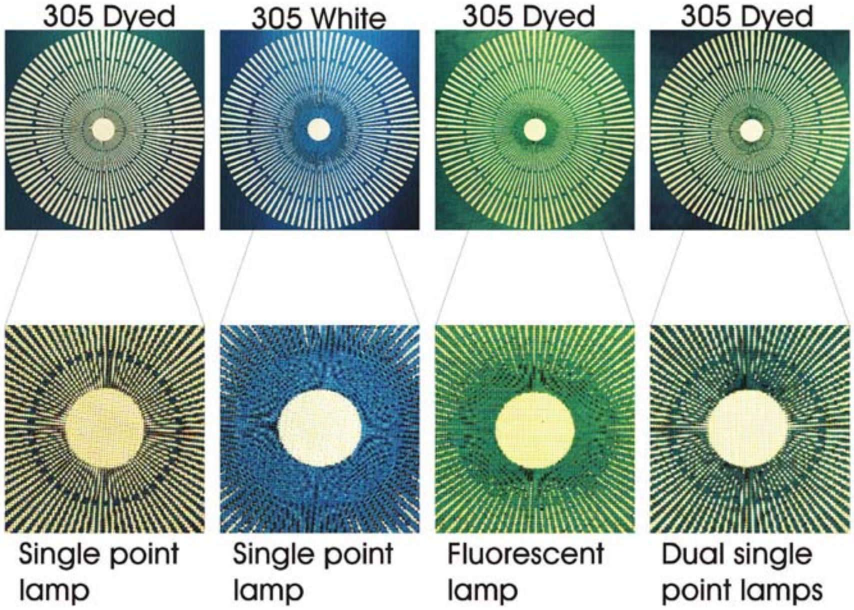


Figure 10



Fluorescent exposure systems do provide more uniform coverage for an even cure, but can lead to a compromise in detail, particularly with fine halftones. It is difficult for the film positive to cast a sharp shadow on the emulsion when lit from all angles. Care also has to be taken when exposing large screens with more than one exposure lamp to give wider coverage. The area of overlap between the lamps can suffer a slight loss of detail, usually in the vertical direction when the lamps are side by side. Highly magnified examples of this loss with fine detail on 305 mesh are shown in Figure 11.

Figure 11



Now if I can assume at this point that we have arrived in the comfort zone. Optimum exposures have been set for all of our mesh count/color/coating combinations. We have adequately exposed screens with all the detail we need, and none of the pinholes we don't. Now, how do we keep it that way? This is where our integrator comes in and compensates by increasing exposure time when the bulb gets old, or the power browns out. It is important to match the photocell filter to the sensitivity curve of emulsion, since a disproportionate amount of the stencil hardening that occurs is caused by those wavelengths that are most penetrating but still usefully absorbed. For instance, a narrow pass 365nm UV filter used with a metal halide bulb makes the integrator blind to fluctuations in the longer wavelength output that makes this bulb so effective in exposing diazo and dual-cure products.

Now I would like to mention the benefits of post exposure, which can be a useful technique for improving the resistance properties of a stencil. The benefits offered depend on the type of emulsion used, and can be summarized as follows.

Diazo emulsion or film - When a diazo emulsion is underexposed, the developed and dried stencil retains a yellow undercast from the unused diazo. This partially exposed diazo does not wash out of the stencil during developing as it has already reacted with, and become attached to, the polymers and resins that make up the stencil. So after drying it is possible to re-expose the screen, bleach out the remaining diazo and further crosslink the stencil to improve its solvent or water resistance. However, it should be noted that depending on the degree of initial under-exposure, the final stencil, although fully chemically crosslinked, may only be a thin skin stuck to the substrate side of the screen- mesh. It will not be as durable and resistant to pinholes as a correctly exposed stencil, where the screen-mesh has been physically encapsulated front and back with hardened emulsion.

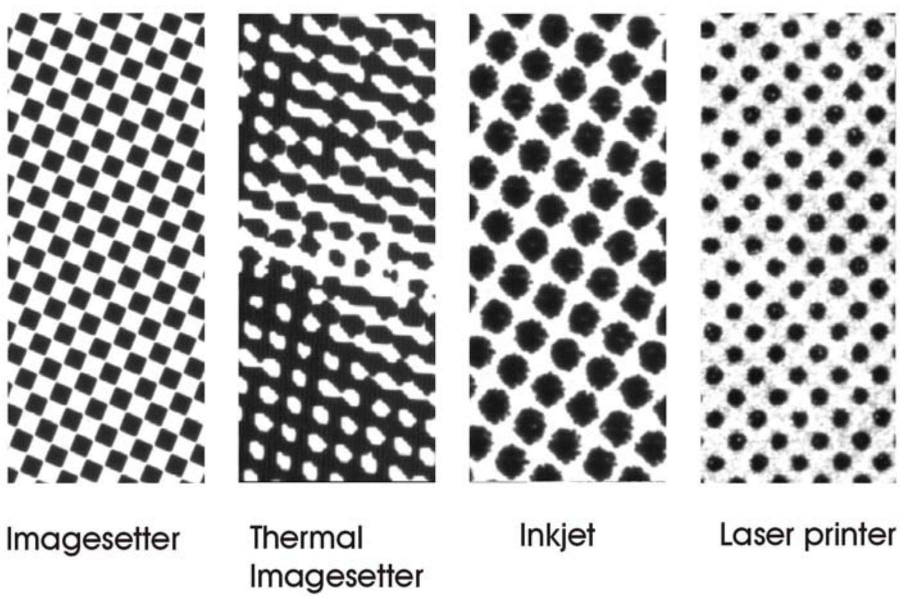
There is absolutely no benefit to exposing a screen made with correctly exposed diazo emulsion, since all the diazo is already used up.

Dual-cure emulsion or film - When under-exposed, the situation is the same as for a diazo emulsion in that the unreacted diazo can further crosslink the stencil on post- exposure and improve its solvent and water resistance. However, the difference is that even correctly exposed dual-cures can benefit from post exposure. The reason is that the secondary crosslinking system can be made to polymerize further, even after all the diazo is used up. This usually improves only the solvent resistance, and can also result in easier reclaiming, since the hardened polymers and resins are affected less by ink and solvents.

Photopolymer emulsion and film – Photopolymer emulsions benefit most of all from post-exposure. Unlike diazo, which can be used with 100% efficiency if the exposure time is long enough, photopolymer molecules can be very stubborn. Only a proportion of them reacts very fast, and are responsible for the short exposure times of photopolymer emulsions. The rest of the photopolymer molecules are not aligned correctly and can crosslink only with difficulty. In this case, increasing the exposure time causes a loss of resolution and detail with little payback in terms of improved stencil durability. However, the potential of this unused photopolymer can be realized with a post-exposure. The reason is that during development, when the stencil is wet, some of the unreacted molecules will re-align and be available for crosslinking the second time around, thus resulting in improved solvent and water resistance. In some cases, the improvement in water resistance can be dramatic.

Finally, I would like to mention the influence of the film positive on the exposure process, since image density and resolution of the film output device have a major bearing on stencil quality. High quality film positive output from an image setter will have a very low Dmin of around 0.05, i.e. the film is clear and transmits more than 90%. Image areas will be a dense black, with a Dmax of 3 or more and will stop at least 99.9% of the light. Various other types of output device are now in common use, and at the other end of the scale is laser toner on vellum. A Dmin of 0.3 sounds good until you realize it blocks 50% of the available light and requires the exposure time to be doubled. Dmax is probably around 1 which stops 90% of the light but, unfortunately lets through the other 10%. The use of a solvent spray or heat treatment to fuse the toner can increase density to 2, but this is barely adequate for any fine detail as 1% of the light penetrates the stencil and this can be enough to compromise washout. Thermal imagesetter and inkjet output generally have very good densities and can be exposed without concern for burning through.
One point to remember is that anytime that anything other than crystal clear film is used to expose screens, then exposure calculators or grayscale sensitivity guides need to be placed behind a sheet of this material when making an exposure test. Otherwise the correct exposure time that is determined from the test will always be an underexposure with a real film. Photomicrographs of halftones produced on a selection of output devices are shown in Figure 12, to enable a comparison of dot quality.

Figure 12



In conclusion then, we have evaluated the output of exposure lamps and tried to match up with the chemistry of stencil materials. We then considered some of the practical aspects of other variables that can impact the exposure process and affect overall stencil quality. If you make screens for a living, I hope there were some snippets here to make your job easier, or at least more satisfying. If you don't make screens on a regular basis, or any basis at all, then perhaps you will have enjoyed your reading experience so much that now you have to go burn one!

The end.