



HANDBOOK

Stencil Processing

How To Reduce Pinholes

CLEANLINESS/QUALITY CONTROL

One of the main causes of pinholes is specks of dirt, lint fibers, adhesive residue from tape, or any other kind of contamination that can get stuck on glass surfaces in the exposure frame, or to the artwork, or even the coated screen itself. Airborne contamination needs to be avoided during coating, drying and storage. This is important particularly while the emulsion surface is still wet.

Maintaining good housekeeping procedures should prevent any build-up of debris on the floors, drying racks, etc., which could be disturbed and then land on coated screens. Exposure frame glass should be kept spotless and positives should be cleaned and inspected before use, if necessary. Artwork which is badly scratched will cause pinholes, and should therefore be re-made. Likewise, deep scratches on the glass inside the vacuum frame will cause pinholes in your screens. If the glass is badly scratched, it should be replaced, or at least reversed so that the scratches do not cast a sharp shadow onto the emulsion during exposure.

EMULSION HANDLING

Bubbles in the emulsion that transfer onto the mesh during coating are a major cause of pinholes. Diazo and dual-cure emulsions need to be stirred during sensitizing with a broad flat paddle until a smooth and even consistency is obtained. If you beat the emulsion with a stick, then it will take ten times longer to enable the trapped air bubbles to escape. The smaller the bubble, the longer it takes to rise to the top and pop. If the emulsion does contain fine air bubbles, then they may not cause a problem when coating fine mesh, since the mesh openings are too small to hold a bubble, but they will cause a problem with your lower mesh counts.

Even if you start with an emulsion free of bubbles, you can still expect to run into

pinhole problems with your coarse mesh counts if you coat too fast. The turbulence generated in the emulsion as the scoop coater rides over the large woven knuckles of lower mesh counts is a great way to make foam. Scoop coaters with a sharp edge increase the likelihood of this occurrence due to the higher rate of shear on the emulsion.

NOTE: when coating a large number of coarse mesh screens, pour off the emulsion in the scoop coater (and let it recover) as soon as it starts to retain a lot of bubbles. Start coating again with fresh emulsion and you will have a lot less pinholes. (Refer to "What Are Optimum Drying Conditions" Tech Tip page 62-63.)

EXPOSURE

Optimum exposure, or rather avoidance of gross under exposure, is the third area that requires attention. The first thing to avoid is batch exposing screens of very different mesh counts. For example, a direct emulsion stencil on a 61 mesh needs twice the exposure compared to 110, and roughly three times when compared to 158 mesh. If you do batch expose, then only combine screens with a narrow range of mesh counts, and don't mix white mesh with dyed mesh screens. With a dyed fabric, even if the mesh count is the same, it still needs an approximately 50% longer exposure time to enable the emulsion to harden properly.

Also, avoid coating screens which have lost tension. The thick patch of emulsion that builds up in the middle of the screen is not only difficult to dry properly, it will also not expose correctly and will cause premature breakdown on press.

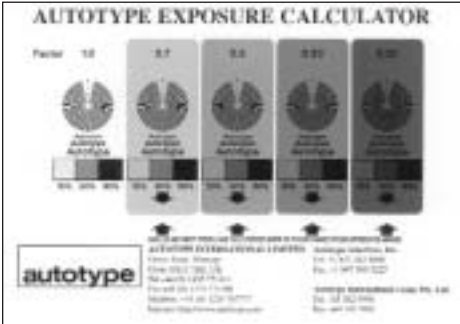
Finally, do some exposure tests to check how near or far you are from optimum exposure. You may use an exposure calculator or digital radiometer. (Refer to "Determining Optimum Exposure" Tech Tip

continued on next page

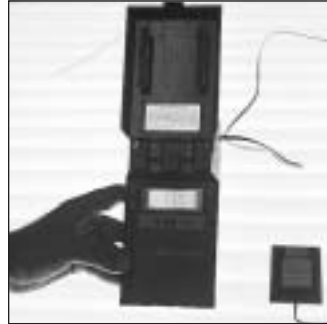
continued from previous page

on page 66.) Another option is using a Saati 21-step grey scale, or stepwedge when exposing your production screens. Position the stepwedge where you can cover it with blockout before printing.

When you wash out the stencil, you should hold 6 or 7 solid steps on the wedge if you are at the correct exposure. For every two steps you are short, you need to double your exposure time.

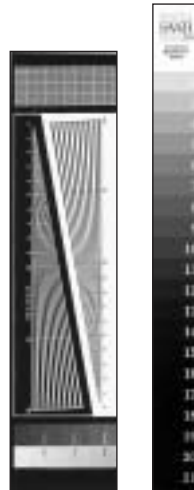


Autotype exposure calculator.



TQM™ Digital Radiometer.

By using these tools to conduct exposure testing you can reduce your chance of pinholes which are caused by under-exposure.



Stouffer Resolution Guide and Saati 21-Step Sensitivity Guide

What To Expect From Your Stencil


PART 1 – INTRODUCTION

The purpose of this guide is to give an outline of commercially available stencil systems and the properties they possess. In doing so, we will touch upon the various technology employed, the effect of processing variables, and finally examine the effect of some of the factors that limit what is achievable.

PART 2 – STENCIL TYPES

Commercially available photostencils fall into four main categories. The first is known as Indirect Film, where the stencil imaging and developing process is carried out independently of the screen mesh. The finished stencil is applied to the mesh with gentle pressure, blotted with newsprint, and dried prior to removal of the backing film. Although capable of the highest quality reproduction, the thin edge of the finished stencil is very fragile and easily damaged, and therefore unsuitable for long print runs or for printing on difficult substrates. Indirect film is only suitable for use on finer mesh counts that are capable of supporting the fragile stencil.

See Figure 1.



The diagram shows a cross-section of an indirect film stencil. A thin, wavy film is positioned above a thick, solid substrate. The film is held in place by small circular indentations or supports. The substrate has a flat top surface.


Indirect Film

- Highest resolution (processed away from the mesh)
- Excellent definition (short print runs only)
- Poor durability, 100's of prints
- Expensive
- Requires skill to process (chemical processing)
- fine mesh only

Figure 1

The second type of stencil is known as Direct Film or Capillary Film. In this case, a much thicker layer of pre-coated photo-

graphic emulsion, that has been manufactured to a precise thickness, is adhered to a wet screen mesh through capillary action. After drying and removal of the backing film, exposure and development produces a much stronger and more firmly adhered stencil than in the previous case, but still with the image quality associated with a film based product. **See Figure 2.**




The diagram shows a cross-section of a capillary film stencil. A thin, wavy film is positioned above a thick, solid substrate. The film is held in place by small circular indentations or supports. The substrate has a flat top surface.

Capillary Film

- Very good resolution and definition
- Medium durability, 1000's of prints
- Expensive
- Range of thickness available to cover most mesh counts
- Automation possible

Figure 2

With the third type of stencil, known as Direct/Indirect, the film is laminated to the mesh with a layer of photographic emulsion instead of water. Once this sandwich has dried, processing is carried out the same as for capillary film, but with the advantage that an even more firmly adhered and durable stencil is produced. The downside is that the stencil making process is more complicated and messy, particularly in larger formats, and is also more costly since both film and emulsion are required. **See Figure 3.**



The diagram shows a cross-section of a direct/indirect stencil. A thin, wavy film is positioned above a thick, solid substrate. The film is held in place by small circular indentations or supports. The substrate has a flat top surface.

Direct/Indirect

- Very good resolution and excellent definition
- Extremely durable, 1000's of prints
- Expensive, both film and emulsion required
- Messy process, requires skill
- Most suitable for small format


Figure 3

continued on next page

continued from previous page

That brings us to the last, and most commonly used, type of stencil which is known as Direct Emulsion. In this case the mesh is coated with a light sensitive emulsion, which when dry is imaged and then developed in the same fashion as capillary film. This is by far the least expensive method, in terms of material cost, and results in the most durable stencils. However it is also capable of producing poorer print quality than any of the film based systems, unless the correct choices are made in terms of emulsion type and methods of processing and bringing several variables under control.

See Figure 4.



Direct/Emulsion

- Good resolution
- Definition poor-excellent, depends on processing
- Extremely durable, 1,000's plus prints
- Inexpensive
- Easy to automate
- Suitable for all size formats and any mesh count
- Widest compatibility with ink chemistry

Figure 4

PART 3 – TECHNOLOGY OF STENCILS

With the exception of indirect stencil films, which generally are thin coatings of gelatin containing an iron salt sensitizer, the other types of photostencil system, mainly direct emulsion and capillary film, which is really pre-coated emulsion, are based upon a resin known as polyvinylalcohol. Polyvinylalcohol possesses an unusual combination of three properties that make it uniquely suited to be used as the basis of most stencil materials. First it is a water soluble polymer, which means that stencil processing and

developing can be carried out with water, rather than organic solvents. Second, it is highly solvent resistant, unlike most other water soluble polymers that tend to dissolve even more readily in solvents, and therefore stencils are able to stand up to a wide variety of different ink types. Third, polyvinylalcohol contains a link in it's polymer chain that is easily broken by the application of dilute aqueous solutions of sodium metaperiodate, (AKA emulsion remover). This means that after printing, the mesh can be recovered and reused by stripping the stencil without harsh chemicals.

In order to make capillary films and direct emulsions light sensitive, there is a choice of three basic types of technology, Diazo, Dual-Cure or Photopolymer. In addition, other ingredients such as fillers or bulking agents are added to increase the solid content and improve wet strength of the stencil during processing. The choice of sensitizers, and the type or combination of fillers used will determine the properties of the end product. Ancillary ingredients include pigments, surfactants which improve coating quality, and defoamers to kill bubbles during processing.

The simplest technology employs a diazo sensitizer which is actually a polymeric yellow dye, that is unstable and decomposes when exposed to actinic blue and UV light. When exposed, the diazo reacts with the polyvinylalcohol crosslinking the polymer chains and decreasing it's solubility in water. This enables the stencil to form on the mesh during developing. The other ingredients that are added during manufacturing of the emulsion determine what it's final properties will be. With diazo emulsions and films, the other main ingredient is known as polyvinylacetate. Polyvinylacetate is used to add bulk, increase solids content, and due to it's water repellent nature is also effective in increasing the wet strength of the stencil during processing by preventing over-

continued on next page

continued from previous page

swelling of the cross-linked polyvinylalcohol, and loss of detail. If enough polyvinylacetate is used then the final stencil can become water resistant enough to be used for printing water-based inks. The problem with polyvinylacetate however is that it is very sensitive to organic solvents. If a high level is used, then the excellent solvent resistance and easy reclaiming conferred on the stencil by the use of the polyvinylalcohol component is compromised. For this reason, diazo emulsions tend to fall into one of two categories, solvent resistant or water resistant. **See Figure 5.**

Diazo Emulsion

Solvent Resistant

- 20-30% solids content
- Easy to reclaim
- Not humidity or water resistant
- Inexpensive

Water Resistant

- 35-45% solids content
- Plastisol & water resistant
- No solvent resistance (can be difficult to reclaim)
- Inexpensive

Figure 5

With Dual-Cure emulsion and film, the diazo sensitizer, which is still used, is fortified by including an additional crosslinking system at the time of manufacture. This additional crosslinking system is used to reinforce, or in certain cases even replace, the polyvinylacetate component of the stencil. By combining these two separate crosslinking systems, each separately for the two main components of the emulsion, it is possible to engineer properties into the stencil that were mutually exclusive with diazo sensitized products. For instance water and solvent resistance, or high solids and easy reclaiming. For this reason, most manufacturers of stencil materials now offer a universal type of dual-

cure direct emulsion that combines most of the properties of the "ideal" stencil.

See Figure 6.

Dual-Cure Emulsion

Universal Type

- 35-40% solids content
- Solvent resistant
- Water resistant (non-textile)
- Easy to reclaim
- Moderately expensive

Specialty Types

- High solids content – up to 50%, or
- Permanent (with catalyst)

Figure 6

Photopolymer stencil products do not contain diazo, since they are manufactured with a light sensitive polymer. Emulsions are supplied presensitized and ready to use with no mixing required, and both photopolymer emulsion and film have a shelf life that is measured in years, and not weeks or months. (Diazo is affected not only by light, but also by heat and humidity). The other distinguishing feature of photopolymer is that exposure times are a fraction of what would be used for either diazo or dual-cure products. This is due to the very high sensitivity of the polymer that is used. The resistance properties of photopolymer fall into the same categories as those for diazo sensitized material, either solvent or water resistant. Having said that however, the water resistance of commercially available photopolymer emulsions does not yet rival that of diazo. Products designed for garment printing are really more suited for use only with plastisol inks, unless a hardener is used to reinforce the screen. The very fast exposure times achievable with photopolymer has also enabled the development of products that are suitable for use with extremely weak light sources, such as projection exposure. **See Figure 7.**

continued on next page

continued from previous page

Photopolymer Emulsions

(presensitized with no mixing)

Garment Printing

- 40-50% solids content
- Very short exposure time (1/4)
- Plastisol resistant
- No solvent resistance (can be difficult to reclaim)
- Expensive

Graphic Printing

- 30-40% solids content
- Very short exposure time (1/3)
- UV ink and solvent resistant
- Expensive

Projection

- 20-30% solids content
- Extremely fast exposing
- UV and solvent resistant
- Very expensive

Figure 7

PROCESSING VARIABLES

Now, a screen printing stencil has to perform four functions. Two are important for any type of screen printing, since the stencil must first reproduce the image that is to be printed, and secondly be resistant to abrasion and chemical attack. The last two functions are particularly important for high quality line or halftone printing, since the stencil can help to control the amount of ink that is printed, and is also responsible for controlling image accutance, more commonly referred to as print edge definition.

Regardless of which type of stencil system is to be used, there are two param-

eters that affect print quality, and these can be measured and controlled. They are the Rz value which regulates edge definition, and the stencil profile which contributes to ink deposit. **See Figure 8.**

Stencil profile is used, along with the screen mesh chosen, to control ink deposit. For certain applications a thick stencil is beneficial, for other applications it is advantageous to minimize the stencil build up. Rz of the finished stencil controls edge definition of the print. For most types of printing, an Rz value of 10 microns or less will result in good edge quality. For highly demanding printing, such as small reversed text, or high line count halftones, a value closer to 5 microns is necessary. Below 5 microns, if the stencil becomes too glossy, then ink splattering or cobwebbing can occur when printing on glossy substrates.

Capillary film is manufactured in different thickness grades, each designed for optimum performance on a narrow range of mesh counts, and best results are obtained by selecting the correct grade for the mesh count being used. Excess water is removed from the mesh during processing with a light squeegee action, pressure is not required, and would in fact lead to detrimental results as the film could become overdissolved. If the correct capillary film thickness is used, the water that remains is sufficient to absorb half to two thirds of the original emulsion layer into the mesh. What remains comprises the stencil profile and controls the Rz value. **See Figure 9.**

With direct emulsion, the factors that are important in controlling the stencil parameters are the solids content/viscosity of the emulsion, and the coating procedure that is employed. High solids content is desirable as it minimizes shrinkage on drying. Shrinkage of the wet emulsion layer on drying leads to high Rz values

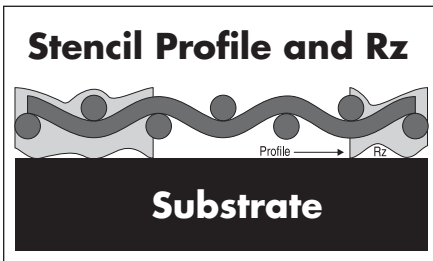


Figure 8

continued on next page

continued from previous page

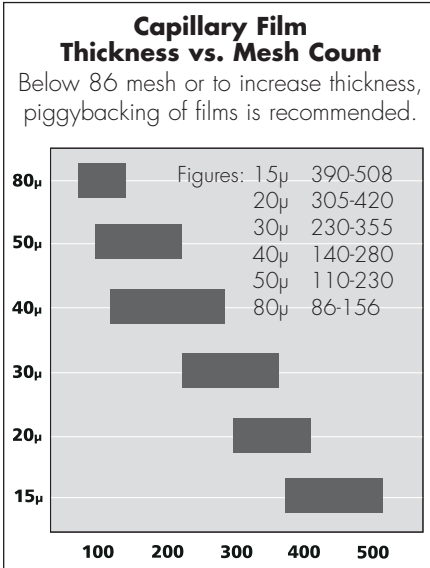


Figure 9

and poor print quality, even if you are using a high solids content emulsion, unless particular attention is paid to the method of coating. In order to optimize stencil profile, and minimize Rz, coating procedure has to be optimized for each application. In general, with a high solids content emulsion of around 40% solids, it is possible to achieve good results with simple wet on wet coating procedures. For very coarse screen mesh, such as 61, two coats on the print side followed by one coat on the squeegee side is all that is required due to the open weave and high percentage open area of the fabric. For 110 mesh, 2+2 should suffice. Once we get to 230 mesh, in order to duplicate the results that would be achieved with capillary film, a 2+3 procedure is required. The additional coats on the squeegee side of the screen in effect cause a build up of emulsion on the print side, which is where we need our stencil. The only time when an additional coating procedure is necessary, after the initial coats have dried, is for instance when printing four color process with UV cured

inks. The very high mesh counts, such as 380 and 460, that are best at minimizing ink deposit, are also good at preventing emulsion build-up during coating. The easiest way to minimize both stencil profile, and Rz value, for this highly demanding application, is to face coat the screen after drying. This ensures that the thin stencils required to minimize ink deposit, will also provide a gasket fit onto the substrate and prevent ink from bleeding beyond the image area under pressure from the squeegee to cause sawtooth lines and the star shaped halftones that cause excessive dot gain.

Lower solids content emulsions are unable to bridge the coarsest mesh counts effectively with simple wet on wet coating methods, and this effectively limits the mesh count range on which they can productively be used. **See Figure 10.**

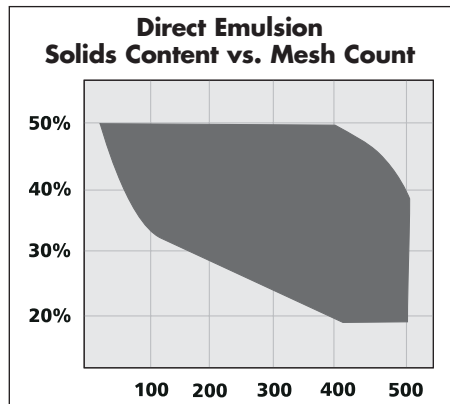


Figure 10

Regardless of which type of stencil system is used, correct exposure is of paramount importance in optimizing printing performance. Producing a screen printing stencil, even for use with the fine mesh counts used for printing halftones, involves exposing a coating that is very thick in comparison with those used for other photographic or imaging processes. Because of this, depth of cure through the stencil becomes a real issue. Poor through cure,

continued on next page

continued from previous page

or underexposure, will cause one or more of the following problems. Loss of detail during processing, excessive pinholes, scum leaking into and then blocking image areas, premature stencil breakdown during printing or clean-up, and last but not least, difficult or impossible reclaim. Remember, we are talking expensive screen mesh here.

Overexposure in comparison will cause detail to shrink on the screen, with eventual loss of parts of the image altogether, and this is usually most severe and easily noticeable with halftones.

A minimum of 20" Hg of vacuum in the exposure frame is required to ensure good enough contact between the artwork and the screen during exposure. This prevents the undercutting of the image, and subsequent loss of detail, that occurs when light leaks under the positive. A good light source fitted with a metal halide type bulb is recommended to produce optimum results since there is a good match between the output spectrum of the bulb, and the maximum sensitivity of most stencil materials. It is also important that the placement of the lamp, and the reflector design, is optimized so as to ensure even coverage of the entire image area during exposure. Even coverage is essential for accurate reproduction of the image, as well as stencil durability. If coverage is very uneven then the exposure latitude of the stencil material may be exceeded, and areas of the screen may be either under, or overexposed, or sometimes even both on the same screen. In this respect, dual-cure emulsions possess the widest exposure latitude, although being overall very similar to diazo products in optimum exposure time. Photopolymer emulsions, since they expose in a fraction of the time and have inherently much less latitude, really do require more even exposure intensity in order to produce consistent results.

To determine optimum exposure, an exposure calculator or 21 step grayscale

should be used. An exposure calculator usually consists of a repeating piece of artwork overlaid with a series of increasingly darker gray neutral density filters. With one test exposure, it is possible to simulate for instance five different exposure times. Examination of the developed and dried stencil reveals rectangles where the strong yellow color from residual unexposed diazo alters the color of the stencil. The trick is to pick the exposure factor for the rectangle that just becomes indistinguishable from the background, and this corresponds to the optimum exposure time. With a 21 step grayscale, an exposure time long enough to give 7 solid steps on a developed stencil is generally very close to the optimum. Since photopolymers do not change color on exposure, then the 21 step grayscale method is a more reliable method of determining optimum cure than an exposure calculator, although the calculator can be used to determine the level of resolution that can be achieved at different exposure times.

When using direct emulsion, it is not possible to gang expose a collection of different mesh counts and ensure that the correct exposure time is given. Longer exposure time is required for thicker coatings and the coarser the mesh, the thicker the layer of emulsion that has to be cured.

Another important variable that should not be overlooked as a cause of possible problems is screen drying. Both capillary film and direct emulsions require very thorough drying prior to exposure, since any residual moisture present in the coating will react preferentially with the photosensitive resins that are supposed to harden the stencil. When you expose a damp screen, you end up with a stencil that exhibits the symptoms of having been underexposed, except that no improvement is ever seen on increasing exposure time.

The type of artwork used can also have a big effect on the properties of the

continued on next page

continued from previous page

finished stencil. Most film positives will have a dense black image area, a high Dmax, and a clear background, a low Dmin. Vellum on the other hand rarely achieves a Dmax much above 1.5, and at the same time, the Dmin is usually around 0.3. What this means is that the vellum only allows 50% of the light to reach the stencil, and before optimum exposure is reached the insufficient Dmax has let light penetrate to the image area so that washout properties and detail are compromised. The expression, about stuck between the rock and the hard place, definitely applies to vellum.

Mesh preparation should not be ignored as an area that can affect stencil performance. Although screen mesh is thoroughly washed after manufacture, dust and oils from handling, along with adhesive overspray etc. cause contamination that should be removed prior to coating. Degreased mesh, although it may be squeaky-clean is, with the exception of stainless steel wire-cloth, not very conducive to good stencil adhesion. Polyester mesh is woven from slick, smooth PET fibers. Water based paint, or photoemulsion, does not stick well to untreated PET. For this reason it is necessary to prepare the mesh properly in order to maximize stencil adhesion. Physical adhesion can be improved by lightly roughening the surface of the mesh with a specially designed abrasive degreaser. Chemical adhesion can be improved by treating the mesh with a meshprep containing a so called wetting agent. After rinsing, this leaves an adhesion promoting surface primer on the mesh that enables the stencil to adhere much better. Meshpreps are even available that combine degreaser, abrasive and wetting agent all in one product. The improvements seen in adhesion are most noticeable at underexposure. Photopolymer stencil materials benefit the most of all from good mesh preparation since they do not

contain diazo that bonds to the fabric during exposure.

LIMITATIONS

Screen mesh comprises two parts, first the threads, and we need enough of these to support all of the detail in our image. Second the holes, the size and number of these, along with the stencil profile will control how much ink is laid down. Below 305 mesh, the main factor that influences ink deposit is the mesh count of the fabric, or how many threads per inch. Once we get above 305, the mesh count is less important, the actual thread diameter and weaving construction, plain or twill, becomes the dominant factor in determining ink deposit. Obviously the higher the mesh count, the finer the detail that can be supported on the screen.

However, the fact that there are threads in the way at all does place limitations on what can realistically be screenprinted. **See Figure 11.**

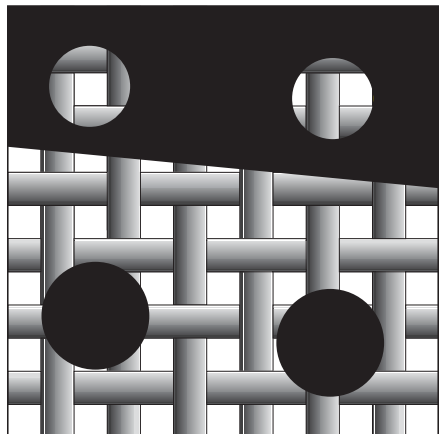


Figure 11

**Minimum Size of Highlight Dot is
1 Opening + 1.5 Threads.**

**Minimum Size of Shadow Dot Needs
2 Openings + 1.5 Threads for Stencil**

continued on next page

continued from previous page

As far as fine detail is concerned, there is a minimum size of opening in the stencil that will consistently allow ink to pass regardless of where it sits on the weave of the mesh. Once the size of the detail on the screen, fine lines or halftone dots, becomes narrower than one mesh opening plus one and a half thread diameters, then it can be obscured by passing over the threads and the knuckles of the weave where the threads cross. Choosing mesh with a thinner thread diameter can help squeeze out a little more detail, but at the cost of producing a more fragile screen. Mesh woven from thicker threads, as well as producing a more robust screen able to be used at a higher tension level for better registration with multicolor printing, provides better adhesion at the shadow end of a halftone range, or for holding fine lines with reverse printing. Once the small specks or strings of stencil that have to block the flow of ink, and differentiate between shadow tones or delineate text, become smaller than two mesh openings plus one and a half thread diameters, they may only adhere to one or two threads and lack sufficient adhesion to withstand the rigors of processing, never mind printing.

As an example, with halftones, the line count or dots per inch determines the tonal range that can consistently be printed on any particular mesh count. As the line count increases, the smaller dots enable viewing from a closer distance without the individual dots themselves being visible. However, increasing the line count effectively decreases the range of tones that can be held before highlights moiré, and then cease to print, and separation between midtones and shadows is lost as everything collapses to a solid print. This is illustrated for 380 mesh below.

See Figure 12.

If a target is set of trying to print from 10% in the highlights, up to 85% in the

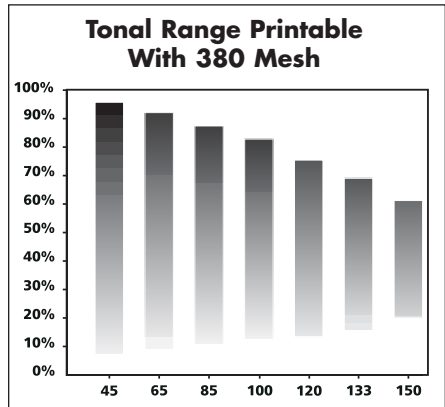


Figure 12

shadows, for a print with good separation between all the tones of the halftone range, then each mesh will have a limit on how high the line count of the halftone can be if this is to be achieved.

See Figure 13.

Printable Tone Range						
MESH COUNT	45 LINE	65 LINE	85 LINE	100 LINE	120 LINE	150 LINE
196	6-86%	13-71%	22-50%			
230	4-90%	9-78%	16-63%			
305	3-94%	5-89%	9-80%	13-71%		
355	2-96%	4-91%	7-85%	10-79%	14-70%	
390	2-97%	4-93%	6-88%	9-82%	13-75%	20-61%
420	2-97%	3-94%	5-90%	8-86%	11-80%	17-68%
460	1-98%	2-95%	4-92%	6-88%	9-84%	13-74%

Figure 13

A perfectly prepared stencil is in fact capable of resolving finer detail than it is physically possible to print, because of the intervening influence of the mesh. However, in order to make the perfect stencil, there are many screens to be burned, obstacles to be overcome, and variables to be controlled.

How To Match A Direct Emulsion's Print Quality Performance With That Achieved By Capillary Film

QUESTION

We recently switched from capillary film to high-solids direct emulsion, applied on an automatic coating machine, and are very pleased with the quality of our stencils on 230 and 305 mesh for solvent-based printing. However, we suffer from poorer print quality on our 380 mesh UV screens, most of which involve reverse printing of very fine detail.

Regardless of how we coat these screens, we are unable to match the stencil thickness achieved with capillary film. Is this the cause of our problems?

SOLUTION

As you have discovered, reverse printing of fine detail is probably the most highly demanding and critical test for the edge definition of a stencil. In order to match the quality produced from a film-based stencil when using a direct emulsion, even a high-solids emulsion combined with a coating machine, particular attention has to be paid to optimizing certain parameters.

The fact that you are unable to match the stencil build-up obtained with capillary film when using direct emulsion is related to your problem, but is not itself the cause.

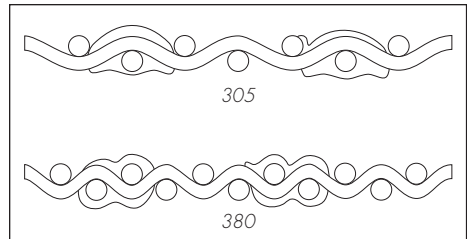
To cut a long story short, the root cause of your poor print quality when running UV can be traced back to the small percentage of open area present in the mesh used, (which is why you chose that mesh in the first place, in order to minimize the ink deposit).

The use of an automatic coating machine does enable you to transfer an even and repeatable amount of emulsion onto the mesh every time you coat a screen, and you are correct to use a high solids content emulsion to minimize shrinkage on drying. However, the problem with the very fine mesh used for printing UV is that it not only minimizes ink deposit, it also impedes the transfer of emulsion through the fabric when using the two-sided, wet-on-wet coating procedures that normally yield satisfactory stencils with more open meshes. You have obviously picked up this effect when monitoring

your stencil thicknesses and compared them to what was obtained with capillary film.

The poor print quality is caused not by the lack of stencil build-up, but by insufficient smoothing over of the knuckles, which are formed during weaving of the mesh. The result being that during printing, the stencil will not provide the gasket seal required to prevent ink bleeding under non-image areas. In technical terms, the stencil Rz value is too high. Rz (surface topography). (Refer to "What Is A Stencil Rz Value?" Tech Tip page 61.)

Compounding the effect of the thin emulsion coating is the fact that the finer UV mesh probably has bigger knuckles to cover in the first place. That's because there is a good chance that with the mesh you are using, the same diameter thread was used to produce both 305 and 380 mesh. Below we have illustrated what happens, by comparing 305 and 380 mesh woven with 34 micron threads, a commonly used thread diameter for these mesh counts.



When the threads are packed more closely together, not only is the percentage of open area reduced from roughly 30% with the 305 mesh, down to around 15% with the 380 mesh (which is good for minimizing ink deposit), but the knuckles formed by the dense weaving structure are much more prominent and difficult to cover.

For the 305 mesh, you might expect to coat a high-solids content emulsion, say, two coats on the print side, with three coats on the squeegee side, and achieve something like a 6-7 micron build-up with a nice smooth finish. With the same procedure, the 380 mesh on the other hand, will only have a 1-2 micron

continued on next page

continued from previous page

stencil thickness, and will not print with the same quality as a film-based stencil.

Attempting to build up a thicker and smoother coating by applying additional coats to the squeegee side during wet-on-wet coating, is a futile task with mesh designed for UV printing. The mesh is not designed to allow the emulsion to pass through freely, and even if you apply an additional three or four coats to the squeegee side, you will be lucky to add a few microns to your stencil thickness. Meanwhile, the emulsion in the scoop coater on the print side of the screen is busy skinning over.

The surest way to guarantee the best print quality when producing this type of stencil, is to seal the fabric with a few coats on each side, and then dry it, prior to polishing up the print side of the screen with an additional coat. With this method, you will still not match the stencil thickness obtained with capillary film, as the additional coat applied after drying will add but a micron to the overall thickness. You should however, be able to match the print quality. Plus the fact that now that you are working with a thinner high-definition stencil, there may even be some benefits in terms of controlling ink deposit (and mileage).

Emulsion Selection & Coating Techniques For Coarse Mesh Counts

QUESTION

We use a high-solids content emulsion and are very happy with the results on our 158 and 110 mesh. We have problems, however, with our 61 mesh and we can't coat our 24 mesh screens at all because the emulsion drips right through. Do we need to find an emulsion with an even higher solids content?

SOLUTION

Not necessarily. You made the right choice in deciding to use a high-solids content emulsion, since you need high solids in order to cover your coarse mesh without too much shrinkage. However, the first thing we need to do is make a distinction between solids content and viscosity, or thickness.

Emulsion manufacturers are able to control solids content and viscosity independently of each other. High solids does not always mean high viscosity. In fact, many high-solids content emulsions are supposed to be low in viscosity because they were designed primarily for producing high quality stencils on fine mesh counts, where the flow properties of the emulsion are more critical. Obviously in your case, where you are using coarse mesh with a high percentage of open area, high viscosity along with the high solids content is an essential feature if you are going to avoid having problems with the mesh counts at the lower end of your range.

If you are using a diazo or dual-cure emulsion, you could try simply adding less water to the sensitizer when you mix it. If the emulsion is already too thin as supplied, or if you are using a pure photopolymer type that requires no mixing, then you may have to switch to an emulsion with a higher viscosity specification.

The second thing you need to address is ensuring that your coating method is optimized for the type of mesh you are using. As you go from 158 down to 24 mesh, the percentage open area of the mesh increases from 32% up to 55%. This, in conjunction with the fact that the openings are so much

bigger, means that for the coarser mesh you really have to reduce the number of coats you apply. If you don't, too much emulsion will be transferred onto the fabric, and even the thickest emulsion will sag and drip if you lay it on too heavily.

For the 158 mesh screens, two coats on the print side, followed by two or maybe even three on the squeegee side, will produce a nice smooth finish to the dried emulsion. For the 110 mesh, two coats on each side should be sufficient. The last two coats should always be on the squeegee side to push the emulsion back where it belongs on the print side of the screen.

For the 61 mesh, cut back to only one coat on the squeegee side. And remember, these screens should always be dried flat with the print side underneath. By now you should have the emulsion onto the print side of the screen, and you want to make sure it stays there. Emulsion on the squeegee side of the mesh is more difficult to harden properly on exposure, and even when it is hardened, is more likely to suffer from abrasion and wear by the squeegee during printing. Thus causing pinholes and breakdown.

By the time you get to the 24 mesh, you need to adopt a different technique. In this case, apply one slow coat to the print side. Then, turn the screen and apply one slow coat to the squeegee side. Immediately after this, use your coater in the horizontal, untilted position to remove the excess emulsion from the print side of the screen by applying a scrape stroke. This will leave enough emulsion on the screen, but should eliminate the possibility for drips to form while the screen dries.

NOTE: one important point to remember is that the coarser the mesh, the slower you should coat in order to minimize bubble formation. With the coarser mesh, for instance 61, and particularly with 24 mesh, there is a tendency for air bubbles to get trapped in the mesh openings. As you probably know already, every trapped bubble is a potential pinhole.

Optimizing Automatic Coating Methods

QUESTION

We make over one hundred screens per day on 86 mesh all the way up to 355 mesh, and have recently bought an automatic screen coating machine fitted with a built-in dryer. Can you give us some advice on optimum coating methods so we get the best print quality from our screens without sacrificing productivity? If possible, we would like to use only one emulsion.

SOLUTION

You can achieve what you want with only one emulsion. However, in order both to ensure high quality, and maximize productivity, you will need to change your coating method to quite different techniques as you go from coarse to fine mesh.

With a 355 mesh, for example, the small percentage of open area with this mesh restricts emulsion transfer when simple wet-on-wet coating methods are used. This means that an awful lot of coats are required to fill, and then smooth out the mesh knuckles to optimize print quality even if you are using a high-solids content emulsion.

In this case, the built-in dryer should be used. The first coating/drying sequence will seal the mesh, and then an additional two coats on the print or substrate side, with drying in between, fills and polishes the coating so that print definition is optimized. This method will provide film-quality stencils with a very thin, but reproducible stencil thickness. Also, because the mesh/coating combination is so thin, drying times will be short enough so as not to affect your productivity adversely.

In the case of an 86 mesh, at the opposite extreme, the large mesh openings and high percentage of open area enable the emulsion to flow very freely. This means that you have to be careful not to put too much emulsion on the mesh!

If you are using a high-solids content emulsion, then the optimum settings we would recommend would be one coat on the print side with two coats on the squeegee side. The screen should then be removed for drying, while subsequent screens are coated. Remember, in order to get the best quality, you should dry these screens print side down. If you don't, then the emulsion will leak back through to the squeegee side. Even if you do manage to harden it properly during exposure, the stencil is not only going to print badly, it will get torn up by the squeegee as soon as you increase the pressure. This in turn will cause all kinds of pinhole and breakdown problems.

As you go higher in mesh count, you can stay with the simple wet-on-wet procedure, but you will need to increase the number of coats in order to maintain the optimum quality. For instance, with two coats on the print side and three coats on the squeegee side, the right emulsion on a 110 mesh will produce a better stencil than you could ever make with capillary film.

Once you get up to 230 mesh, you need to add an additional squeegee-side coat for a 2+4 procedure. However, anyone else reading this shouldn't be fooled into thinking that 2+4 means six individual coating passes. With the first two coats, both substrate and squeegee sides are coated simultaneously. After this, two more coats are then applied only to the squeegee side, for a total of four operations. In fact, since the coating trough on the squeegee side is slightly lower than the one on the print side, the squeegee side has effectively had the last three coats. The result of this is that with the right emulsion you produce a stencil with approximately fifteen microns thickness, with an Rz of around five microns.

Once you get to 305 mesh, you need to make a distinction between

continued on next page

continued from previous page

mesh woven from normal, or from heavy threads. If you are using a 305 mesh with a 34 micron thread diameter, then the 2+4 wet-on-wet method will work just fine. You can expect a stencil profile of about ten microns, and again the print quality will be similar to that achieved with capillary film. If however, you are using 305 mesh woven with 40 micron threads, then the wet-on-dry procedure developed for the 355 mesh is more appropriate. The reason for this is that the heavier threads reduce the percentage of open area and restrict emulsion flow. Also, the large knuckles formed where the thicker threads cross will not smooth over sufficiently with a wet-on-wet procedure, until the stencil becomes excessively thick. In this case, resorting to wet-on-dry keeps the thickness under control, while still providing the quality you seek.

These three or four coating procedures should enable you to produce the high-quality stencils you are looking for on your

range of mesh counts, while still allowing enough time for the productivity levels you need.

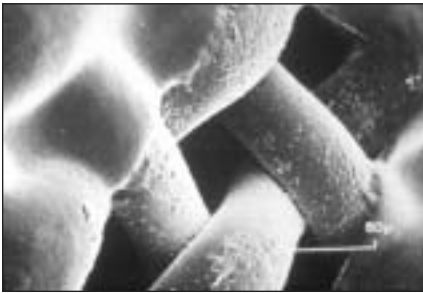
NOTE: you should use an emulsion with a high solids content. Lower solids content products shrink too much on drying, with the result that you tie up the coating machine by having to apply an excessive number of coats. Something around 35-40% solids would be ideal, but with a medium viscosity. There are plenty of dual-cure emulsions available with these properties. There are some higher solids content products around, but they may not have the versatility to work with the wide range of mesh counts that you are using. Also, the viscosity of some have a tendency to increase rapidly while you are trying to work with them on the machine. This can cause all types of problems, from varying stencil thickness to skinning over in the coating trough.

What Is A Stencil Rz Value And Why Is It Important?

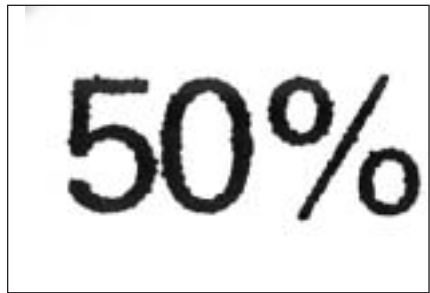
Rz is a measure of the roughness or smoothness of a surface. It is an important screen parameter because it measures how efficiently the print side of the stencil controls edge definition when printing demanding artwork. For example, artwork containing fine lines or halftone dots. The stencil not only carries the detail of the image to be printed, it also has to function as a gasket to prevent ink from bleeding outside the image area under pressure from the squeegee during the print stroke. Any undesirable spreading of the ink typically causes a saw-toothed appearance on the edge of detail and fine lines. Plus

it will obliterate fine reverse type. It also results in star-shaped halftone dots that cause dot gain and loss of contrast and detail, and can induce localized moiré.

In order to ensure a high-quality stencil, the Rz value must be controlled within narrow limits. Too rough, and the stencil will not gasket correctly onto the substrate. Too smooth, and the vacuum formed when printing on polished substrates will cause cobwebbing and splattering of the ink. Ideal values for most high-quality printing applications fall in the range of 4-10 microns.



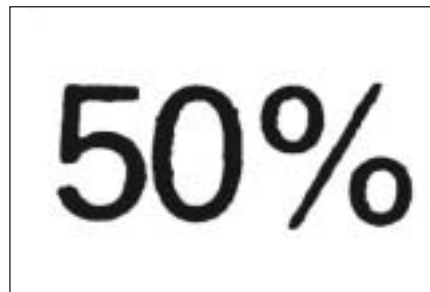
Stencil with high RZ



Print result of stencil



Stencil with low RZ



Printed result of stencil

What Are Optimum Drying Conditions?

QUESTION #1

We try to keep the temperature in our screen coating/drying room around 75 degrees Fahrenheit, and use fans and a dehumidifier to dry our screens. However, we've noticed that during the summer, our busy season, screens take a long time to dry.

QUESTION #2

Also, we would like to switch to using a dual-cure emulsion, because we like the better detail and easier reclaiming, but these screens seem to take forever to dry. We have even had some get stuck down to the glass in our vacuum frame.

SOLUTION

The optimum drying conditions for coated screens are the same, regardless of whether you are using dual-cure emulsions, diazo emulsions, photopolymer emulsions, or even capillary film for that matter.

The reason you have had a problem with dual-cure emulsions, is not really that they are any more difficult to dry than other types. It's simply that prior to exposure, they have a softer surface finish than coatings made with other types of emulsion, due to the plasticizing effect of the photopolymer component.

The other factor could be excessive heat generated during exposure, which bakes the screen onto the glass, particularly when you are shooting a lot of screens and things really start to heat up. Or in your case, since you have already determined that you have a drying problem, the other factor is more likely to be residual moisture trapped in the screen. (Refer to "Determining Stencil Moisture Content" Tech Tip on page 64.)

Regardless of what type of emulsion you are using, residual moisture trapped in the coating prior to exposure can cause a whole host of problems. Stencils made with diazo emulsion may not be sticking to the glass in your exposure frame, but you are probably experiencing some

other problems down the line. It may be excessive pinholes, premature stencil breakdown, or even poor reclaiming problems that you may not normally associate with a screen drying problem.

What are optimum drying conditions for any type of emulsion? Unless you are located in an environment like Arizona in the summertime, we would recommend that you split your coating and drying operations between two adjoining rooms. Degreased screens can still be dried in your coating room, but you should really have a separate environment to dry your coated screens. Ideally you should use a drying chamber, although how feasible this is depends on the size, and number of screens you are coating.

When drying coated screens, there are two important aspects. First, from a productivity point of view, you want screens to dry quickly. Second, from a quality point of view you want the screens to dry thoroughly.

By thorough, we mean drying down to a very low equilibrium moisture content. De-humidified air, being drier, is obviously more efficient at removing moisture from your coated screens than normal room air. But by itself, it is not necessarily the most effective method. The relationship between relative humidity, temperature, and drying capacity is fairly complicated, but fortunately very well understood. Heating and air-conditioning engineers routinely use psychrometric charts, which relate these varying parameters, when designing climate-controlled environments.

Thus, what we would like to do is try and explain the basis of drying in terms of these basic parameters. First, we would like to introduce the concept of vapor pressure. Vapor pressure exists when you turn a liquid into a gas. When the liquid is water, then vapor pressure is the driving force responsible for evaporation and condensation.

continued on next page

continued from previous page

When you put a wet screen in a drying room, the bottom line is that in order for the screen to want to dry out, there has to be a difference in vapor pressure. A difference has to exist between the vapor pressure of the moisture in the coating, and the vapor pressure of moisture already in the air. If there is no difference, then the screen will never dry. It is the size of this difference which controls moisture flow, and is important in determining: first, how fast your screens will dry, and second, how dry they ultimately become. *(We should add at this point, to beware the salesman who tells you that his emulsion has a higher vapor pressure than anyone else's!)*

The vapor pressure of the moisture in a wet coating is basically dependent on temperature, and the higher the temperature the higher the pressure. The vapor pressure of the moisture already present in the air is dependent on the dew point. This is the temperature at which condensation starts to form. Removing humidity from the air lowers the dew point, and hence lowers the vapor pressure.

The question is, what is the most effective way to maximize the difference between these two vapor pressures? Is it to raise the temperature of the coating? Or is it to dehumidify the air?

Let's start with, for example, a drying room at 75°F with a relative humidity of 60%. Just say we coat some screens and leave them to dry. Now if the fans being used to dry the screens change the air in the room to prevent moisture building up and saturating the air, the screens will eventually dry. A look at some charts, and a quick calculation, tells us that we have been working with a vapor pressure difference of 0.17 psi.

Now let's add a dehumidifier to the room, and say we are able to lower the

relative humidity from 60%, and hold it down to a nice dry 20% (which requires a good de-humidifier). Consulting our charts, and performing the same calculation, shows that the vapor pressure difference is now 0.34 psi. This means we have twice the drying capacity, in terms of the evaporation load that the air is able to carry away from a wet emulsion coating. Screens should dry in about half the time, and equilibrium moisture content should be lower too. If however, we allow the relative humidity to creep up, due to a heavy load of screens for example, then drying efficiency falls off quite quickly.

Instead of using a de-humidifier, let's say we decide to use a heater to warm the air entering our drying room. If the air coming in was at 75°F and 60% relative humidity, and we warm it up to 100°F, although the amount of moisture in the air hasn't changed, the relative humidity drops to around 25% since warmer air has a much greater drying capacity. We are now working with a vapor pressure difference of 0.7 psi (due to the higher temperature of the coatings), and have four times the drying capacity of the original example.

Screens will dry faster and harder with the application of a little heat, than with a lot of de-humidification. In this case, we are also better able to cope with adverse conditions, such as a heavy load of screens to be dried, or even an increase in relative humidity of the outside air.

De-humidification does start to make more sense with very warm and damp conditions. But even dealing with temperatures of 90°F and relative humidity of 75%, you still get greater drying efficiency from a 10 degree rise in temperature, than from a de-humidifier able to remove 50 grains of moisture/lb. of air.

Determining Stencil Moisture Content

QUESTION

How can I tell when my screen is dry enough to expose?

SOLUTION

Number one, you can't tell by looking at it. Number two, unless it is very damp, you can't tell by feeling it either. You may get some indication when you have trouble peeling the artwork back off the screen, or when the emulsion sticks to the inside of the glass in your exposure frame. But by then, it's too late.

Your best bet is a contact moisture meter. This inexpensive electronic device will tell you exactly how much percentage moisture is being retained in your coated and dried screens by measuring directly on the surface of the emulsion.

As you know, you can definitely eliminate a lot of costly stencil breakdown problems if you ensure that your coated screens are thoroughly dried prior to exposure. As far as emulsion goes, the drier the better, in order to obtain a tough stencil.

There are some guidelines you can follow when measuring the moisture content of your screens to make sure that during exposure most of the sensitizer is reacting with emulsion and not water. If the moisture content of the coated screen is less than 4%, you should always get a nice tough stencil, assuming you are using the correct exposure time. Between 4% and 6%, you will notice a deterioration in wet stencil strength during washout, and you will also have more pinholes. This is most critical for emulsions that use a low diazo level in order to get a shorter exposure time. Above 6% moisture content, most emulsions will produce soft stencils regardless of exposure time, and you run a real risk of breakdown on press. In this case, depending on your run length, you may or may not have a problem when printing plastisol. However, you will have a problem if you try to print water-based inks.

As coated screens become more damp, stencils will be progressively softer. Eventually you reach the stage where they suffer spray damage during washout, regardless of how long you expose your screens.

Once you are able to measure the moisture content of your screen, how should you proceed if it isn't dry enough? Typically, if the area where you dry your screens is affected by the weather to such a degree that it affects the way the emulsion dries, then simply leaving the screens to dry longer is not going to make any difference. The emulsion will have reached equilibrium with the conditions around it. At that point, all you can do is wait for the weather to change before your screens will dry out any more (unless, you take steps to reduce the relative humidity in the area where your screens are drying).

Preferably you need a drying chamber in order to dry screens properly. At the least, you really need to have a separate, dedicated drying room. There is no point in putting a de-humidifier in the corner of a room and expecting to see a big improvement if doors (assuming you have them) are open constantly, and someone is using a pressure washer to de-haze screens in the next room.

The temperature in the drying chamber or dedicated drying room should be approximately 100°-110°F. Coated screens placed in this environment will dry faster, and will dry down to a much lower moisture content, as long as you use a fan to pull out the damp air and keep the relative humidity as low as possible.

Raising temperature is by far the most efficient way of reducing relative humidity and maximizing drying capacity. After all, how many hair dryers work on the principle of de-humidification?

Choosing An Exposure Unit

QUESTION

There are mercury-vapor, metal halide, fluorescent, incandescent quartz, and halogen lamps for exposure units each with its own wattage rating. What type is better? How do I compare lamp types and wattage in order to make an intelligent choice?

SOLUTION

You have to remember that stencil materials only respond to a narrow range of wavelengths. Namely those corresponding to UV, violet and blue light, together known as actinic light. This is the reason that we can work safely under yellow lights when coating and drying screens.

The best types of bulbs for exposing screens should therefore have a high actinic output. Incandescent quartz, white fluorescent tubes and halogen lamps spread their output evenly over a wide spectrum to give the appearance of white light. Most of the electrical power going in is not producing the type of light you need to shoot screens. Therefore any unit designed with these types of bulbs will have a low intensity and long exposure times.

High power mercury-vapor bulbs come in different versions, each of which emits a great deal of actinic light. The most effective bulbs for exposing screens contain doped mercury vapor, and there are two main types. The diazo or metal halide lamp, which contains gallium iodide, and the multi-spectrum or tri-metal halide, which, in addition to the gallium, also contains some iron salts.

These additional ingredients, along with the mercury vapor, boost the amount of useful actinic light (mainly violet/blue) which these bulbs emit.

The result is that you get about twice the output in comparison to standard mercury-vapor lamps. This means a higher intensity of light delivered to the stencil

surface, and shorter exposure times.

Another measure of the efficiency of an exposure unit is the evenness of coverage. When exposing screens, depth of cure is very important. In other words, you have to harden the stencil evenly all the way through in order to avoid pinholes and premature breakdown.

To shorten exposure times, the temptation is to push the exposure unit closer to the screen. With larger vacuum frames, this leads to the formation of a "hot spot" in the center that gets overexposed and loses detail. However, with a rapid fall-off in intensity towards the edges of the frame, screens here can be underexposed and full of pinholes. A good reflector design can minimize or compensate for this effect. Once the lamp gets close enough to the screen, however, direct illumination from the bulb will always produce a hot spot.

The moral here is to make sure your exposure unit has enough kilowatts to enable you to pull the lamp back far enough to get even coverage, while keeping exposure times at a reasonable length.

On the subject of evenness of intensity, this is really the main claim to fame of exposure systems based on fluorescent tubes. Fluorescent tubes have been developed with a special phosphor coating on the inside of the glass that produces an actinic output around ten times greater than that of high output white fluorescents. The best type of tube only emits a very intense blue light of the optimum wavelength for exposing photostencils.

Typical intensity of this type of exposure unit is equivalent to a 6kW multi-spectrum at about 60" from the screen. Since 60" is the minimum recommended distance for exposing an image of around 40" x 40", this gives these fluorescent-based exposure units the edge in speed when it comes to exposing very large formats.

Determining Optimum Exposure

QUESTION

Why is optimum exposure important?

SOLUTION

Screen printing is dependent on optimum exposure time at the beginning of the process as a means of guaranteeing quality and performance at the end. Since probably 99% of incorrect exposure of direct photo-stencils is caused by underexposure, taking a little extra time and care during screen exposure can help you eliminate:

- Loss of fine detail during washout
- Excessive pinholes
- Scum leaking into and blocking the image areas
- Premature breakdown during printing or cleanup
- Difficult or impossible reclaimability

QUESTION

What is optimum exposure?

SOLUTION

Conventional and dual-cure emulsions contain a photosensitive ingredient, the diazo, that strongly absorbs blue and UV light. During exposure it decomposes, losing its absorption and causing the stencil to cross-link. This happens incrementally through the thickness of the stencil. In order for the emulsion in and behind the mesh to be properly cross-linked, it is necessary for the highly absorbing diazo in the emulsion in front of the mesh (i.e., closest to the light source) to be "bleached-out" by having a long enough exposure.

Unlike diazo, emulsions pure photopolymer products contain light-absorbing ingredients that react together to cause cross-linking. Although these products are photographically faster than diazo containing systems, the surface layers still need to be exposed first in order to properly cure deeper parts of the stencil. Remember, the cross-linked emulsion that encapsulates the mesh fibers gives direct stencils their superior durability, and this vital "inner" part of the stencil is most affected by underexposure.

As most of you know, underexposing stencils on purpose as a way of guaranteeing high resolution for fine-detail printing is a fairly common practice. While this may make a noticeable difference in resolution

capability under adverse conditions (i.e., a low-resolution emulsion on white fabric), today's higher quality emulsions, when used on a correctly dyed fabric, are capable of resolving finer details than most inks are capable of printing. As long as you use high quality materials in the screen-making process, resolution should not be a factor in choosing exposure time. The optimum exposure time is always the point where the stencil has been fully cross-linked.

QUESTION

What affects optimum exposure?

SOLUTION

If you asked 100 screen makers to list the variables that affect exposure time, chances are they would all come up with basically the same answers. If, however, you asked them to arrange the items in order of importance, you would probably end up with 100 different versions. Basically, you should examine six different variables, listed in the approximate order that they affect screen exposure time:

- Intensity of light
- Distance from lamp to screen
- Mesh thickness
- Mesh color
- Coating thickness
- Emulsion type

QUESTION

How do I quickly and accurately predict optimum exposure time?

SOLUTION

While there are several options to predict optimum exposure, (i.e., the "color-change" method), there is a new method that eliminates lengthy and less accurate testing procedures that are difficult to interpret. By measuring the output of an exposure lamp in a narrow spectral band (i.e., violet/blue) where the photoemulsion is at its most sensitive, it is possible to predict what the required exposure time will be. Through extensive testing, manufacturers of stencil materials are able to compile the necessary data that relates the exposure dose required by a product when used under almost any condition. The quality control device used in this method is a digital radiometer.

Understanding Emulsions & Stencil Exposure

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, multi-spectrum and certain specialty fluorescent tubes produce light very rich in these wavelengths. Other types of bulb are not suitable for high quality stencil production.

If you consider the light sensitive chemistry that is used in direct emulsions and capillary films, then you 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 nm 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 nm 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.

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.

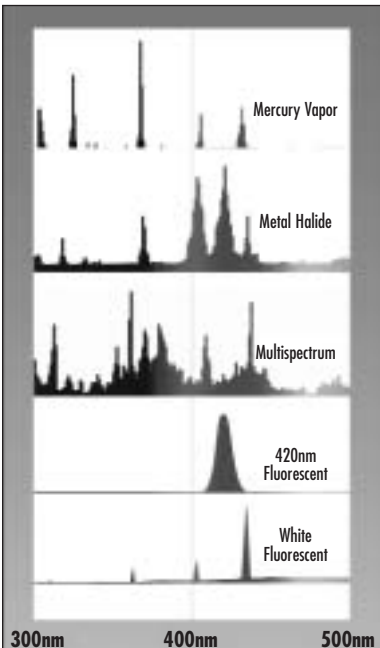


Figure 1

continued on next page

continued from previous page

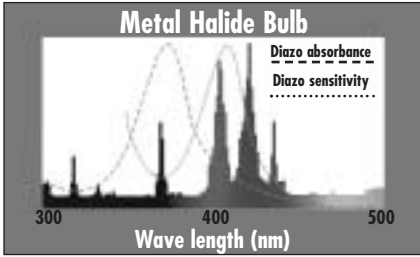


Figure 2

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

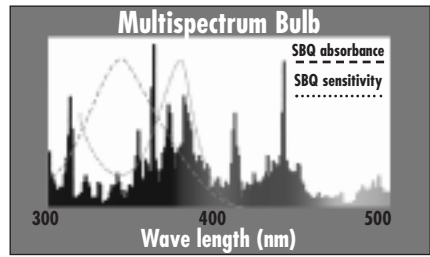


Figure 3

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

continued on next page

continued from previous page

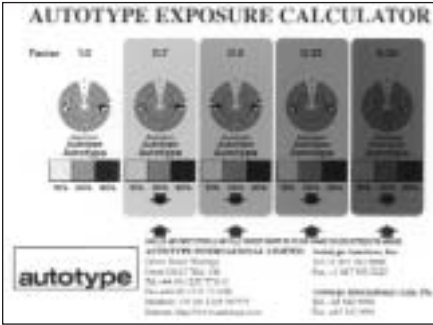


Figure 4



Figure 5

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.

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**.

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 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

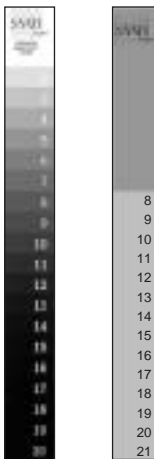


Figure 6 and 7

continued on next page

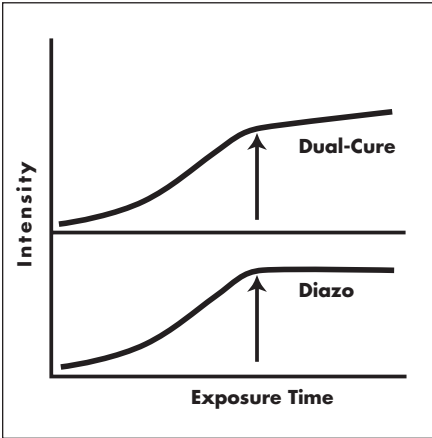


Figure 8

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**.

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

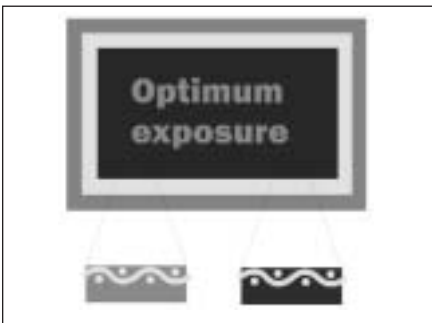


Figure 9

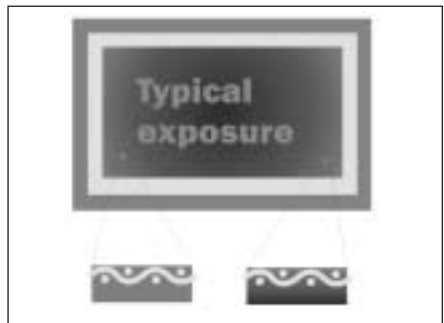


Figure 10

continued on next page

continued from previous page

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.

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**.

Now if we can assume at this point that you have arrived in the comfort zone. Optimum exposures have been set for all of our mesh count/color/coating combinations. You have adequately exposed screens with all the detail you need, and none of the pinholes you don't. Now, how do you 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.

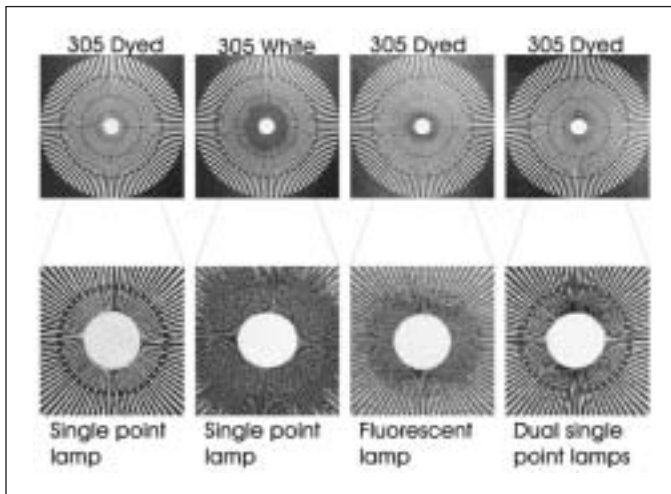


Figure 11

continued on next page

Now we 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 cross-link 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 cross-linked, 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 underexposed, the situation is the same as for a diazo emulsion in that the unreacted diazo can further cross-link 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 cross-linking 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 cross-link 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, let's review the influence of the film positive on the exposure process, since image density and resolution of the film output device has a major bearing on stencil quality. High quality film positive output from an imagesetter will have a very low D_{min} of around 0.05 (i.e. the film is clear and transmits more than 90%). Image areas will be a dense black, with a D_{max} 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 D_{min} of 0.3 sounds good until you realize it blocks 50% of the available light and requires the exposure time to be doubled. D_{max} is probably around 1 which stops 90% of the light but, unfortunately lets through the other 10%. The use of a

continued from previous page

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.

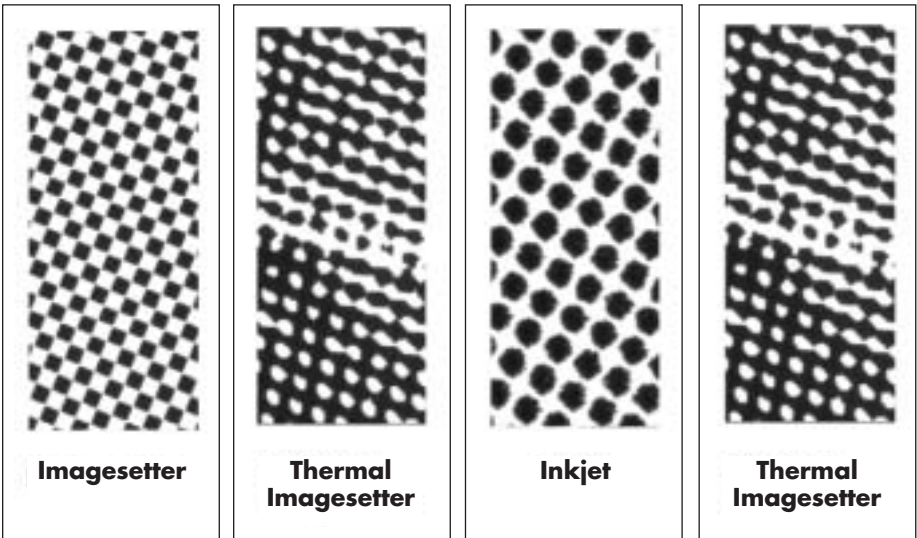


Figure 12

Using the Radiometer to Pinpoint 100% Correct Exposure Time

There is an option to measuring the intensity of your exposure lamp and using the chart of recommended exposure dose as a guideline to calculate exposure times. It is possible to use the radiometer as an analytical tool to pinpoint the 100% correct exposure time for any dual-cure or diazo emulsion on any mesh with your own particular coating method and exposure lamp.

This is accomplished by placing the sensor from the radiometer behind the coated screen in an area where the emulsion is to be fully exposed. Then, by taking a series of measurements during the exposure, at say five-second intervals, it is possible to

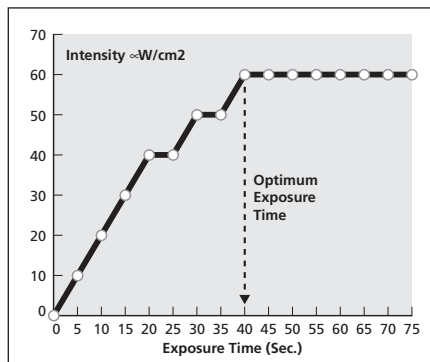
draw a graph that shows the intensity readings increasing rapidly as the exposure progresses. This happens as the diazo sensitizer is bleached out by actinic light from the exposure lamp, thereby allowing more light to penetrate through the back of the coating.

As optimum exposure is reached, and all the diazo has been used to harden the stencil, the intensity readings level off to a steady value and allow the absolute optimum exposure time to be determined for that particular combination of emulsion/mesh/coating method.

(See table and graph below.)

Grafic HU42 Photoemulsion Coated 2+3 on 420/PW31 Amber Hitech Mesh Exposed on 5KW Metal Halide at 40"

Exposure Measurements	Intensity Behind Screen
Start of Exposure	0 Microwatts/cm ²
5 seconds	10 microwatts/cm ²
10 seconds	20 microwatts/cm ²
15 seconds	30 microwatts/cm ²
20 seconds	40 microwatts/cm ²
25 seconds	40 microwatts/cm ²
30 seconds	50 microwatts/cm ²
35 seconds	50 microwatts/cm ²
40 seconds	60 microwatts/cm ²
45 seconds	60 microwatts/cm ²
50 seconds	60 microwatts/cm ²
55 seconds	60 microwatts/cm ²
60 seconds	60 microwatts/cm ²
65 seconds	60 microwatts/cm ²
70 seconds	60 microwatts/cm ²
75 seconds	60 microwatts/cm ²



The Benefits Of Emulsion Stencil Post-Exposure

Post-exposure can be a useful technique for improving the resistance properties of a stencil. The benefits offered depend however on the type of emulsion used, and can be summarized as follows.

DIAZO EMULSION

When a diazo emulsion is under-exposed, the developed and dried stencil retains a yellow undercast from unused diazo. This is the basis for the color change method of determining optimum exposure. 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. After drying, it is possible to re-expose the screen, bleaching out the remaining diazo and further cross-linking the stencil to improve its solvent and water resistance. However, it should be noted that depending on the degree of initial under-exposure, the final stencil, although fully chemically cross-linked, 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 screenmesh has been physically encapsulated, front and back, with hardened emulsion.

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

DUAL-CURE EMULSION

When under-exposed, the situation is the same as for a diazo emulsion in that the unreacted diazo can further cross-link the stencil on post-exposure and improve its solvent and water resistance. However, the difference is that even correctly exposed dual-cure stencils can benefit from post-exposure. The reason is that the second cross-linking system, the part that makes an emulsion dual-cure, 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.

PURE PHOTOPOLYMER EMULSION

Photopolymer emulsions benefit the most 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 react 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 cross-link 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, while the stencil is wet, some of the unreacted molecules will re-align and be available for cross-linking the second time around. Thus resulting in improved solvent and water resistance. In addition, the post-exposure can be made much longer than the original imaging exposure in order to maximize the cross-link density.

