WHAT TO EXPECT FROM YOUR STENCIL

INTRODUCTION
STENCIL TYPES
TECHNOLOGY OF STENCILS
PROCESSING VARIABLES
LIMITATIONS

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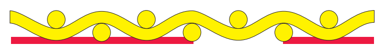
PART 1 • INTRODUCTION

The purpose of this presentation 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 photo-stencils 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 screenmesh. 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.

INDIRECT FILM

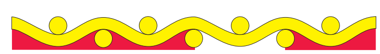


- **Highest resolution (processed away from the mesh)**
- **Excellent definition (short print runs only)**
- **Poor durability, 00's of prints**
- **Expensive**
- **Requires skill to process (chemical processing)**
- **Fine mesh only**

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 photographic emulsion, that has been manufactured to a precise thickness, is adhered to a wet screenmesh 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.

CAPILLARY FILM



- **Very good resolution and definition**
- **Medium durability, 000'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.

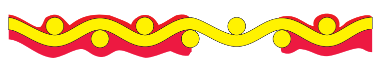
DIRECT/INDIRECT

- **Very good resolution and excellent definition**
- **Extrememly durable, 0000's of prints**
- **Expensive, both film and emulsion required**
- **Messy process, requires skill**
- **Most suitable for small format**

Figure 3

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 much 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**
- **Extrememly durable, 0000's of prints**
- **Inexpensive**
- **Easy to automate**
- **Suitable for all size formats and any mesh count**
- **Widest compatability with ink chemistry**

Figure 4

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. Firstly it is a water soluble polymer, which means that stencil processing and developing can be carried out with water, rather than organic solvents. Secondly it is very 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. Thirdly, 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 expensive screenmesh 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 or Dual-Cure or Photopolymer. In addition, other ingredients such as fillers or bulking agents are added to increase solids content and improve wet strength of the stencil during processing. The choice of sensitizer, and the type or combination of fillers used will determine the properties of the end product. Ancillary ingredients include pigments, surfactants to improve coating quality, and defoamers to kill bubbles during processing.

The simplest technology employs a diazo sensitizer, 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 screenmesh during developing. The other ingredients that are added during manufacture 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, to increase solids content, and due to it's water repellent nature is also effective in increasing the wet strength of the stencil during processing, preventing over-swelling of the crosslinked 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, one each 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 Emulsions

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 shelflife 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

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 & solvent resistant**
- **Expensive**

Projection

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

Figure 7

Now, a screenprinting stencil has to perform four functions. Two are important for any type of screenprinting, 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 parameters 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.

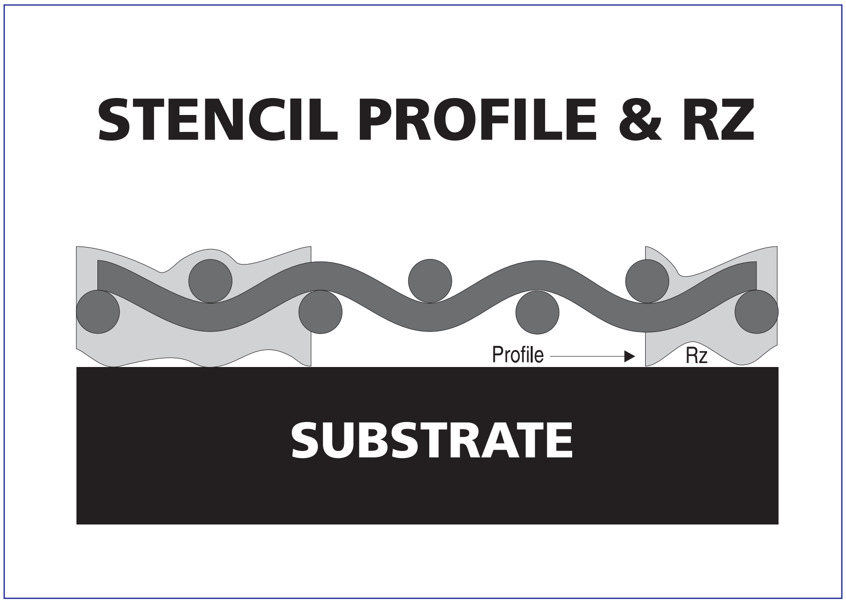


Figure 8

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.

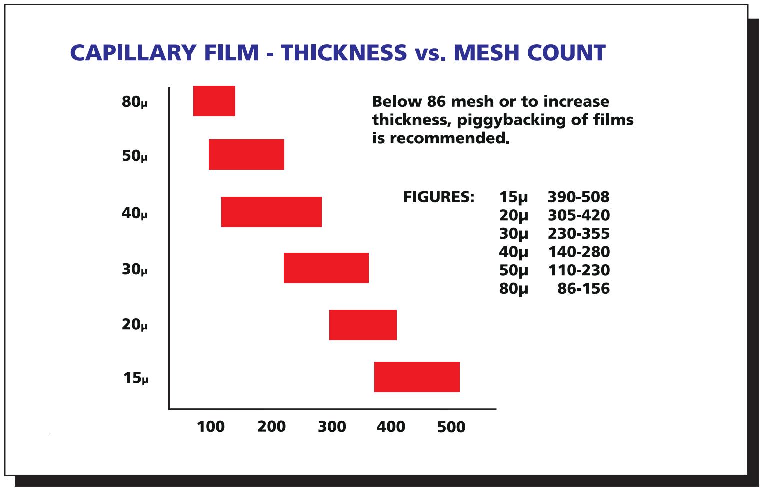


Figure 9

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 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 screenmesh, 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.

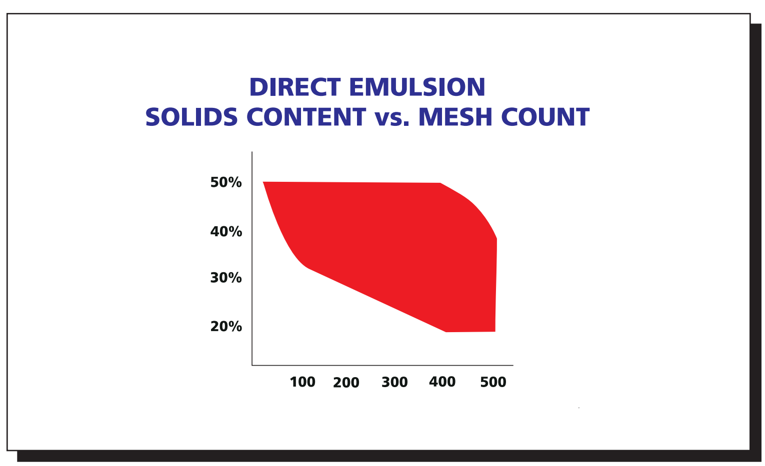


Figure 10

Regardless of which type of stencil system is used, correct exposure is of paramount importance in optimizing performance. Producing a screenprinting 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, 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 screenmesh 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 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 screenmesh is thoroughly washed after manufacture, dust and oils from handling, along with adhesive over-spray 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 wirecloth, 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, and 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

Screenmesh comprises two parts, firstly threads, and we need enough of these to support all of the detail in our image, and secondly holes, and it is the size and number of these, along with the stencil profile, that 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, become the dominant factors 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.

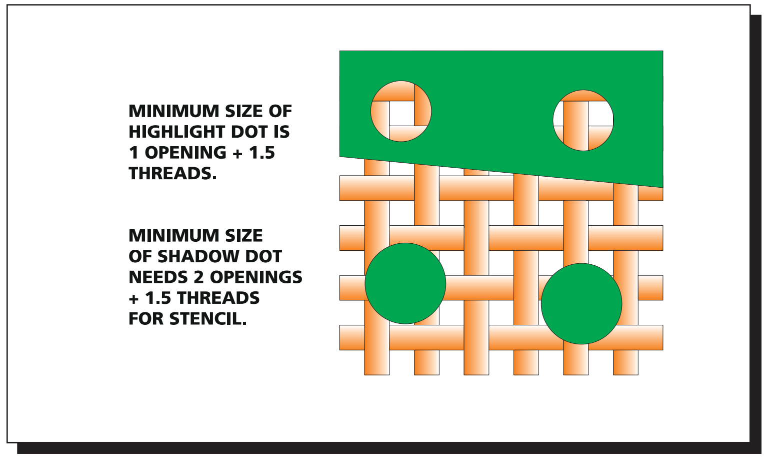


Figure 11

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.

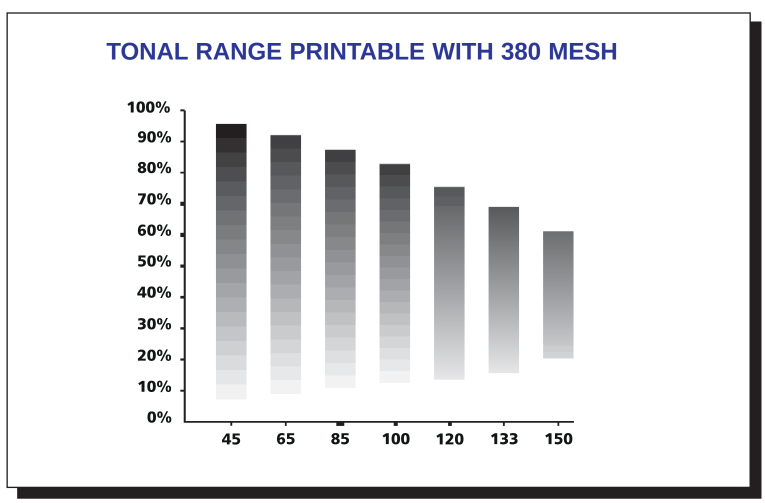


Figure 12

If a target is set of trying to print from 10% in the highlights, up to 85% in the 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%	
380	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.

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