



HANDBOOK

Quality Control & General Press Guidelines

Mesh Guidelines For Printing 4-Color Process

QUESTION

When printing four-color process, we know the importance of the angles used for the dots on the color separations. We also know we have to avoid certain combinations of mesh count with dots per inch on the positive in order to avoid moiré. What we are looking for are some guidelines on which mesh specification is most suitable for printing four-color process, and how fine a dot we should be able to hold.

GUIDELINES

The first thing to realize when printing four-color process is that screen tension is of paramount importance. Within this area, there are two factors that need to be controlled. Number one, it is important that all four screens are at the same tension level within one to two newtons, or you will have registration problems. If you increase off-contact in order to get better release of one screen out of the wet ink film, then the image on that screen prints bigger, causing misregistration.

Second, a minimum tension level of 20N is suggested. Less than this may not provide enough snap to cleanly release the stencil from the wet ink film once the squeegee passes. Failure to achieve this means that the screen drags in the wet ink and causes dot gain.

To address both these points, you will have maximum control over your screens if you use a Hitech (low-elongation) screen mesh. This type of mesh is designed to be more stable with respect to holding tension over time. This doesn't mean, however, that you should push the fabric to its limit by trying to achieve the highest possible tensions. It is more important to achieve consistent tension levels while working above the minimum requirement.

Our next recommendation is to use plain weave mesh. As a result of advances in weaving techniques, plain

weave mesh is available in some of the finer mesh counts that traditionally were too difficult to produce, and so had to be woven with a twill, or even a double twill construction. The bottom line is that plain weave mesh interferes less with the way ink flows on the print, by virtue of its minimal contact area, or footprint, since only the crown of the mesh knuckles touch the substrate. Twill weave mesh will cause more problems with dot gain, and can even introduce moiré where you wouldn't expect it.

As far as how fine a dot you should be able to hold, that depends mainly on the mesh count you use, and on the thread diameter chosen. Minimum printable dot size, in microns, will then translate into a certain percentage of highlight dot, which depends on the halftone ruling (or number of dots per inch).

This minimum detail, that you can cleanly and consistently print, corresponds to openings in the stencil that are equal to one mesh opening plus one and a half thread diameters. Hence the relationship with mesh count and thread diameter.

If we choose a 305 plain weave mesh with 34 micron threads as an example, then so long as everything else is optimized (screen tension, ink, squeegee etc.), it should be possible to print down to 100 micron dots. This corresponds to 3% on a 45-line halftone, but only 9% on an 85-line. Detail smaller than this, for instance if your 85-line positive contains 7% dots, will always print as a moiré pattern.

An analogous situation exists in shadow areas of the print in order to ensure stencil durability during printing. Small spots of stencil clinging to the mesh, which you rely upon to block the flow of ink and distinguish between heavy mid to shadow tones, have to bridge between and adhere to a minimum of three mesh threads. Less than this, and shadow areas

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will quickly develop a spotty appearance, and again this may take the form of a moiré pattern. If we take the case of our 305.PW 34 mesh, the darkest tone on your positive that is safe to print corresponds to 94% on a 45-line halftone or 80% on an 85-line.

The following table compares the tonal range of some common halftone rulings that should be able to be printed through the mesh types shown.

If your specifications were that you have to be able to print a tonal range of 10% – 85%, then you can see from the chart that there is a minimum mesh count that you shouldn't drop below. For instance, an 85-line halftone would require the use of a 355 mesh or higher.

Higher mesh counts than the minimum can also be used if you want to print with a lower ink deposit, or you may be able to simply switch thread diameter. (This, however, enters us into a whole different story!)

MESH	RANGE OF DOT PERCENT		
	45 Line	65 Line	85 Line
Mesh Count / Weave / Thread Diameter			
196.PW 55	6% – 86%	13% – 71%	21% – 51%
230.PW 48	4% – 90%	9% – 78%	15% – 63%
280.PW 40	3% – 93%	6% – 86%	11% – 75%
305.PW 34	3% – 94%	5% – 89%	9% – 80%
305.PW 31	2% – 96%	4% – 91%	7% – 85%
380.PW 31	2% – 97%	4% – 93%	6% – 88%

Take Control Of Your Screens For Printing 4-Color Process With UV Ink

PART 1 – INTRODUCTION

The complexities of screen printing four color process are further complicated when using UV cured ink, by extra demanding requirements in controlling ink deposit.

It's not enough to have to deal with the relationship of dots per inch with mesh count, or carefully selecting the angle of dots on each separation so you avoid not only mesh/dot moiré, but even dot to dot moiré between the overlaid colors. Now you also have to avoid the problems that can occur from printing halftones with an excessive ink deposit. Problems will occur when printing third and fourth colors if ink transfer from the screen to the substrate is severely affected by excessive ink deposit from the first two colors down. This is due to the high solids/low shrinkage characteristics of UV cured inks.

In terms of detail, highlight dots represent a major challenge. For instance, a 10% dot on an 85 line halftone is 0.004" across. To put this in perspective, if it were the size of a quarter, a 2" X 3/8" squeegee would be nine feet thick and forty two feet high. Therefore, in order to give ourselves the best chance of being able to successfully reproduce over seven thousand of these 0.004" dots per square inch of print, and to do it consistently with a carefully controlled ink deposit, we need to be in total control of our screen making process.

PART 2 – THE STENCIL

A screen-printing stencil performs four functions. Two are important for any type of screen-printing, since the stencil must first reproduce the image which is to be printed, and then be resistant to abrasion and chemical attack. The last two functions however are particularly important for high quality halftone printing with UV ink. The stencil will increase the quantity of ink which is printed, and is also responsible for controlling image accutance, more commonly referred to as print edge definition.

Photostencils fall into four main cate-

gories. The first is known as Indirect Film, where the stencil imaging and development process is carried out independently of the screen mesh. The stencil is applied to the mesh with gentle pressure and dried prior to removal of the backing film. Although capable of high 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 some difficult substrates.

The second type of stencil is known as Direct Film or Capillary Film. In this case, a much thicker layer of photographic emulsion 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.

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 the same as for capillary film, but with the advantage that an even more firmly adhered and durable stencil results. The downside is that the stencil making process is more complicated, particularly in larger formats, and is also more costly.

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 stencil materials and methods of processing, and bringing several variables under control.

The two most important stencil parameters which affect print quality, because of

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their influence on both ink deposit and print definition, are stencil profile and Rz value. **See Figure 1.**

Regardless of which type of stencil system is used, if fine halftones are to be reproduced, an important area where total control is required is during exposure. Producing a screen-printing stencil, even for use with the fine mesh counts used for printing UV cured inks, involves exposing

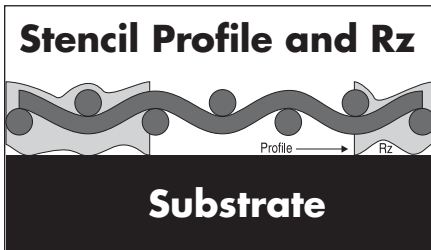


Figure 1

a coating which 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 in shadow areas during development, 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 your dots to shrink, leading to moiré in the highlights and a lack of density in the print, and eventually loss of parts of your image altogether. In order to optimize the exposure process it is important that the equipment used is capable of producing high resolution stencils without the need to underexpose. A minimum of 20" Hg of vacuum in the vacuum frame is required to ensure good enough contact between the artwork and emulsion during exposure. This prevents the undercutting of the image that occurs when light leaks under the pos-

itive. A good point light source fitted with a metal halide, or diazo, bulb is also recommended to produce optimum results, since there is a good match between the output 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 image area during exposure. Even coverage is essential for accurate reproduction 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 over exposed, and sometimes even both on the same screen!

Another important variable related to exposure is drying. Both capillary film and direct emulsion coatings require very thorough drying prior to exposure, since any residual moisture present in the coating will react preferentially with the photosensitive resins which are supposed to harden the stencil. When you expose a damp screen you end up with a stencil which exhibits the symptoms of having been under-exposed, except that no improvement is seen on increasing exposure time.

Processing variables aside, the ideal stencil for printing halftones with UV ink should be thin and flat, and the parameters we need to control in order to achieve consistent, high quality results are stencil profile and Rz value. For optimum edge definition a stencil with a smooth flat underside is required, ie a low Rz value. This is because the stencil, as well as reproducing the image, also has to act like a gasket and prevent the ink from bleeding beyond the image area under pressure from the squeegee. The ragged edge of poorly defined dots can induce moiré, flattens contrast due to dot gain in the highlights, and loses any separation between midtone and shadow areas.

Minimizing stencil profile is important not only because of its contribution of extra ink deposit, but also because of its

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affect on durability. High profile stencils are more prone to breakdown in shadow areas, where the image depends upon small isolated spots of stencil clinging to the mesh. Mechanical abrasion, and sometimes loss of adhesion, causes heavy midtone and shadow areas to develop a spotty appearance which sometimes takes the form of a dark moiré pattern.

Ideal values are shown in **Figure 2**, stencil profile should normally be in the range of 2-10 microns, ideal Rz value is normally in the range of 4-8 microns. Smooth or polished substrates require an Rz at the top end of the range to prevent cob-webbing or splattering of the ink due to static. For rough substrates, the lower the Rz the better.

Stencil Properties Required for Printing UV Ink
Stencil Should Be Thin and Flat
Stencil Profile : 2–10 microns
Stencil Rz Value : 4–8 microns

Figure 2

With capillary film, as long as the correct film thickness is selected, both stencil profile and Rz should automatically fall in the range of optimal values. **See Figure 3.** With direct emulsion the situation is not so simple. Simple wet on wet coating methods, which work so well for coarse and medium mesh counts, usually fail to transfer enough emulsion onto and through the fine mesh counts which are typically used for printing UV cured inks. The small percentage of open area, which is what restricts ink transfer, also prevents emulsion from passing through the mesh and building up on the print side of the screen. Even when using a high solids content emulsion, the shrinkage that occurs on drying may prevent us from achieving Rz values in the optimum range. **See Figure 4.**

Capillary Stencil, Profile & Rz On 380 PW 34		
Stencil	Profile	Rz
15µ Capillary	2µ	3µ
20µ Capillary	8µ	2µ
15µ Capillary w/Emulsion	10µ	3µ

Figure 3

This problem is most evident with mesh types which are the best at minimizing ink deposit, particularly if you are using a sharp edge emulsion coater. In these

Emulsion Stencil, Profile & Rz On 380 PW 34		
Stencil	Profile	Rz
40% Solids 2+3 Sharp Edge Coater	2µ	12µ
50% Solids 2+3 Sharp Edge Coater	3µ	10µ
40% Solids 2+3 Dull Edge Coater	7µ	10µ
50% Solids 2+3 Dull Edge Coater	9µ	8µ

Figure 4

circumstances, an additional coat of emulsion after drying can cut the Rz value in half, hopefully bringing it into the range we require, whilst adding barely a micron to the stencil profile. **See Figure 5.** Needless to say, maintaining constant stencil thickness and Rz values from screen to screen is all important if consistent print results are to be obtained, and if direct emulsion is the stencil of choice, then the use of an automatic coating machine is highly recommended to remove variables from the coating process.

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Emulsion Stencil, Profile & Rz On 380 PW 34		
Stencil	Profile	Rz
40% Solids 2+3 Dry +2 Sharp Edge Coater	3 μ	5 μ
40% Solids 2+3 Dry +1 Dull Edge Coater	8 μ	5 μ

Figure 5

PART 3 – THE MESH

Before deciding which type of mesh to use, important consideration must be given to tensioning. Consistency of tension from screen to screen is of paramount importance when printing four-color process, and as with any type of multi-color printing, registration problems will occur if different tension screens are used. This is due to the higher off contact requirement for lower tension screens causing image enlargement. As a minimum, 20N of tension is suggested. Printing with low tension screens can cause poor ink release as the screen separates from the wet ink film, and dot gain may occur if the squeegee drags the stencil in the wet image. Increased off-contact can counteract this to a certain extent, but then the image will print too big, and the excessive squeegee pressure required will cause premature stencil wear.

Now screen-printing mesh comprises two parts, first threads, and you need enough of these to fully support the detail in the stencil, and secondly holes, and it is the size and number of these that controls your ink deposit. Normally mesh-count is the dominant factor in determining ink deposit. Above 305 mesh however, when we are dealing with the types of mesh designed for printing UV cured ink, ink deposit is no longer determined by mesh count. Thread diameter and the weaving construction itself become the over-riding considerations.

Fine mesh, which has traditionally been woven in a twill weave configura-

tion, with the finest counts such as 460 being double twill, is now available in plain weave. In twill weave, the threads pass over one/under two, in double twill it's over two/under two. Plain weave mesh by comparison, with it's over one/under one configuration, has a much lower percentage open area since a thread is being inserted into every space in the weave. This not only shrinks the size of the mesh openings, but also results in a thinner fabric. The net result is that plain weave mesh prints less ink than twill weave mesh woven from the same thread, just what we need when printing four-color process with UV cured inks. If we take 380 mesh woven from 34 micron threads as an example, changing weave construction from twill to plain reduces ink deposit from 11 microns to 7 microns.

See Figure 6.

Comparison of 380 Plain & Twill Weave			
	Fabric Thickness	% Open Area	Ink Deposit
380 PW 34	56 μ	13%	7 μ
380 TW 34	63 μ	17%	11 μ

Figure 6

Another area where plain weave mesh is capable of superior results is image definition. With twill weave mesh, the 'foot-print' of the mesh on the substrate, ie the area where the surface of the threads contact, is quite substantial. In some circumstances it interferes with the flow of ink, and can cause poor print quality. With plain weave mesh since only the crown of the mesh knuckle contacts the substrate, interference with ink flow is kept to a minimum, and substantial improvements in print quality can generally be seen.

Plain weave mesh suitable for printing four-color process with UV cured ink is now available in 355, 380, 420 and 460 mesh counts. The 355 and 380 mesh is even available with a choice of

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34 or 31 micron thread diameters. The result of this is that by selecting the appropriate mesh, ink deposit can be varied from 7 microns, up to 15 microns, depending on your application or color-matching requirements, while still realizing the benefits of better print quality conferred by using plain weave fabric.

See Figure 7 for mesh specifications.

Comparison of 355, 380, 420 & 460 Plain Weave				
	Fabric Thickness	% Open Area	Ink Deposit	
355 PW 31	48 μ	28%	15 μ	
355 PW 34	55 μ	16%	9 μ	
380 PW 31	48 μ	20%	10 μ	
380 PW 34	56 μ	13%	7 μ	
420 PW 31	49 μ	17%	8 μ	
460 PW 27	43 μ	18%	8 μ	

Figure 7

PART 4 – THE LIMITATIONS

When it comes to screen-printing halftones, the fact that we need the mesh to provide support for the detail in our image means that we are not going to be able to print a tonal range of 1% to 99%, **See Figure 8.**

At the highlight end of the tonal range, when the openings in our stencil become smaller than one mesh opening plus one and a half thread diameters, then they can be obscured by falling on or very near a thread. Trying to print dots this small invariably results in a moiré pattern, despite the fact that all the rules concerning angles and dots per inch have been observed. This limit of how fine a highlight we can satisfactorily print, depends mostly on mesh count, and to a lesser extent on thread diameter, but using 380 PW34 mesh as an example, the minimum stencil opening which will consistently print without moiré is 85 microns in diameter. This corresponds to a 4% dot for a 65 line halftone, 7% for 85 line, and 10% when we go to 100 line.

At the shadow end of the tonal range, the limit is reached when the small specks of stencil that have to block the flow of ink, and differentiate between the shadow tones, become smaller than two mesh openings plus one and a half thread diameters. Smaller than this, and they may adhere to only one or two threads and lack sufficient adhesion to withstand the rigors of processing. For instance, when trying to print a halftone which is too fine for the mesh in use, what usually happens is that the tonal range will collapse after the mid-tones. Once we exceed the detail carrying capacity of the mesh, we can print only one tonal value, and that is 100%. Again the mesh count, and to a lesser extent thread diameter are the important factors in determining the limit of what can be satisfactorily printed. In this case however, unlike the highlights where thinner threads are better, thicker threads extend the printable tonal range by offering improved adhesion. The upper limits for 65, 85 and 100 line halftones printed with 380 PW34 mesh correspond to 93%, 88% and 82% dots respectively.

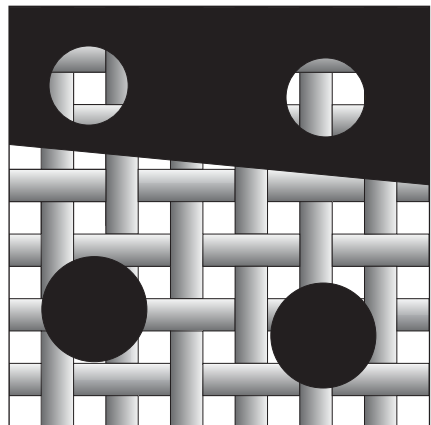


Figure 8

**Minimum Size of Highlight Dot Is
1 Opening + 1.5 Threads**

**Minimum Size Of Shadow Dot Needs
2 Openings + 1.5 Threads For Stencil**

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For more extensive information for 380 mesh. **See Figure 9.**

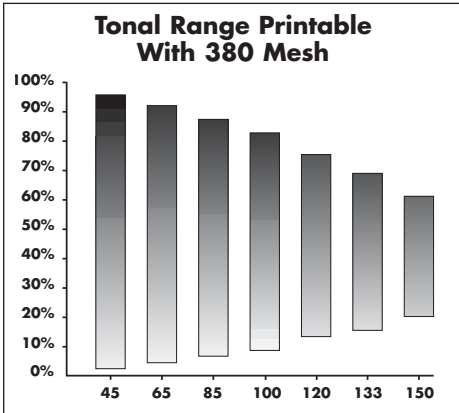


Figure 9

When selecting the optimum mesh type to use, both ink deposit and tonal range are usually taken into account. **See Figure 10,** which shows a comparison of both ink deposit, and minimum high-light dot which can be printed through plain weave mesh from 355 up to 460.

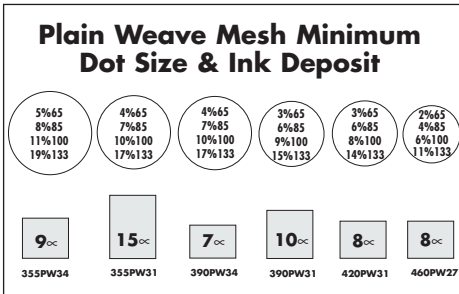


Figure 10

Two developments in methods of color separation, one established, and one very new, offer improved results for certain types of four color process printing with UV cured inks. The first method, which is widely used, is known as GCR or Gray Component Replacement. It enables a reduction in ink deposit in areas of the print where yellow, magenta and cyan all

occur together. GCR will eliminate an equal amount of all three, which in some areas removes one of the colors entirely if 100% GCR is used. The missing gray is then restored with the final black printer.

See Figure 11.

The second development, which is still being refined, is a new method of producing separations and is known as frequency modulated halftone, or stochastic screening, or random dot. The separations produced by this method are based upon randomly distributed, very small uniform sized dots, which simulate tones by increasing in packing density. This differs from conventional separations, where the dots are equally spaced and simulate tones by changing size. These random dot separations, because they have no angles, offer wider latitude in avoiding moiré, and are also capable of reproducing a wider range of tones. On the downside, they require an extremely high resolution stencil, and exquisite control over screen exposure if the image is not to be lost altogether. They may also be less suitable for reproducing certain types of artwork, as they sometimes suffer from a grainy appearance in highlight areas. However, this alternative technology offers promise in overcoming some of the problems some of the time, and may provide the opportunity to expand the use of screen-printing into otherwise difficult applications.

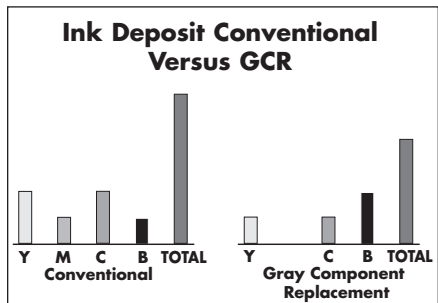


Figure 11

Controlling Off-Contact For Successful Printing

QUESTION

I have been told by many people that controlling off-contact is the key to success in printing. But how does it really affect my results?

SOLUTION

Off-contact is the distance between the substrate and the screen. This distance is needed to keep the screen from staying in contact with the substrate during printing and to control proper snap-off. While off-contact is not the only variable in the ocean of possible problems, it is a decent size fish as far as press variables go. The off-contact distance can affect your printing in any number of ways. Before you tackle this problem, however, you must make sure your screen has proper tension. Check your mesh manufacturer's tension recommendations. (Refer to "Using Proper Tensioning Techniques to Achieve the Desired Tension Level" Tech Tip on page 32.)

Assuming that your screens are at the proper tension levels, we will begin by covering the problems caused by too little off-contact. Poor release: if the fabric sticks to the substrate after the squeegee has passed, and the screen is lifted, you'll notice it takes a percentage of the ink with it and leaves mesh marks. You then have two options; either raise the off-contact, or slow down the print speed to accommodate this poor release. This is a common but incorrect solution. If you make no adjustments, double images can appear, as well as image distortion. Not to mention the poor ink coverage that will result.

High off-contact, which is as common, causes a myriad of other problems. (Again, we will assume that your screen

tension is correct.) Registration problems: these occur due to the excessive fabric deflection brought on by high off-contact. Inadequate squeegee pressure: As the off-contact distance increases, the squeegee pressure must be increased to force the fabric into contact with the substrate. This causes slower press speeds, image distortion, squeegee wear, and screen failure. Faster snap-off: Increasing the off-contact and squeegee pressure creates a faster snap-off. This can cause print defects such as bubbles, smearing, incomplete images, mis-registration and print voids.

Until recently, there were only a few ways to determine the off-contact distance. The most accurate method was by using a mechanical gauge. However, this process could take valuable time away from production, so it was usually abandoned and left to the operator to "eyeball" the distance. Now, the newly developed Positector 6000 off-contact gauge, with an easy-to-read digital display, can provide measurements automatically in minutes. Thus repeatability can be built into this print variable. Keep in mind, however, that this measurement provides the actual off-contact distance, not a determination of what is the proper off-contact distance. It is up to you, through testing, to determine the proper distance required for each press, screen tension, and format size. Having this tool to measure the distance, and maintain uniformity, makes the process more repeatable.

NOTE: a good rule of thumb is to have your screen as close as possible to the substrate, while maintaining the proper snap-off.

Choosing The Best Squeegee For Your Application

1. DUROMETER AND PRINTING EDGE (As Related To Ink Deposit)

The lower the durometer, and the less sharp the print edge, the more ink is deposited. The higher the durometer, and the sharper the print edge, the less ink is deposited. The more irregular or rougher the surface of the substrate is, the softer the durometer needed. (And vice versa.) To maximize solvent resistance, always use the hardest durometer that is practical for the particular job. The harder the squeegee, the more dense the urethane and therefore the stronger the chemical resistance.

2. COLOR CODING

Use color coding as a means of fast and easy identification of the correct squeegee durometer once you've established the hardness for your application.

3. PROFILE EDGE

- a) Rectangular: applies to 95+ % of flat type printing.
- b) "V" shape: applies to 90+ % of cylindrical printing. (Square is also used in some instances.)

- c) Ballnose (rounded): used for more ink deposit — generally in some textile printing and industrial specialized heavy deposit applications. However, print edge sharpness is sacrificed. (Also used for direct/indirect stencil making and emulsion reinforcement of capillary film stencils.)
- d) Dual-Durometer: used to optimize ink transfer efficiency and squeegee setting (pressure, angle, shear) via decreasing the blade's susceptibility to bending.
- e) Composite: (similar to above) used for maximum rigidity.

4. LENGTH OF SQUEEGEE

Try to maximize the "free mesh area." This is the distance between the ends of the squeegee and the inside of the frame profile. This area is vital to provide the important flex and snap functions of the screen. It affects registration, print clarity, uniformity of ink deposit, and the life of the stencil, fabric and squeegee.

Care And Maintenance To Extend Squeegee Life

Even the most solvent and abrasion resistant squeegees, such as our Duralife™ brand, can benefit from some preventive maintenance to maximize longevity.

1. STORAGE

- a) Store in a dry and generally cool area (50–85 degrees Fahrenheit).
- b) Do not store coiled; lie flat to avoid distorting the print edge.

2. MAINTENANCE/ROTATION

For optimum squeegee life, rotate your blades in use as much as possible. All squeegees tend to swell and soften to some extent while in use. If they are given

the opportunity to dry and return to their original state, they will last longer.

- a) Establish a rotation schedule, based on the aggressiveness of your particular ink system, to allow the squeegee to "rest".
- b) Inspect for signs of swelling – After approximately 2-4 hours of continuous printing with aggressive inks and solvents.

After approximately 6-8 hours of continuous printing with moderate to weak inks and solvents.

- c) Change the squeegee at the first sign of swelling.

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- d) Before resting squeegee, clean thoroughly with a solvent to remove any ink residue.
- e) Never soak any squeegee in a solvent for an extended period; irreversible damage could result.
- f) Depending on the durometer, and the ink and solvent aggressiveness, the squeegee may require a minimum of 12 to 48 hours of rest before re-use or re-sharpening. (Softer duros tend to absorb more and require longer recovery.)

3. SHARPENING

- a) Before sharpening, the squeegee may require a 12 to 48-hour rest (depending on ink and solvent aggressiveness) to allow any solvents to evaporate.

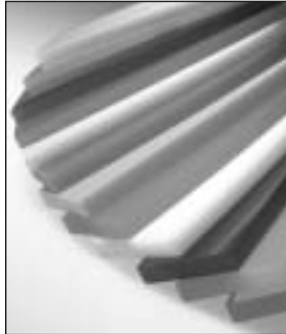
- b) A blade-cut type sharpener, versus a belt or grinding wheel sharpener, will yield a print-ready squeegee after just one pass.
- c) Belt or grinding wheel sharpening is acceptable for most applications. It is best done in a two-step process using multiple passes (and limited pressure) that take off as little material as possible. This reduces heat buildup, which can melt the squeegee.

STEP 1. Coarse grit (60-120) to remove worn edge.

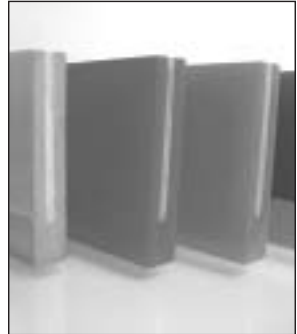
STEP 2. Fine grit (160-300) to create a sharp edge and a smooth, polished finish.



Duralife™ dual-durometer squeegees.



Duralife™ color-coded squeegees.



Duralife™ composite squeegees.

Guidelines To The Use Of A Transmission Densitometer For Screen Making

With the increasing use of artwork generated by laser printers, the need for checking the overall density of screen positives is more crucial. Vellum can particularly be a nightmare. Use of a transmission densitometer is the ideal quality control check for maintaining the density criteria required for optimum performance. For example, background density should be as low as possible. Preferably below 0.1, since a high background density will cause underexposure problems. Density of the image area should be as high as possible. Preferably above 3, to prevent fogging and poor washout.

A transmission densitometer, used in the % mode, is also ideal for checking the tonal range on halftone positives. It can be used as a QC measure on any films supplied, with attention paid to difficult areas, to determine if they fall within the appropriate range. screen-printing can not reproduce the 1%-99% dot range that can be held with offset printing. The range that can be reproduced successfully depends on the mesh count chosen, and the lines per inch count of the artwork. If everything else is perfect, such as tension, ink, squeegee, etc., then the following limits apply.

Mesh Count	65 Line	85 Line	100 Line	120 Line
305	5-89%	9-80%	13-71%	-
355	4-91%	7-85%	10-79%	14-70%
380	4-93%	6-88%	9-82%	13-75%
420	3-94%	5-90%	8-86%	11-80%
460	3-95%	5-92%	7-88%	9-85%



Use the TQ+™ Densitometer to maintain consistent film positives.

Guidelines To The Use Of A Reflection Densitometer For Screen-Printing

A reflection densitometer can be indispensable in checking your prints to quantify ink deposit, or solve ink mixing (pigment ratio) problems that may develop during long print runs and can cause shade differences. It can also be used to distinguish hue differences with ratio of CMYK values, and aid in color matching.

When printing four-color process, a reflection densitometer can be used to detect if any of the inks are under or over strength by quantifying problems with gray

balance in 100% print areas. If calibrated on a 100% print area of a particular color, it can then detect the degree of dot gain (or loss) for that color by comparison with the transmission density readings from the positive. The standard procedure is to conduct these evaluations on step wedges that are printed with the image. For those printers who do not have the luxury of running test strips that can be trimmed off, an option is to settle on selected areas of the print that can be tested consistently.



This advanced, menu-driven IQ 150™ Reflection Densitometer provides the easiest means of density readings available.

Preventive Checklist

(For More Predictable & Repeatable Screen Making)

1. MESH SELECTION

- My mesh selection is based on the most suitable blend of tension/print characteristics for the degree of detail, length of run, ink deposit thickness and substrate surface.
- With my mesh count, I've chosen the proper thread diameter for my print requirements (higher tension, longer print life, better edge definition, 4-color process).
- The tension level I use corresponds to the mesh count/thread diameter (thinner = lower tension).
- I use a plain weave with a thin thread diameter, the combination recommended for optimum print detail.
- I have taken into consideration that twill weaves deposit more ink than plain weaves.

2. FRAME SELECTION & MESH TENSIONING

- I considered the format size and tension levels used when selecting the frame type, material and profile.
- When selecting my tensioning equipment, the determining factors were: my application, production capacity, tension levels, mesh type (polyester, nylon or stainless steel) and mesh count (coarse or fine).
- A tension meter, used correctly and optimally, is a standard part of my stretching process.
- I avoid taking the mesh to ultimate tension levels, as this sacrifices screen life.
- I use the most effective frame adhesive based on such factors as solvent and water resistance, production time requirements and odor.
- Production adheres to the mesh manufacturer's recommended tension levels.
- Correct tensioning procedures were established by reviewing the equipment manufacturer's recommendations, and by testing and documenting what works best in my operation.

3. MESH PREPARATION

- The screen making area is kept as isolated and clean as possible, as airborne dust and oils can cause pinholes and fisheyes.
- I degrease my screens from the first time they are used, and each time thereafter.
- Use of a wetting agent is standard, as it is critical for proper film application, and beneficial to uniform emulsion adhesion.
- A mesh prep with an abradant is used on "virgin" mesh (conventional synthetic monofilament).
- Household cleaners are never substituted for mesh degreasers or abradants, as they can damage the fabric, and contain oils/lanolin that can interfere with screen performance.
- Compressed air is not used to remove excess water from screens; it contains oils and water impurities that can cause fisheyes and pinholes.

continued on next page

Preventive Checklist

(For More Predictable & Repeatable Screen Making)

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4. STENCIL SELECTION & APPLICATION

- My emulsion has been chosen based on ink type, solvent and water resistance, exposure time, artwork detail and durability.
- Tests have been run, and results documented, regarding what performs best in my particular operation.
- When coating manually, I use a screen coating trough designed for this purpose.
- Automatic coating has been evaluated in relation to production capacity, print requirements and the need for coating thickness consistency.
- The proper coating procedures are used, based on the manufacturer's recommendations and what works best in my process.
- I adjust coating sequence based on mesh specification.
- An emulsion thickness measuring device is used during stencil making.
- The proper emulsion thickness is matched to the resolution I need to hold.
- Stencil smoothness is matched to substrate smoothness using an Rz meter.

5. EXPOSURE

- Dried screens are checked for residual moisture before exposure by using a stencil moisture meter.
- My exposure system has been matched to my particular emulsion.
- The correct distance between my exposure system and vacuum frame is calculated and maintained.
- As a process control, an exposure calculator is used regularly and properly (and read accurately) on production screens.
- A radiometer is used to measure my exposure system's lamp uniformity and intensity.
- A radiometer is also used to help determine appropriate exposure times.
- The correct exposure time is determined specifically for each mesh count and emulsion type.

Regulatory Resources: Guidance Tools

As screen printers, you are called upon to handle regulated or hazardous materials. As a safety-conscious manufacturer/supplier, we've included the following additional resource suggestions to help you learn more about the safe use, disposal and transport of such materials. We've also included (on the next page) a step-by-step guide to waste classification and disposal. For more information or assistance, please call our Regulatory Affairs Coordinator at (847) 296-5090.

1. CODE OF FEDERAL REGULATIONS (CFR) & FEDERAL REGISTER

- Regulatory bible.
- Regulations as specified by the Occupational Safety & Health Administration (OSHA/29 CFR), Environmental Protection Agency (EPA/40 CFR) & Department of Transportation (DOT/49 CFR).
- The Federal Register is the most current listing of both proposed and finalized regulations.

SOURCE: Local library, safety supply companies, consulting companies, and the Government Printing Office
Phone: (202) 783-3238 • www.access.gpo.gov

2. COMPLIANCE MANUALS

- Regulations are translated into layman's terms.
- Easier to understand & translate legal terminology.
- Step-by-step compliance.
- Some address one specific regulation.
- Offer update services.

SOURCE: Safety supply companies, consulting companies.

3. TRADE MAGAZINES ("OCCUPATIONAL HEALTH & SAFETY", "ENVIRONMENTAL PROTECTION")

- Discussions of regulations.
- Regulation updates (proposed & finalized).
- Informative articles written by environmental and safety professionals, industrial engineers, chemists, etc.
- Methods for waste treatment, recycling & water treatment are presented.

SOURCE: Stevens Publishing Company. Phone: (972) 687-6700 • www.stevenspublishing.com

4. MONTHLY NEWSLETTERS & BULLETINS

- Offer regulation updates and discussions of current "hot" topics.
- The Screen Printing & Graphic Imaging Association's (SGIA) monthly "Tabloid" includes a government affairs section.

SOURCE: Consulting companies, professional trade associations (Chemical Manufacturer's Association and SGIA) and trade magazines. Phone: (703) 385-1335. www.sgia.org

5. SEMINARS & COURSES

- Focus on specific agencies and specific regulations.
- Offer framework for understanding and complying with regulations.
- Speakers/instructors are often former employees of OSHA, EPA, or DOT, consultants, and/or industry experts.
- Offer certification programs.

SOURCE: Consulting companies, professional trade associations (Chemical Manufacturer's Association and SGIA) and trade magazines.

continued on next page

Regulatory Resources: Guidance Tools

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6. CONSULTING COMPANIES

- Offer advisory legal hotlines for compliance guidance.
- Will perform safety and environmental audits of your facility.
- Will assist in completing & filing complicated regulatory reports, permits, waste documentation, etc.

SOURCE: Company direct, Yellow Pages, industrial directories.

7. LOCAL & LAW LIBRARIES

- To obtain copies of city/county codes, state/federal regulations (CFR, Federal Register).
- Research specific areas (like wastewater treatment technology, etc.).

SOURCE: Telephone directory/Yellow Pages, local business or community directory, city agencies.

8. MANUFACTURERS/SUPPLIERS

- To obtain/interpret Material Safety Data Sheets (MSDS).
- To obtain technical information regarding product use, handling and disposal.
- Usually offer compliance assistance/guidance.
- Often employ a regulatory/compliance officer and, in some cases, an entire staff.

SOURCE: Product labels, product literature, MSDS, trade and/or industrial directories.

9. MATERIAL SAFETY DATA SHEETS (MSDS)

- Provide an excellent quick reference source.
- Provide chemical composition information; usually disclose hazardous ingredients.
- Often provide OSHA, EPA and DOT information on a single document.
- Sometimes offer specific methods for safe handling, pollution control and waste treatment.

SOURCE: Manufacturer, supplier, distributor.

10. LOCAL AUTHORITIES

- Local OSHA/EPA/DOT offices, water reclamation district (Publicly Owned Treatment Works/POTW), county health department.
- To obtain copies of regulations.
- To obtain compliance assistance.
- Offer 800# hotlines for regulation updates and interpretation.

SOURCE: Local telephone directory, local business or community directory, government agencies, SGIA, manufacturers/suppliers.

Step-By-Step Guide To Waste Classification & Disposal

I. IDENTIFY THE WASTE AND/OR ITS CONSTITUENTS.

A. Consult resources.

1. Review Material Safety Data Sheets (MSDS).
2. Contact the manufacturer.
 - a) To obtain assistance interpreting the MSDS.
 - b) To obtain component information/ingredient disclosure.

II. CLASSIFY THE WASTE (HAZARDOUS/NONHAZARDOUS).

A. Consult resources.

1. Review MSDS for hazardous ingredients (usually disclosed down to 1%; carcinogens/toxins down to 0.1%).
2. Consult the Code of Federal Regulations (CFR)/compliance manuals for hazard class definitions and lists of hazardous/regulated chemicals.
 - a) Do the chemical constituents meet the definition of "hazardous", as specified by either the Occupational Safety & Health Administration (OSHA), Department of Transportation (DOT) or the Environmental Protection Agency (EPA)?
 - b) Are the chemical constituents specifically listed/regulated by any of the above-mentioned agencies?
 - c) Are the chemical constituents any of the following?
 - Volatile Organic Compounds (VOCs)/Federal Clean Air Act?
 - Ozone Depleting Chemicals (ODCs)/Federal Clean Air Act?
 - Hazardous Air Pollutants/Federal Clean Air Act
 - Toxic as per Superfund Amendments & Re-authorization Act of 1986 (SARA Title III)?
 - Priority Pollutants as per the National Pollutant Discharge Elimination System (NPDES)/Clean Water Act?
 - d) Are any of the chemical constituents either listed or characteristic hazardous wastes, as specified by the Hazardous & Solid Waste Amendments (HSWA)/Resource Conservation & Recovery Act of 1976 (RCRA) in Title 40 of the Code of Federal Regulations (40 CFR)?
3. Review state and local authorities' regulations.
 - a) Are the chemical constituents regulated under a state hazardous/solid waste program?
 - b) Are the chemical constituents regulated under a state/local air quality program?
 - c) Are the chemical constituents regulated/prohibited from discharge by the local Publicly Owned Treatment Works (POTW/sewer authority)?
4. If waste is hazardous, determine its appropriate class/characteristic (ie. ignitable, corrosive, reactive or toxic).

III. DETAIL INFORMATION ON THE PRINTING/RECLAIMING OPERATIONS AND THE QUANTITIES OF WASTE INVOLVED.

- A. How is the chemical (pollutant) being used in the operation?
- B. If the waste is a mixture, what percentage is hazardous?
- C. Is the waste (or its constituents) being emitted from your facility?
If yes, then: Review state/local air permitting requirements.

continued on next page

Step-By-Step Guide To Waste Classification & Disposal

continued from previous page

- D.** Does the waste (or its constituents) enter your effluent (waste stream)? If yes, then:
 - 1.** What is the concentration of the pollutant at the point of introduction?
 - 2.** What is the water usage/consumption on a typical production day?
 - 3.** Is the effluent being substantially diluted by other waste streams?
 - 4.** What is the probable concentration of the pollutant in the exiting effluent?
 - 5.** Is the waste (or its constituents) either acidic or alkaline in nature?
 - 6.** Is the waste (or pollutant) known to be biodegradable?
 - 7.** What are the Biochemical Oxygen Demand (BOD)/Chemical Oxygen Demand (COD) values of the constituents?

IV. CONDUCT (RECOMMENDED) WASTE CHARACTERIZATION AND/OR EFFLUENT SAMPLING/TESTING.

V. MAKE GENERAL ASSESSMENT BASED ON THE ABOVE INFORMATION.

- A.** If waste characterization and/or effluent testing can be done, then it's advisable to wait for the results before making a determination.
- B.** If the waste involved is, in fact, hazardous, consider switching to safer, non-hazardous alternatives, if possible. You may be able to significantly reduce, or eliminate, your hazardous waste inventory and subsequent pollutants.
- C.** If very large quantities of waste are involved, then waste hauling may be recommended (whether the waste is hazardous or not).
- D.** If a generally accepted method of recycling/pretreatment is plausible for the particular waste, then it should be considered at this point.
- E.** Research potential recycling/pretreatment strategies. (Examples: distillation, filtration, neutralization, aeration, oil/water separation, toxics precipitation.) These recovery/pretreatment techniques can sometimes allow for recycling of solvents and/or cleaning up polluted waste streams.
- F.** Gather information from vendors regarding available systems, operation/maintenance of equipment and associated costs. Weigh the pros and cons of "in-house" treatment versus waste hauling.
- G.** If "in-house" treatment is not viable, and/or large quantities of "known" hazardous waste are being generated, then it is recommended that the printer safely collect and retain the waste for haulage. Manufacturers can offer guidance in regard to handling of waste associated with their products.

Conversion Guides

To Convert From	To	Multiply By
Bar	Kilogram per square centimeter	1.01977
	Pascal	100000.0
	Pound per square foot	2088.576
	Pound per square inch	14.504
British Thermal Unit	Footpound	778.6
	Joule	1055.0
	Kilocalorie	0.252
	Kilogram-force meter	107.6
	Kilowatt hour	0.000293
British Thermal Unit Per Second	Horsepower	1.415
	Joule per second	1055.0
	Kilocalorie per second	0.252
	Kilowatt	1.055
Centigram	Dram	0.00564
	Gram	0.01
	Kilogram	0.00001
	Ounce	0.00035
	Pound	0.00002
Centimeter	Foot	0.0328
	Inch	0.3937
	Meter	0.01
	Millimeter	10.0
	Yard	0.0109
Centipoise	Gram-force second/square centimeter	0.0000102
	Kilogram per meter hour	3.6
	Poise	0.01
	Pound per foot hour	2.419
	Pound per foot second	0.000672
	Pound per inch second	0.000056
	Pound-force second per square foot	0.0000209
	Pound-force second per square inch	0.000000145
Cubic Centimeter	Cubic foot	0.000035
	Cubic inch	0.06102
	Cubic meter	0.000001
	Cubic yard	0.0000013
	Fluid ounce	0.03382
	Liter	0.001
	Milliliter	1.0
Cubic Foot	Cubic centimeter	28317.0
	Cubic inch	1728.0
	Cubic meter	0.0283
	Cubic yard	0.037
	Gallon	7.48

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Cubic Inch	Cubic centimeter	16.387
	Cubic foot	0.00058
	Cubic meter	0.000016
	Cubic yard	0.000021
	Fluid ounce (Imp.)	0.57677
	Fluid ounce (U.S.)	0.5541
	Gallon (Imp.)	0.00361
	Gallon (U.S.)	0.00433
	Liter	0.01639
	Milliliter	16.387
	Quart (Imp.)	0.01442
	Quart (U.S.)	0.01732
Cubic Meter	Cubic centimeter	1000000.0
	Cubic foot	35.3145
	Cubic inch	61023.5
	Cubic yard	1.3079
	Gallon	264.2
	Liter	1000.0
Cubic Yard	Cubic centimeter	764559.0
	Cubic foot	27.0
	Cubic inch	46656.0
	Cubic meter	0.7648
Fluid Ounce – Imperial	Cubic inch	1.7338
	Fluid ounce (U.S.)	0.9607
	Gallon (Imp.)	0.00625
	Gallon (U.S.)	0.0075
	Liter	0.02841
	Milliliter	28.4132
	Quart (Imp.)	0.025
Quart (U.S.)	0.03	
Fluid Ounce – U.S.	Cubic centimeter	29.57286
	Cubic inch	1.80469
	Fluid ounce (Imp.)	1.0408
	Gallon (Imp.)	0.0065
	Gallon (U.S.)	0.0078
	Liter	0.02957
	Milliliter	29.57286
	Quart (Imp.)	0.026
Quart (U.S.)	0.03125	

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Foot	Centimeter	30.48
	Inch	12.0
	Meter	0.305
	Milliliter	304.8
	Yard	0.333
Foot – Pound	British thermal unit	0.00129
	Joule	1.356
	Kilocalorie	0.000324
	Kilogram – force meter	0.1383
	Kilowatt hour	0.00000376
Gallon – Imperial	Cubic inch	277.42
	Fluid ounce (Imp.)	160.0
	Fluid ounce (U.S.)	153.723
	Gallon (U.S.)	1.201
	Liter	4.546
	Milliliter	4546.112
	Quart (Imp.)	4.0
	Quart (U.S.)	4.804
Gallon – U.S.	Cubic foot	0.1337
	Cubic inch	230.947
	Cubic meter	0.00379
	Fluid ounce (Imp.)	133.2334
	Fluid ounce (U.S.)	128.0
	Gallon (Imp.)	0.8327
	Liter	3.7853
	Milliliter	3785.327
	Pounds of water	8.40336
	Quart (Imp.)	3.33
Quart (U.S.)	4.0	
Gram	Centigram	100.0
	Dram	0.5644
	Kilogram	0.001
	Ounce	0.0353
	Pound	0.0022
Grams Per Liter	Ounces per gallon	0.13353
	Pounds per gallon	0.008345

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Gram-Force Second/ Square Centimeter	Centipoise	98070.0
	Kilogram per meter hour	353000.0
	Poise	980.7
	Pound per foot hour	237200.0
	Pound per foot second	65.9
	Pound per inch second	5.492
	Pound-force second per square foot	2.048
	Pound-force second per square inch	0.01422
Horsepower	British thermal unit per second	0.7073
	Joule per second	745.7
	Kilocalorie per second	0.1782
	Kilowatt	0.7457
Inch	Centimeter	2.54
	Foot	0.08333
	Meter	0.0254
	Millimeter	25.4
	Mil	1000.0
	Yard	0.02777
Joule	British Thermal Unit	0.00095
	Foot-pound	0.7376
	Kilocalorie	0.00024
	Kilogram-force meter	0.102
	Kilowatt hour	0.000000278
Joule Per Second	British thermal unit per second	0.00095
	Horsepower	0.00134
	Kilocalorie per second	0.00024
	Kilowatt	0.001
	Watt	1.0
Kilocalorie	British thermal unit	3.97
	Foot-pound	3087.0
	Joule	4187.0
	Kilogram-force meter	426.9
	Kilowatt hour	0.00116
Kilocalorie Per Second	British thermal unit per second	3.968
	Horsepower	5.614
	Joule per second	4187.0
	Kilowatt	4.187
Kilogram	Centigram	100000.0
	Dram	564.383
	Gram	1000.0
	Ounce	35.274
	Pound	2.205

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Kilogram Per Meter Hour	Centipoise	0.2778
	Gram-force second/square centimeter	0.0002833
	Poise	0.002778
	Pound per foot hour	0.672
	Pound per foot second	0.000187
	Pound per inch second	0.0000155
	Pound-force second per square foot	0.0000058
	Pound-force second per square inch	0.00000004
Kilogram Per Square Centimeter	Bar	0.98067
	Pascal	98066.5
	Pound per square foot	2048.112
	Pound per square inch	14.223
Kilogram-Force Meter	British thermal unit	0.0093
	Foot-pound	7.233
	Joule	9.807
	Kilocalorie	0.00234
	Kilowatt	0.00000272
Kilowatt	British thermal unit per second	0.9484
	Horsepower	1.341
	Joule per second	1000.0
	Kilocalorie per second	0.239
Kilowatt Hour	British thermal unit	3413.0
	Foot-pound	2655000.0
	Joule	3597000.0
	Kilocalorie	860.0
	Kilogram-force meter	367100.0
Liter	Cubic centimeter	1000.0
	Cubic inch	61.02
	Cubic meter	0.001
	Fluid ounce (Imp.)	35.195
	Fluid ounce (U.S.)	33.8148
	Gallon (Imp.)	0.22
	Gallon (U.S.)	0.264
	Milliliter	1000.0
	Quart (Imp.)	0.88
	Quart (U.S.)	1.0567
Meter	Centimeter	100.0
	Foot	3.281
	Inch	39.37
	Millimeter	1000.0
	Yard	1.094
Micron	Centimeter	0.0001
	Mil	0.03937

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Mil	Inch	0.001
	Micron	25.4
Milliliter	Cubic inch	0.06102
	Fluid ounce (Imp.)	0.0352
	Fluid ounce (U.S.)	0.0338
	Gallon (Imp.)	0.00022
	Gallon (U.S.)	0.000264
	Liter	0.001
	Quart (Imp.)	0.00088
	Quart (U.S.)	0.00106
Millimeter	Centimeter	0.10
	Foot	0.00328
	Inch	0.03937
	Meter	0.001
	Yard	0.00109
Ounce	Centigram	2834.9
	Dram	16.0
	Gram	28.3495
	Kilogram	0.0284
	Pound	0.0625
Ounces Per Gallon	Grams per liter	7.489
Pascal	Bar	0.00001
	Kilogram per square centimeter	0.0000102
	Newton per square meter	1.0
	Pound per square foot	0.0209
	Pound per square inch	0.000145
Poise	Centipoise	100.0
	Gram-force second/square centimeter	0.00102
	Kilogram per meter hour	360.0
	Pound per foot hour	241.9
	Pound per foot second	0.0672
	Pound per inch second	0.0056
	Pound-force second per square foot	0.00209
	Pound-force second per square inch	0.0000145
Pound	Centigram	45359.2
	Dram	256.0
	Gram	453.5924
	Kilogram	0.4536
	Ounce	16.0
Pounds Per Gallon	grams per liter	119.832

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Pound Per Foot Hour	Centipoise	0.4134
	Gram-force second/square centimeter	0.0000042
	Kilogram per meter hour	1.488
	Poise	0.004134
	Pound per foot second	0.000278
	Pound per inch second	0.0000231
	Pound-force second per square foot	0.00000863
	Pound-force second per square inch	0.00000006
Pound Per Foot Second	Centipoise	1488.0
	Gram-force second/square centimeter	0.01518
	Kilogram per meter hour	5357.0
	Poise	14.88
	Pound per foot hour	3600.0
	Pound per inch second	0.08333
	Pound-force second per square foot	0.032
	Pound-force second per square inch	0.000216
Pound Per Inch Second	Centipoise	17860.0
	Gram-force second/square centimeter	0.1821
	Kilogram per meter hour	64290.0
	Poise	178.6
	Pound per foot hour	43200.0
	Pound per foot second	12.0
	Pound-force second per square foot	0.373
	Pound-force second per square inch	0.0026
Pound Per Square Foot (PSF)	Bar	0.00048
	Kilogram per square centimeter	0.00049
	Pascal	47.88
	Pound per square inch	0.00694
Pound Per Square Inch (PSI)	Bar	0.06895
	Kilogram per square centimeter	0.07031
	Pascal	6894.8
	Pound per square foot	144.0

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Pound-Force Second Per Square Foot	Centipoise	47880.0
	Gram-force second/square centimeter	0.4882
	Kilogram per meter hour	172400.0
	Poise	478.8
	Pound per foot hour	115800.0
	Pound per foot second	32.17
	Pound per inch second	2.681
	Pound-force second per square inch	0.00694
Pound-Force Second Per Square Inch	Centipoise	6895000.0
	Gram-force second/square centimeter	70.31
	Kilogram per meter hour	24820000.0
	Poise	68950.0
	Pound per foot hour	16680000.0
	Pound per foot second	4633.0
	Pound per inch second	386.1
	Pound-force second per square foot	144.0
Quart (Imperial)	Cubic inch	69.355
	Fluid ounce (Imp.)	40.0
	Fluid ounce (U.S.)	38.43
	Gallon (Imp.)	0.25
	Gallon (U.S.)	0.3002
	Liter	1.1365
	Milliliter	1136.528
	Quart (U.S.)	1.201
Quart (U.S.)	Cubic inch	57.75
	Fluid ounce (Imp.)	33.308
	Fluid ounce (U.S.)	32.0
	Gallon (Imp.)	0.2082
	Gallon (U.S.)	0.25
	Liter	0.9463
	Milliliter	946.3316
	Quart (Imp.)	0.8327
Square Centimeter	Square foot	0.00108
	Square inch	0.15502
	Square meter	0.0001
	Square yard	0.00012
Square Foot	Square centimeter	929.0304
	Square inch	144.0
	Square meter	0.0929
	Square yard	0.1111

Conversion Guides (cont'd.)

To Convert From	To	Multiply By
Square Inch	Square centimeter	6.45162
	Square foot	0.00694
	Square meter	0.00065
	Square yard	0.00077
Square Meter	Square centimeter	10000.0
	Square foot	10.764
	Square inch	1550.388
	Square yard	1.196
Square Yard	Square centimeter	8361.274
	Square foot	9.0
	Square inch	1296.0
	Square meter	0.836
Threads Per Centimeter	Threads per inch	2.54
Threads Per inch	Threads per centimeter	0.394
Yard	Centimeter	91.44
	Foot	3.0
	Inch	36.0
	Meter	0.915
	Millimeter	914.4

Conversion Guides (cont'd.)

TEMPERATURE CONVERSION EQUATIONS

Fahrenheit to Celsius	$(^{\circ}\text{F} - 32) \cdot .5555$	=	$^{\circ}\text{C}$
Celsius to Fahrenheit	$(^{\circ}\text{C} \times 1.8) + 32$	=	$^{\circ}\text{F}$
Fahrenheit to Kelvin	$(^{\circ}\text{F} + 459.67) \cdot .5555$	=	$^{\circ}\text{K}$
Kelvin to Fahrenheit	$(^{\circ}\text{K} \times 1.8) - 459.67$	=	$^{\circ}\text{F}$
Celsius to Kelvin	$^{\circ}\text{C} + 273.15$	=	$^{\circ}\text{K}$
Kelvin to Celsius	$^{\circ}\text{K} - 273.15$	=	$^{\circ}\text{C}$

VOLUMETRIC CONVERSION FORMULAS

Imperial Gallon	x 1.2	=	U.S. Gallon
Pounds of Water	x 0.119	=	Gallons
Cubic Feet	x 7.48	=	Gallons
Cubic Inches	x 0.00433	=	Gallons
Cubic Meters	x 264.2	=	Gallons
Cubic Meters	x 1000	=	Liters
Cubic cm (cm ³)		=	Milliliter
Cubic cm	x 0.0338	=	Fluid Ounces
Fluid Ounces	x 29.57	=	Cubic cm
Liters	x 1000	=	Cubic cm
Grams/Liter	x 0.008345	=	Pounds/Gallon
Grams/Liter	x 0.1335	=	Ounces/Gallon
Pounds/Gallon	x 119.8	=	Grams/liter
Ounces/Gallon	x 7.489	=	Grams/liter

Conversion Guides (cont'd.)

UNITS OF CAPACITY – U.S. Liquid Measure

Unit	Fluid Ounce (fl oz)	Quart (qt)	Gallon (ga)	Milliliter (ml)	Liter (l)	Cubic Inch (in ³)
Fl Ozs	1	32.0	128.0	0.0338	33.8148	0.5541
Quarts	0.03125	1	4.0	0.00106	1.0567	0.01732
Gallons	0.0078	0.25	1	0.000264	0.264	0.00433
Mls	29.57286	946.3316	3785.327	1	1000.0	16.387
Liters	0.02957	0.9463	3.7853	0.001	1	0.01639
Inches ³	1.80469	57.75	231.0	0.06102	61.02	1

UNITS OF CAPACITY – Imperial Liquid Measure

Unit	Fluid Ounce (fl oz)	Quart (qt)	Gallon (ga)	Milliliter (ml)	Liter (l)	Cubic Inch (in ³)
Fl Ozs	1	40.0	160.0	0.0352	35.195	0.57677
Quarts	0.025	1	4.0	0.00088	0.88	0.01442
Gallons	0.00625	0.25	1	0.00022	0.22	0.00361
Mls	28.4132	1136.528	4546.112	1	1000.0	16.387
Liters	0.02841	1.1365	4.546	0.001	1	0.01639
Inches ³	1.7338	69.355	277.42	0.06102	61.02	1

UNITS OF AREA

Unit	Square Inch (in ²)	Square Foot (ft ²)	Square Yard (yd ²)	Square Centimeter (cm ²)	Square Meter (m ²)
Inches ²	1	144.0	1296.0	0.15502	1550.388
Feet ²	0.00694	1	9.0	0.00108	10.764
Yards ²	0.00077	0.1111	1	0.00012	1.196
Cms ²	6.45162	929.0304	8361.274	1	10000.0
Meters ²	0.00065	0.0929	0.836	0.0001	1

Conversion Guides (cont'd.)

UNITS OF WORK

Unit	Foot-Pound (ft-lb)	Kg.m	Joule	Kilo-Calorie (kcal)	British Thermal Unit (btu)	Kilowatt-Hour (kW-h)
Ft-Lb	1	7.233	0.7376	3087.0	778.6	26.55x10 ⁵
Kg.m	0.1383	1	0.102	426.9	107.6	36.71x10 ⁴
Joule	1.356	9.807	1	4187.0	1055.0	35.97x10 ⁵
Kcal	0.000324	0.00234	0.00024	1	0.252	860.0
Btu	0.00129	0.0093	0.00095	3.97	1	3413.0
kW-h	3.76x10 ⁻⁷	2.72x10 ⁻⁶	2.78x10 ⁻⁷	0.00116	2.93x10 ⁻⁴	1

Note: kg_f=kilograms force

UNITS OF POWER

Units	Horsepower (hp)	Kilowatt (kW)	Joule/Second (Watt)	Kcal/Second	Btu/Second
Hp	1	1.341	0.00134	5.614	1.415
kW	0.7457	1	0.001	4.187	1.055
Joule/s	745.7	1000.0	1	4187.0	1055.0
Kcal/s	0.1782	0.239	0.00024	1	0.252
Btu/s	0.7073	0.9484	0.00095	3.968	1

Note: to convert from units/sec. to units/min., divide by 60. 1 Joule/sec. = 1 watt

UNITS OF PRESSURE

Units	Lb _f /In ² (PSI)	Lb _f /Ft ² (PSF)	Pascal (Pa)	Bar	Kg/Cm ²
PSI	1	0.00694	0.000145	14.504	14.223
PSF	144.0	1	0.0209	2088.576	2048.112
Pa	6.89x10 ³	47.88	1	1x10 ⁵	9.81x10 ⁴
Bars	0.06895	0.00048	0.00001	1	0.9807
Kg/Cm²	0.07031	0.00049	0.0000102	1.0197	1

Note : 1 Pascal = 1 Newton/square meter (N/m²) Lb_f=pounds force

Conversion Guides (cont'd.)

FRACTIONAL EQUIVALENTS

Fractional Inches	Decimal Inches	Milli-meter	Fractional Inches	Decimal Inches	Milli-meter
1/64	0.015625	0.397	1/2	0.50	12.7
1/32	0.03125	0.794	17/32	0.5312	13.494
3/64	0.046875	1.191	9/16	0.5625	14.288
1/16	0.0625	1.588	19/32	0.5937	15.081
3/32	0.09375	2.381	5/8	0.625	15.875
1/8	0.125	3.175	21/32	0.6562	16.669
5/32	0.15625	3.969	11/16	0.6875	17.463
3/16	0.1875	4.763	23/32	0.7187	18.256
7/32	0.21875	5.556	3/4	0.75	19.05
1/4	0.250	6.35	25/32	0.7812	19.844
9/32	0.2812	7.144	13/16	0.8125	20.638
5/16	0.3125	7.938	27/32	0.8437	21.431
11/32	0.3437	8.731	7/8	0.875	22.225
3/8	0.375	9.525	29/32	0.9062	23.019
13/32	0.4062	10.319	15/16	0.9375	23.813
7/16	0.4375	11.113	31/32	0.9687	24.606
15/32	0.4687	11.906	1	1.00	25.4

MESH COUNT CONVERSION FORMULAS*

Threads/Inch x .394 = Threads/cm
 Threads/cm x 2.54 = Threads/Inch

THICKNESS CONVERSION FORMULAS

Microns x 0.03937 = Mils
 Mils x 25.4 = Microns
 Mils x 0.001 = Inches
 Microns x 0.0001 = cm

THICKNESS CONVERSION CHART

Mils	Microns	Mils	Microns	Mils	Microns
1	25.4	9	228.6	17	431.8
2	50.8	10	254.0	18	457.2
3	76.2	11	279.4	19	482.6
4	101.6	12	304.8	20	508.0
5	127.0	13	330.2	21	533.4
6	152.4	14	355.6	22	558.8
7	177.8	15	381.0	23	584.2
8	203.2	16	406.4	24	609.6

*Data represents the closest possible approximation.

Conversion Guides (cont'd.)

MESH COUNT CONVERSION CHART*

Threads /inch	Threads /cm	Threads /inch	Threads /cm	Threads /inch	Threads /cm	Threads /inch	Threads /cm
25	10	85	34	156	61	280	110
30	12	92	36	163	64	305	120
37	15	96	38	173	68	330	130
45	18	103	40	186	73	355	140
54	21	110	43	195	77	381	150
60	24	115	45	206	81	409	161
63	25	123	48	215	85	420	165
74	29	131	51	230	90	457	180
76	30	137	54	240	95	495	195
83	32	148	58	254	100	508	200

*Data represents the closest possible approximation.

Conversion Guides (cont'd.)

SCREEN FABRIC SELECTION FORMULAS*

To Calculate For	Mesh Count (#/cm) & Thread Diameter (cm)	Mesh Count (#/cm) & Percent Open Area (%)	Image Thickness (cm) & Finline Resolution (cm)
Mesh Opening Mo (cm)	$Mo = \frac{1 - McD}{Mc}$	$Mo = \frac{\sqrt{A}}{Mc}$	$Mo = \frac{d_1 \sqrt{\frac{lh}{.364d_1}}}{5 \left(1 - \sqrt{\frac{lh}{.364d_1}} \right)}$
Percent Open Area A (%)	$A = (1 - McD)^2$	—	$A = \frac{1h}{.364d_1}$
Image Thickness lh (cm) (Wet Film Ink Height)	$lh = 1.82D(1 - McD)^2$	$lh = \frac{1.82A(1 - \sqrt{A})}{Mc}$	—
Relative Strength S (cm²/cm)	$S = \frac{McD^2}{4}$	$S = \frac{Mc(1 - \sqrt{A})^2}{4Mc^2}$	$S = \frac{d_1^2}{100} \text{ or } \frac{5 \left(1 - \sqrt{\frac{lh}{.364d_1}} \right)}{d_1}$
Finline Resolution d₁ (cm)	$d_1 = 5D$	$d_1 = 5 \frac{1 - \sqrt{A}}{Mc}$	—
Halftone Dot Resolution d₂ (cm)	$d_2 = \frac{\sqrt{2}(1 + McD)}{Mc}$	$d_2 = \frac{\sqrt{2}(2Mc - Mc\sqrt{A})}{Mc^2}$	—
Mesh Count Mc (#/cm)	—	—	$Mc = \frac{5 \left(1 - \sqrt{\frac{lh}{.364d_1}} \right)}{d_1}$
Thread Diameter D (cm)	—	$D = \frac{1 - \sqrt{A}}{Mc}$	$D = \frac{d_1}{5}$

Source: T. Frecska, *Screen Printing Magazine*

*Data represents the closest possible approximation.