Screens Matter

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The mesh manufacturers are unrivaled at providing tons of data on their product. But perhaps it is better suited for the scientist than for the screen-printer. I don't question the intent or the precision of these specifications, only their utility to the layman. The data is accurate, but not nearly as relevant. We printers want to know "what's in it for me?" and the data sheets explicitly tell us "what's in it for them." Let's take ink deposit as an example expressed in cm^3/cm^2. If the ink is high tack, we will deposit less ink. If we use an articulated blade, the deposit of a co-solvent ink will be less than half. If we put an industry typical EOM on the mesh, the deposit will be greater at the perimeter than in the central parts of the image elements. If the ink is highly shear-thinning (>7.0) and we speed the blade, we will get more ink. Case in point: the ink volume data is comparative and not intended to tell us how much ink it will allow us to print.

In any industry other than screen-printing, "mesh" is used as a filtration cloth or "strainer. They prefer a robust yarn (thread) and a minimal opening—the thickness of their filtration cloth is not often an issue.

However, when it comes to screen-printing, "mesh" is the foundation of the process and generally, the first aspect to be established in house. So, it is critical we understand the mesh and that means more than just the mesh count in the warp direction. We must try not to succumb to selecting mesh with only a vague "I use an 'S'" or "I do it to fix the ink", "to establish resolution" or "to make the stencil guy's life easier". Those who opt to purchase mesh based solely on price and count (CRMC) are guaranteed to forfeit more than the dollars they saved with every stroke of the blade! Instead, select mesh based upon the following criteria:

1) **Optimal wet ink film thickness** – The mesh meters the ink thickness and the top stencil regulates the ink volume while the bottom stencil regulates the resolution and edge acuity. Using a stencil to control deposit is like the tail wagging the dog—painful.
2) **Maximum fluid flow rate** – The most difficult task on press is to optimally fill the mesh—witness the excessive strokes, fibrillation slow speed, extra flashes or revolver mode. Second to thickness, select the largest opening and the thinnest yarn for maximum fluid flow rate.
3) **Capable of maximum positive & negative elements** – The mesh doesn't hold detail, it compromises detail. The mesh opening is the limitation to the negative elements (think shadow dots) while the yarn and knuckle are the limitations to the positive elements (think highlight dots).

4) **Balanced warp & weft stress/strain and mesh counts** – The mesh count is defined by the warp count. However, the weft count of the mesh *should not be the same*. Also, the warp develops tension gradually while the weft yarns develop tension more rapidly. So the preferred mesh has a weft count higher than the warp by the same ratio of stress-strain. Properly tensioned, this mesh will be stable and permit halftones without radial, progressive, or frequency moiré.
5) **Higher modulus yarns** – Generally speaking, as we reduce the yarn diameter, we should increase the elastic modulus (the tendency of the yarns to deform as they are elongated). The elastic modulus of the yarn must keep pace with the yarn diameter despite any increase in fabric mass.
6) **Optimal dye color** – This is required to minimize light scatter, which protects resolution and edge acuity without over burdening exposure latitude.

Mesh that meets these requirements is readily available and highly recommended if one's goal is to minimize set up time on press, minimize number of strokes, minimize fibrillation, optimize ink coverage, maximize throughput, and minimize scrap rate.

What's First?

If the axiom is true that "abstraction is the domain of experts," then the best evidence we have for that assertion may come in the form of a mesh-specification and tolerance sheet. There is no better place for an expert to duck, dwell and deliberate than in the pages of these white-space limited, googlesque, product data sheets.

After more than half a century, most of the T-shirt industry still clings dearly to 86, 110, 156, 230 and 305 thread counts. (Thread diameters are redacted to protect the innocent) It gets to a point where one might begin to question the utility of these precisely prepared papers. With the exception of a gaggle of geeks who lock the papers in the techno-vault, almost no one uses the data for more than a list of "what's available for testing," because the way the information is presented is not very accessible.

But as the name "screen-printing" implies, *the screen* or more specifically *the mesh* is the starting point—the foundation of all that follows. The onus is upon us to decipher these cryptograms in order that we might select a sensible fabric—probably more than one, but rarely, if ever, more than four "counts". That being said, the mesh should never be selected merely 1) to make up for tacky inks (FIX THE INK), 2) as the primary determiner of resolution, edge-acuity and detail (FIX THE STENCIL) or 3) just to make the stencil guy's life easier (FIX THE STAFFER).

Mesh Selection

The ABC's of mesh selection should be based upon a) what the mesh does to the ink, b) what the ink does to the garment, and c) what the mesh does to the image. We are going to restrict our parameters and definitions to white ink since it constitutes about half of the "colors" consumed, and because it needs to resist penetration into the garment. It resides at the tricky end of the color pallet. Five points of criteria follow and we will discuss their relationship to the ink, garment and image.

1. High tolerance surrounding a specific ink deposit

The first facet of mesh selection is whether or not it will allow us to meter sufficient opacity, as our test case is white ink. Know that the mesh does not determine the deposit, but it may well limit the deposit and neither incremental stencil EOM, nor double strokes are the best solution for an inadequate mesh.

Depending on ink tack, shearing force, and the substrate specifics, the de-facto (but not recommended) standards will permit approximately the following mils [1/100th of an inch] deposits:

85 ~ 0.005" thick layer athletics
110 ~ 0.004" low fabric mass shirts
156 ~ 0.003" high fabric mass shirts
230 ~ 0.002" highlight and detail white
305 ~ 0.001" halftone underbase

Maximum ink deposit *tolerance* comes from fabrics with a large opening plus a low capacity—thin thread, low count, high compression. Consider the most prevalent 305/40 mesh. It has a very small opening and high capacity—we can spend all day trying to fill it and will eventually find we can't!

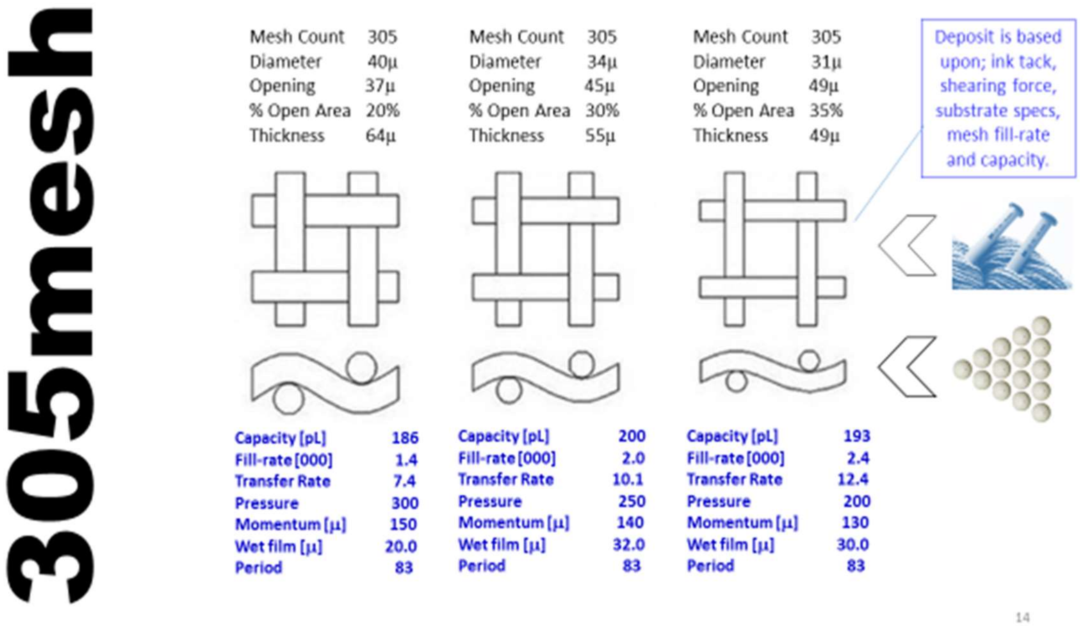


Fig 1.0: This image depicts three qualities of 305 count screen mesh which are all too often imprecisely labeled "HD, T, M, S" or "SL." The nominal specifications are usually 305 in the warp count, something else in the weft count, and from left to right: typically 40 micron yarn diameter, approximately 37 micron opening, a nominal 20% open area, and a very rough 64 microns thickness.

But from these estimates we can see the capacity of the "305/40" is 186 with a minimal fill-rate of 1.4 with a flow rate of a mere 7.4 demanding 300 units or very high pressure. Additionally, the white ink will need to flow 150 microns which is a long distance to give us a wet-film-thickness of 20.0 microns (about 80% of 0.001" or 1-mil).

Alternatively, the 305/34 has 7% higher capacity, but a 43% higher fill-rate for 36% higher fluid-flow at 17% less pressure to meter 60% more ink. Although delicate, the 305/31 has a mere 4% increase in capacity, with a 71% higher fill-rate for 68% higher fluid-flow at 33% less pressure to meter 50% more ink. Transfer and deposit actually improve with the 34 or 31 micron 305's but since almost all white inks are built to be tacky, there is still a better alternative—see 305/40 VS 280/35 below.

2. Transfer white ink with minimum angle & pressure at maximum speed

The ideal mesh will transfer white ink (if it works best for white, it will work for all other colors) with minimal angle and minimum "pressure" or downward force on the blade. This pairing determines shear-stress. Furthermore, the mesh should allow maximum stroke speed (shear-rate). *Shear-stress* is ideal for sealed, collapsible containers with a single, small point of egress opposite the force. This is precisely opposite the configuration we use to screen print T-Shirts—an open, fixed container with multiple varying sized points of egress, and varying distances from the applied force. Therefore, our ideal shearing force needs to be *shear-rate*.

Shear-rate is computed by the flatness of the mesh divided by the stroke speed of the blade while speed is limited by the fill-rate divided by the tack level of the ink, mitigated by the minimum compressive force of the blade. Maximum stroke speed with minimum blade compression combine to properly fill the mesh up to its capacity, providing the fill-rate permits.

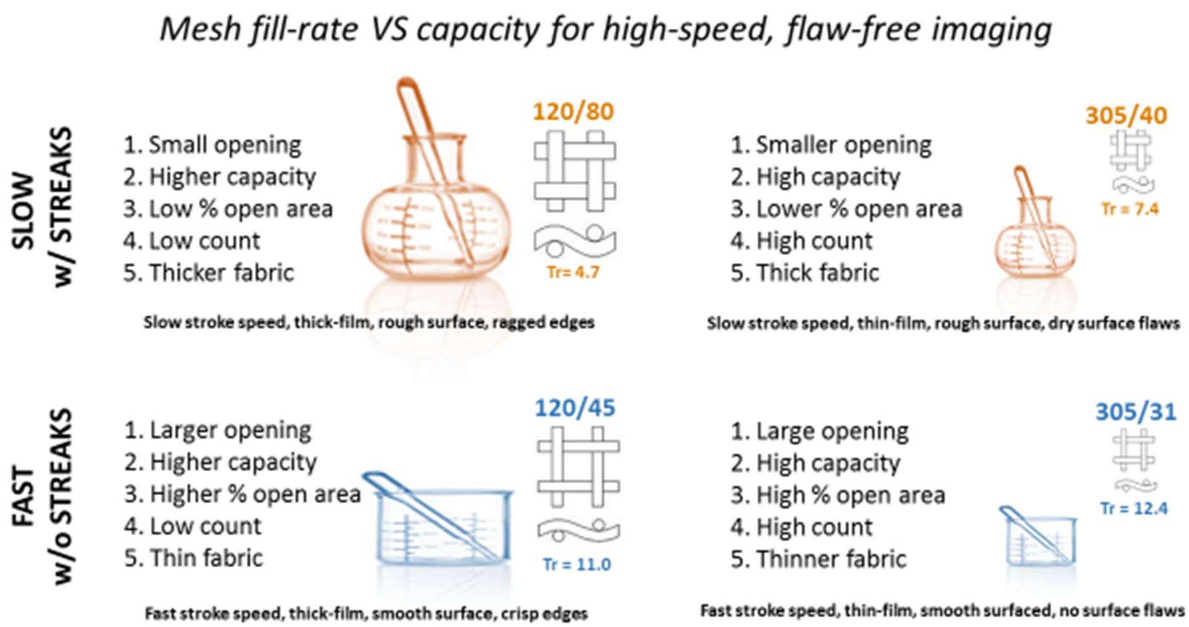


Fig. 2.0: We've stolen a couple of beakers from our ink lab and are using the openings and volumes as metaphors for the fill-rate and capacity of screen mesh. If we look to the top and bottom fabrics on the left, we see some mesh has a small opening with a high capacity to hold ink, like the 120/80 mesh depicted above with its fluid flow rate of 4.7 units. Now, keep the same mesh count (nominally 120 threads per inch), but reduce the thread diameter to 45 microns, thus increasing the opening. The fluid flow rate increases by 2.3 times to 11.0 units. This configuration will allow for less blade angle and a thinner stencil, which will accommodate both lower EOM and lower RzS1. It will also allow less pressure to transfer a greater volume, which will allow reduced screen stretch.

The irony is that despite common knowledge which suggests a thicker mesh will deposit a thicker layer of ink, sometimes this is simply not the case—the thinner thread may actually have greater capacity. Secondly, even if the thicker thread mesh has higher capacity, we must be able to adequately fill it with ink, and this is constrained by the fill-rate of the mesh. Finally, the shear-rate which thins the white ink is constrained by the flatness of the mesh and thicker threads of the same count are never as flat.

3. High modulus yarns / high compression fabric

Now that we agree on the superior transfer of thinner thread meshes, we must address the equally pragmatic issue of durability, i.e. “how long will the mesh last in the screen room, and more importantly how long will the mesh last on-press?” Don’t forget that the cost of the screen in the screen room is pennies compared to the cost of downtime a screen-pop causes on-press. There are four main points which govern the longevity of the mesh as manufactured: modulus of the yarn, diameter of the yarn, number of yarns per linear measure, and the fabric thickness.

The modulus of the yarn (thread) is its stress / strain or in our parlance, elongation over tension. Higher modulus yarns require less elongation to develop a given tension level, and these yarns tend to hold tension longer. At a given modulus, the thicker the yarn the greater its strength, and the greater the number of yarns per linear measure (inch), the stronger the fabric. If we do have access to a spec sheet on mesh we will see the fabric thickness is *never* twice the thickness of the thread. This is because the fabric is crimped in the finishing process. Otherwise, it would not last through a single pass of even the gentlest blade.

In the traditional 305 range of meshes, the fabric thickness runs about 1.60 times the thread diameter. The newer meshes range closer to 1.45 times the thread which makes for a stronger fabric since the threads are less likely to shift the opening out of shape. This generation of fabrics allows the traditional weakling to be stronger than the ones which don’t print well!

4. Balanced stress-strain and counts

Once we know the mesh will afford our requisite deposit, will transfer the ink with *minimum shear-stress* (pressure) at *maximum shear-rate* (speed), and will last on press, we need to look at the subtleties of its construction.

Stress-strain analysis measures the rate of elongation of the mesh when a constant force is applied. Although this is a critical factor in mesh manufacturing, the data is not really user friendly to the screen-room practitioner. So, we will use a cheat known in the industry as “biaxial stress-strain.”

Biaxial stress-strain is the tension developed with a given amount of elongation in either warp or weft direction. Due to the nature of the weaving and finishing processes, the warp must typically be pulled farther to develop tension than the weft.

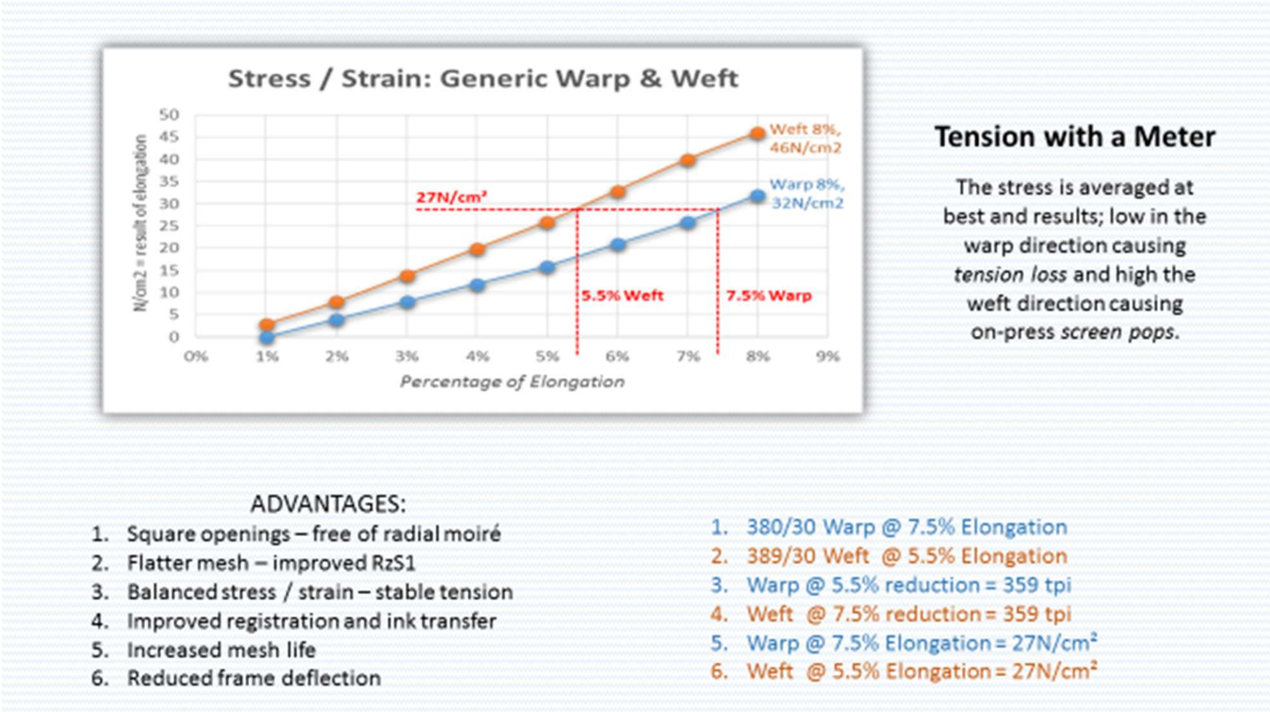


Fig. 3.0: This example is a 380/30 high modulus mesh which we have chosen to take to a tension level of 27N/cm² by using inverse tensioning. Biaxial stress-strain analysis indicates the warp, which typically has a higher amplitude, will achieve the desired tension at 7.5% elongation while the lower amplitude weft will achieve the same tension at 5.5% elongation. There are two implications here. First, if warp and weft in this case are elongated to the same distance, the weft will develop considerably higher tension and will lead to a pop. Conversely, the warp will not achieve the same level and will lead to tension loss. Second, if the application is halftone printing, a square opening is preferred. In our context, the warp "stretches" further so the weft count must be higher to start. The first condition will reduce the chance of progressive moiré and the second will reduce the chance of radial and frequency moiré.

5. Maintain dimensional accuracy

Dimensional accuracy is a participation sport. It not only has to do with the mesh composition and construction or static tension levels, but most important is the dynamic tension—the tension on press. Press calibration is imperative, and the off-contact gap should be set at the maximum distance permitted by the image and the tack level of the ink. (Higher ink tack means lower gap, rougher finish, poorer matte-down, slower speed and more inconsistent from edge-to-edge).

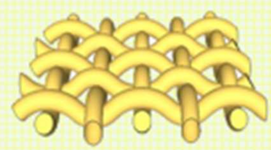
A couple of notes on registration as it is influenced by the gap:

1) If the gap is excessive, the registration error will occur on all four sides, not only in the stroke direction
2) Meshes with higher modulus and higher fabric mass will be best suited with lower static tension or lower gap
3) If the white is stretching in the stroke direction more than the other colors, the problem may be any of the following, presented in order of likelihood:
    a. The white ink is too tacky
    b. The gap may be too low
    c. The blade angle and pressure may be too high
    d. The fill-rate of the mesh may be too low
    e. All of the above.

Plain Ol' Language

The following table is based on industry jargon so we can compare two halftone meshes and learn "what's in it for us?" As we will immediately see, the higher modulus, higher compression 280/35 outperforms the traditional 305/40 low elongation mesh in virtually all aspects.

Halftone Under-Base & Colors:



Parameter	305/40	280/35	
Clearing the mesh	58%	100%	clearing – dot consistency
Surface smoothness	89%	100%	smoothness – more imprintable
Pressure to transfer	100%	78%	pressure – dimensional accuracy
Garment coverage	84%	100%	coverage – reduced color variance
Print stroke speed	58%	100%	speed– fibrillation control
Fluid momentum	98%	100%	distance – comparable shortness
Drape [hand]	100%	97%	drape – comparable hand & mileage
Opacity	97%	100%	opacity – comparable image contrast
Highlight min.	78%	100%	of highlights – more specular detail
Shadow max.	100%	92%	of shadows – less shadow transition
Tonal range	78%	76%	tonal range – comparable grey levels

***NexGen** Cotton & **NexGen** Poly transfer perfectly through either mesh, but the 280/35 prints better halftones!*

Fig. 4.0: It is at least as good, but in the most critical aspects the 280/35 is far superior to the uncooperative 305/40, the marginal 305/34, and the ultra-fragile 305/31. White will not clear the 305/40 as well due to its low fill-rate and thick fabric. It is not as smooth, which limits the stroke speed on press. In addition, it will require added stencil to achieve the same resolution as its 280 counterpart. The standard 305/40 will require a lot more pressure just to attempt to fill its cells, and this will compromise registration. Coverage in the form of bridging will be weaker, so indirectly matte-down, smoothness and opacity will suffer. The speed will be drastically reduced, and speed is the key to matte-down. The travel distance, drape and wet-film thickness between the two meshes are very similar. The crucial highlight dots will suffer, and although the shadows are at a mathematic disadvantage, humans don't see shadows very well and the tonal range or reproducible grey levels are almost identical. The higher modulus yarn of the 280/35 and higher compression make it extremely resilient on press.

For those of you literally from Missouri (the "Show Me State") or those with an honorary membership, you are wondering, maybe even worrying, about the CRMC (Conspicuous Raw Material Cost). If you don't care to tension properly and are about to auto-slap 1x1 or 2x2 passes of emulsion on a press which was calibrated when installed and drag a blueish blade across the mesh, keep the 305. If alternatively you want to make more, better looking shirts and the profits which go along with speed and excellence, select the right stuff!