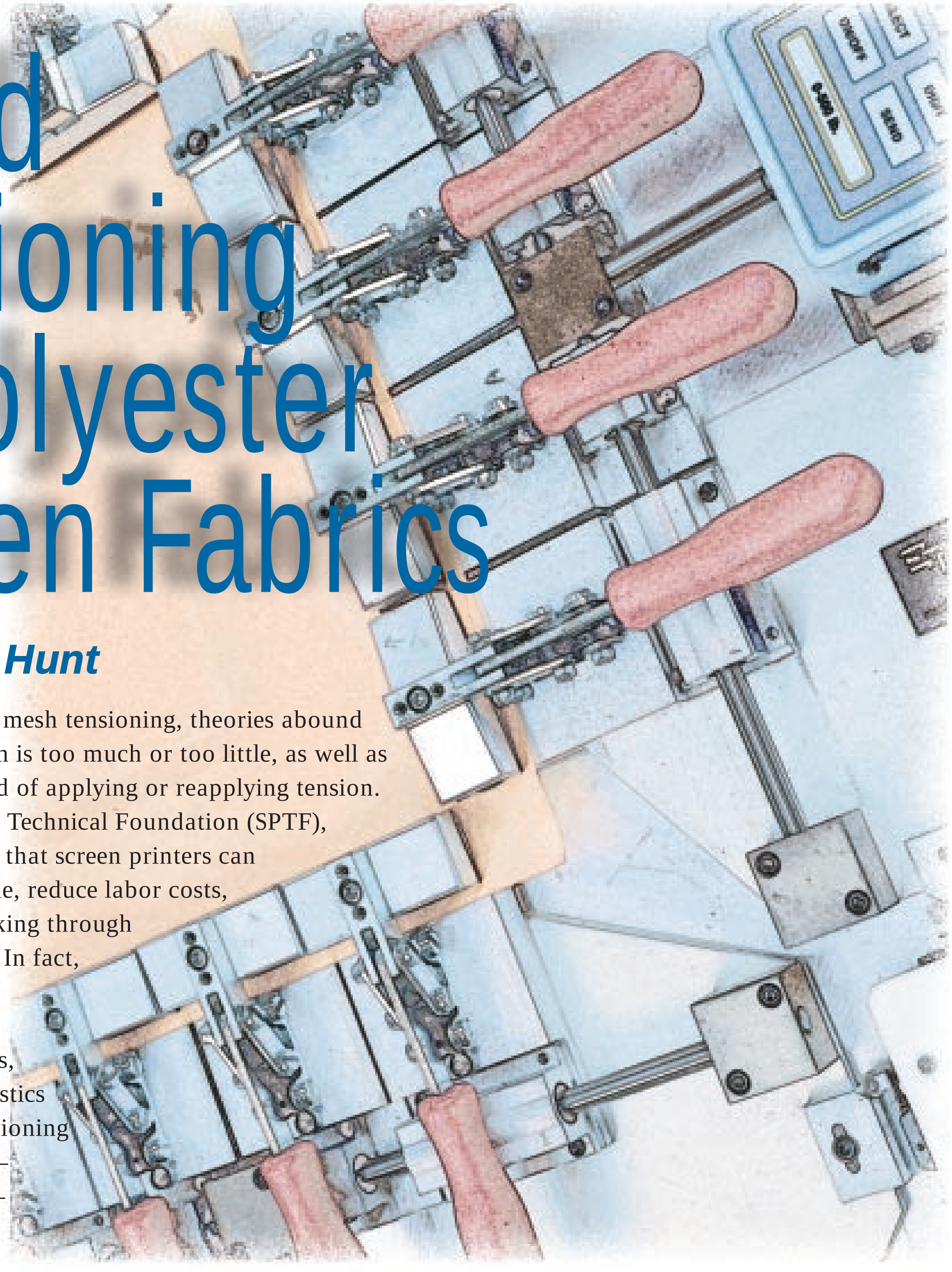
Rapid Tensioning of Polyester Screen Fabrics



by Dennis D. Hunt

When it comes to mesh tensioning, theories abound as to how much tension is too much or too little, as well as what is the best method of applying or reapplying tension. But the Screen Printing Technical Foundation (SPTF), Fairfax, VA, has found that screen printers can shorten production time, reduce labor costs, and simplify screenmaking through rapid mesh tensioning. In fact, SPTF research has shown that tension loss, quality parameters, and printing characteristics produced by rapid tensioning prove comparable to — and even better than — slower tensioning.

Despite the myriad of methods used to tension a screen, one universally uncontested “truth” has been that the slower the force is applied to a fabric, the better the product would be. It was thought that fabrics needed time to relax and must be tensioned in stages to allow an elastic cold flow to occur. Only this slow-but-sure approach could ensure a consistently high-quality product with good stability and little tension loss over time.

Or so we thought. SPTF research has produced results that directly contradict this commonly held belief.

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Objective

In an attempt to find the best tradeoff between time, tension, and quality, the SPTF completed a series of experiments on a cross section of commonly used screen-printing meshes.

Mesh counts selected for the experiments were 230, 305, 390, 460, and 508 threads/in. in both regular and high modulus fabrics. The tested fabrics were from three different weaving mills, ensuring that the results obtained were not unique to a particular manufacturer. It was assumed that staged tensioning was a viable process variable whose reduction would result in quality and/or tension losses. It was further assumed that at some point these tension losses would become unacceptable for high resolution printing.[1]

It was the objective of SPTF to establish a point of diminishing returns where quality losses would be contrasted against the time invested to reach an acceptable level of tension and fabric stability.

The quality parameters tested were tension loss after 24 hours and after printing. In addition, any measurable physical changes in the fabric at the microscopic level that would affect either the printing characteristics or physical strength and durability of the mesh were documented. Finally, beta sights were also established at various locations in the field to ensure process improvements could be achieved in a real world printing environment.

Staged-Tensioning Procedures

All scientific testing was completed on a commercially available pneumatic tensioning system using the "round-robin" option (i.e., air pressure was applied simultaneously and uniformly to the warp and weft directions). However, the **baseline procedure** used for comparison to the more rapidly stretched fabric was as follows:

- Apply tension to the mesh in the warp and weft directions independently, bringing the fabric up to 50% of the manufacturer's recommended tension.
- Wait 60 sec. and increase the tension by 2 N/cm in the warp and weft directions.
- Repeat the previous step until the desired final tension is achieved.
- Wait 15 min. and retension to final tension in both directions.

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[1] This was later expanded to include over twenty seven additional meshes ranging from 61 to 508 threads per inch. Both plain weave and twilled weave, high modulus and regular fabrics have been tested.

- Wait another 15 min. and retension to final tension in both directions.
- Wait an additional 30 min. and retension to final tension in both directions.
- Glue the mesh to the frame and cut it away from the tensioning device.

For a direct comparison of tension loss over time, mesh tension was carefully documented:

- after the mesh was cut away from the stretching device;
- when 24 hrs. had passed;
- immediately before printing;
- after the print run and reclaiming procedure.

Rapid-Tensioning Procedures

In contrast, three different rapid-tensioning procedures were used to determine the effect of a sudden stress applied to polyester mesh. Although the total elapsed time to arrive at the final tension for each mesh was essentially the same (approx. 36 sec.), the time the force was allowed to continue stressing the fabric varied from 5 min. to a maximum of 8 hrs. Here's a description of the procedures used:

- *Procedure R1* Using round-robin pneumatic tensioning, the mesh arrives at the target tension in approximately 36 sec. Tension meter readings are taken in the warp and weft directions, and the mesh is glued in place to the frame. Total elapsed time is approximately 5 min.
- *Procedure R2* Procedure R1 is repeated on new mesh with the fabric remaining under constant stress applied by the pneumatic system for 30 min. before gluing.
- *Procedure R3* Procedure R1 is repeated on new mesh with the fabric remaining under constant stress applied by the pneumatic system for 8 hrs. before gluing.

The reason for repeating the procedure (R2 and R3) is to determine the long-term result of applying continuous stress to the fabric. Procedure R1 is the end result of determining how the upper limits of rapid fabric tensioning affect the stabilization process and overall print quality. Figures 1–3 represent typical tension-loss curves for both slow and rapid tensioning at these various stages. For this particular fabric, the greatest tension difference is about 0.5 N/cm. However, the time difference between tensioning procedures is 15:1. Is 0.5 N/cm. really worth an investment of an additional 70 minutes per screen?

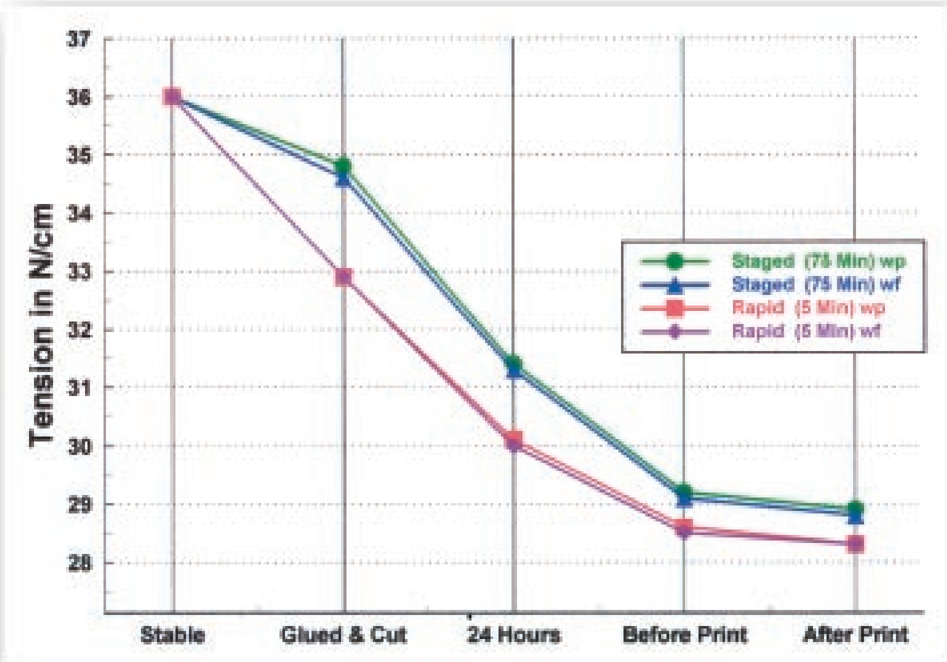

Figure 1. Rapid (5 min.) vs. Staged (75 min.). Typical tension loss curves for both slow and rapid tension at various stages. Notice the difference at "cut away" is approaching 2 N/cm. However, this difference is reduced to 0.5 N/cm or less after only 100 printing impressions. In many cases, field testing has shown rapid tensioning's ability to hold tension continues to increase with longer print runs.

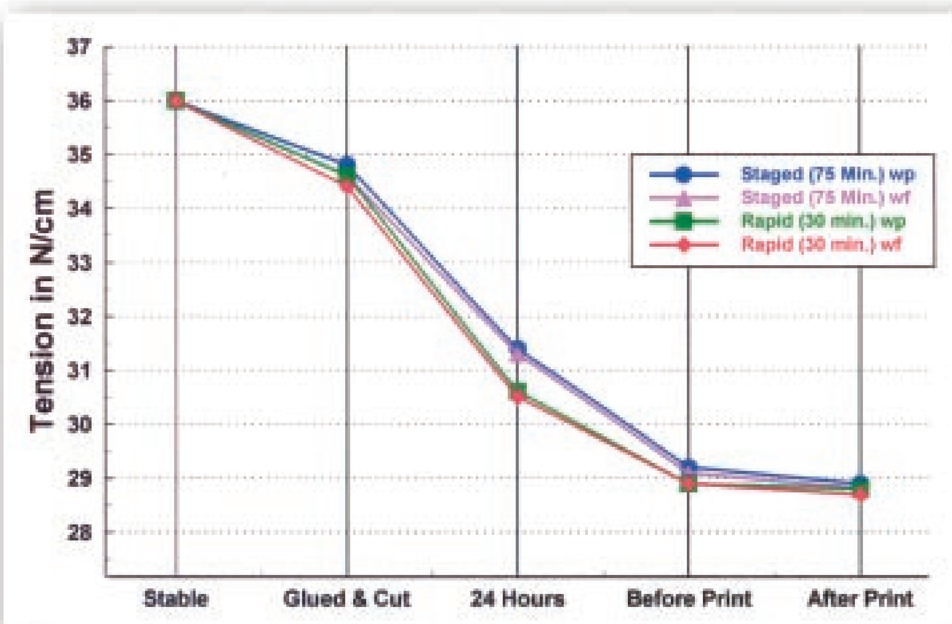

Figure 2. Rapid (30 min.) vs. Staged (75 min.). Advantages of continuing to pull the fabric using constant force or "controlled stress" tensioning typical of a pneumatic stretching system. In this way the fabric is allowed to distribute the forces along the path of least resistance in the woven material. This assumes all the pneumatic clamps are tied together and receiving equal air pressure.

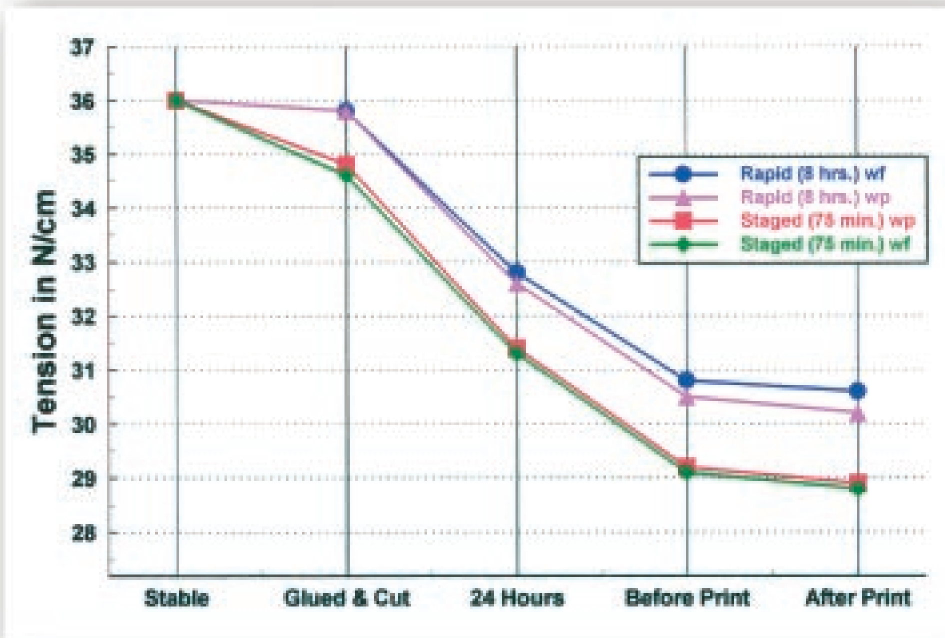

Figure 3. Rapid (8 hrs.) vs. Staged (75 min.). Eight hours of constant stress applied to the fabric in four directions results in a 1 N/cm tension loss advantage over 75-minute staged tensioning and a 2 N/cm advantage over the five minute rapid tension method.

Further Testing

The combination of different mesh counts, mesh manufacturers, and testing procedures have resulted in more than 110 laboratory print runs and 24 months of outside field testing. These tests have produced positive results that, due to the volume of data, field testing, and parallel results in Europe are no longer contestable.

Rapid tensioning produces tension losses after printing that are typically less than 1 N/cm different from the slower method of tensioning in stages.[2] This will vary somewhat with different fabrics, tensioning systems, and mesh manufacturers; however, the results will generally not be greater than a 2 N/cm difference after printing, and often will be considerably less (Figure 4). Field testing of rapid tensioning with print runs between 5000–500,000 impressions suggest meaningful gains in plant wide tensions over the life of the screen. It seems that the longer the print run the greater the difference between rapid and staged tension screens, with

[2] The overall average difference between the 75 minute staged tensioning method and the five minute rapid tensioning method for all meshes tested is 0.72 N/cm or 3.11%.

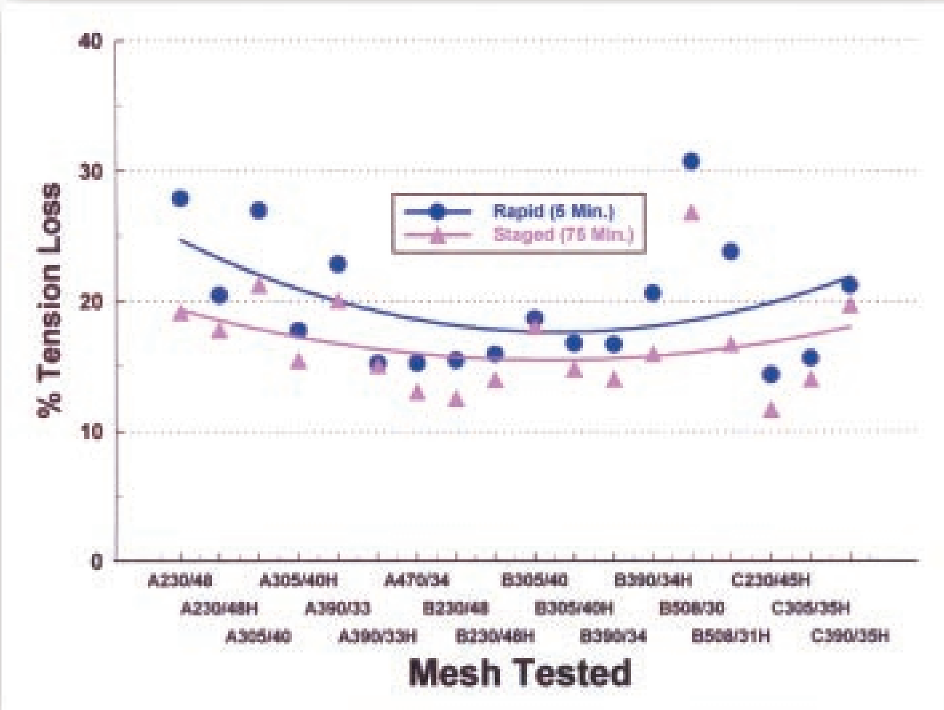

Figure 4. Rapid (5 min.) vs. Staged (75 min.) Since these meshes were tensioned to manufacturer's recommended tensions which varied from 15-35 N/cm, no direct comparisons between meshes are possible with this data. However, direct comparisons can be made between rapid and staged tensioning for each individual fabric tested. In addition a general comparison across the family of fabrics tested can be made by looking at the two curve fitted data groups. The overall average difference between tensioning procedures was 3.11% or 0.72 N/cm.

rapid being the more stable of the two. Quality parameters and printing characteristics remain the same or better than slower methods. Elongation is nearly identical (Figures 5–7).

It is also interesting to note that even when force is applied to the fabric continuously for up to eight hours, the greatest additional elongation beyond what occurs during the 75 minute staged tensioning method is 0.5 percent (typically the average will be on the order of 0.25 percent or less). This is yet another key indicator that a high degree of stability occurs in a very short period of time,[3] contrary to popular belief.

Another quality parameter of interest is the mesh opening size and variation when tension is applied to the fabric. Critics of rapid tensioning have suggested that this procedure produces more irregularity in the mesh openings and a weakening of

[3] This refers to stabilization that can be achieved using purely horizontal forces during the initial tensioning procedures.

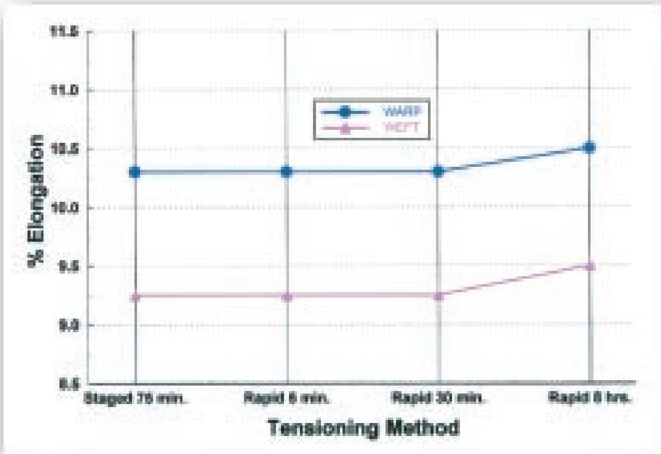

Figure 5. Elongation: Rapid vs. Staged (390/35 "HM" Fabric 36 Ncm)

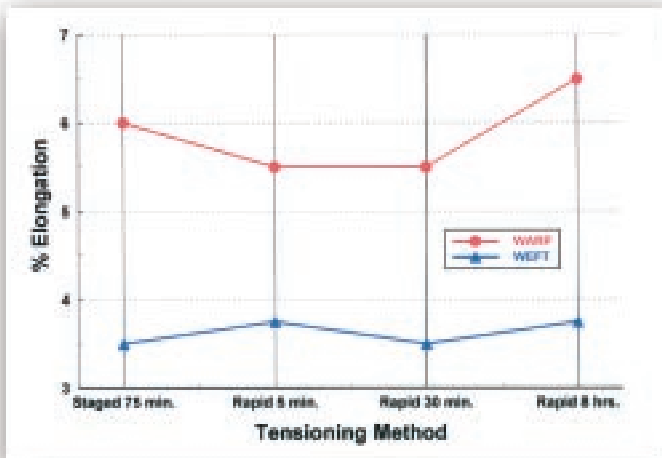

Figure 6. Elongation: Rapid vs. Staged (390/33 "HM" Fabric 22 Ncm)

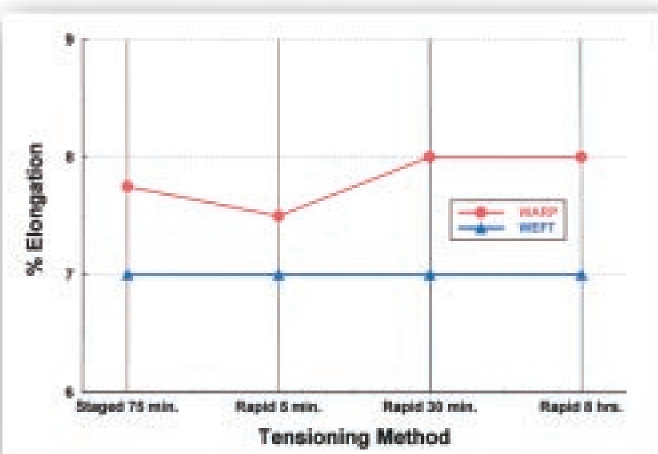

Figure 7. Elongation: Rapid vs. Staged (390/34 "HM" Fabric 25 Ncm)

Figures 5–7 illustrate the small differences in elongation between staged tensioning and three different rapid tensioning procedures. The fabrics selected represent typical responses. A direct comparison of the 75-minute staged and 5-minute rapid procedure produces no difference in elongation. It is also interesting to note that even eight hours of constant stress applied to the fabric only produces between 0.25 and 0.50 percent additional elongation when compared directly to staging. This suggests most of the stabilization occurs in the first few minutes of tensioning (when the forces are applied on the horizontal plane).

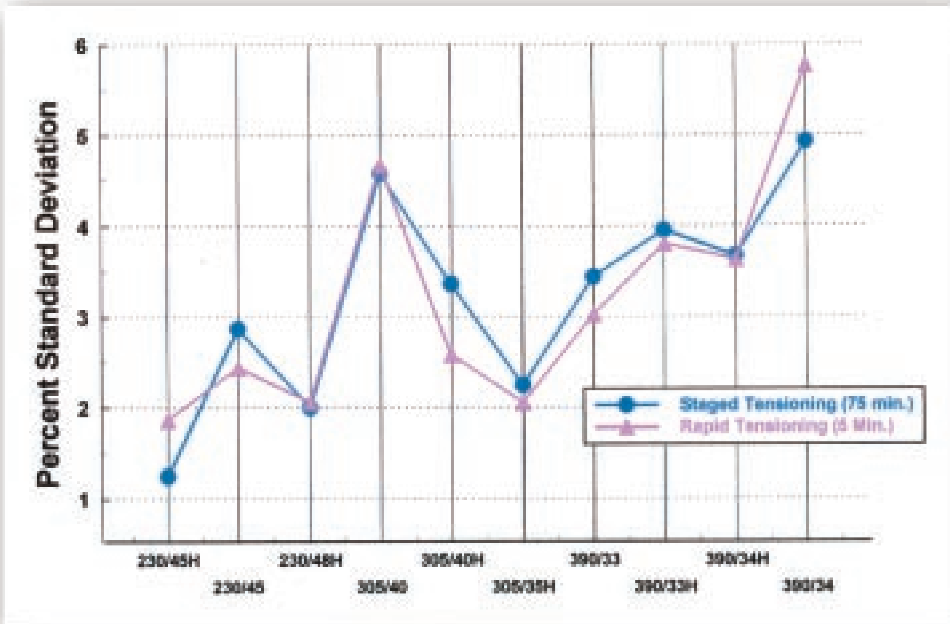

Figure 8. Mesh Opening Variation (as a percent of the Std. Dev.). Mesh opening size variation is not adversely affected by rapidly tensioning the fabric. In many cases it actually improves the mesh opening uniformity when directly contrasted to staged tensioning.

the fabric due to excessive thinning of the thread. The data does not support either of these claims. In Figure 8 you will see a comparison of the mesh opening variation in size for staged tensioning and rapid tensioning procedures. This variation is expressed as a percent of the standard deviation (i.e., the standard deviation, a statistical estimate of the variation of the process is divided by the mean mesh opening size).

This gives us a statistical estimate of how much the size of the mesh opening is varying when compared to the average mesh opening and is expressed as a percent of that average. In this example a larger percent standard deviation means a larger amount of variation in the mesh opening. As you can see from the graph, rapid tensioning actually offers an improvement in mesh uniformity over the slow staged method in six out of the ten cases; is equal to it in two examples and only falls below by approximately 0.5 percent in the remaining two examples.

Predictable Tension Losses

The data used to generate the graph for Figure 9 was produced from high modulus, plain weave polyester fabric, rapid tensioned to a target window of 21–22 N/cm.[4] Although the mesh varied from 61–460 threads per inch and included several manufacturers, all tension losses were within a one N/cm window after printing. This suggests that rapid tensioning also improves the uniformity and predictability of tension losses during the print run.

Screen printing is, after all, a predictable process if we will only do things in a predictable way. How many times have you either looked for or tried to produce four screens of exactly the same tension for a four color job? With the right information and correct application of that knowledge it is actually quite easy to produce screens within one N/cm of each other, even with different manufacturers and mesh counts.

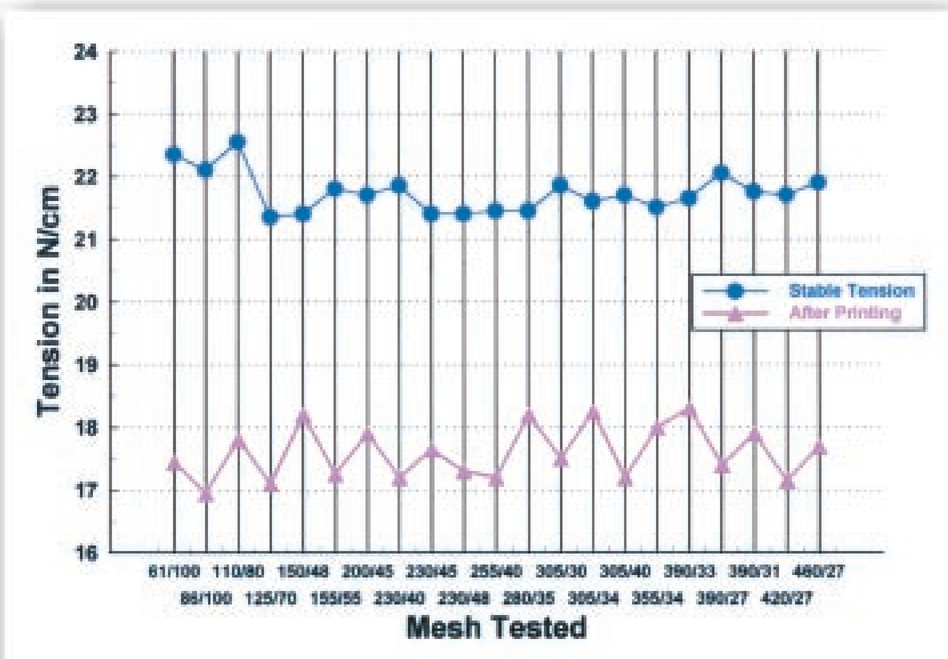

Figure 9. Predictable Tension Loss After Printing. Twenty-one different high modulus fabrics were tensioned to a target of 21–22 N/cm. Although these meshes represent several different manufacturers and a wide range of mesh counts (61–460 TPI). After printing, tension losses were still within approximately 1 N/cm of each other. This suggests very uniform and predicable tension losses.

[4]The 61/100 is not high modulus.

Going Beyond Rapid Tensioning

As effective as rapid tensioning has proven to be, there are techniques that are better still in terms of tension loss than anything described so far. One of those techniques is "pulsed" tensioning. Pulsed tensioning differs from "rapid" tensioning in the following way. After bringing the fabric up to the target tension rapidly (in 30–40 sec.), the mesh is held at that tension for only 30 seconds. Next all of the tensioning force is removed, allowing the mesh to relax back down to zero tension. This is repeated five times before securing the fabric to the frame.

The results of these tests are represented typically by Figure 10. As you can see from the data, there is an improvement over the staged method (and earlier rapid methods) without any additional time loss to complete the procedure. Additional study into the variables affecting screen stability will be conducted using the power of "Statistical Experimental Designs" in order to optimize the tensioning procedure. It is the opinion of this author that given the proper conditioning, polyester woven

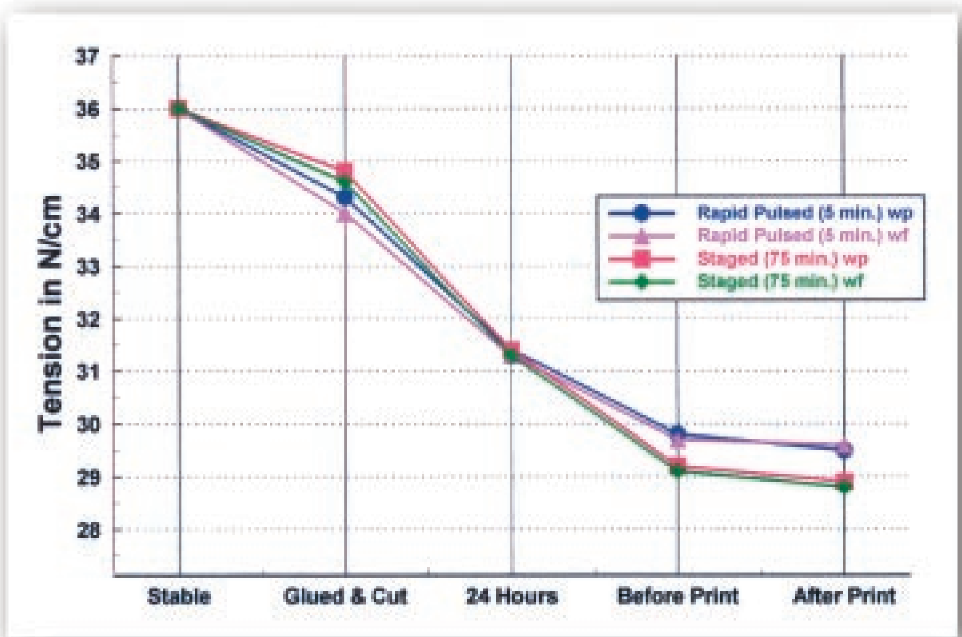

Figure 10. Rapid Pulsed (5 min.) vs. Staged (75 min.) Pulsed tensioning is also a rapid tensioning procedure that requires approximately five minutes to complete. It differs from earlier rapid tensioning procedures by the number of times the fabric is brought to tension and then released before securing the mesh to the frame. Pulsed tensioning requires at least five "pulses" or trips up to the target tension where it is held for 30 seconds and released. This method has yielded the best results to date. Investigations into how to optimize this affect continues.

materials can be brought to a high state of stability in a short period of time that will rival the long term benefits of "aging" the fabric by extensive cycles of printing, reclaiming, and retensioning.

In Summary

Rapid tensioning procedures have produced drastically faster tension times without sacrificing print quality. They have also resulted in substantial cost savings due to decreased labor and increased through put. It allows for simpler screenmaking and easier plant-wide standardization. Finally, it reduces the time needed to train new employees. However, as important as all of these benefits are to the screen printing industry at large, I believe there is yet a more important lesson to be learned from this investigation. By failing to challenge the current theories and assumptions with sound scientific investigations into all aspects of the process, we run the very real risk of lumbering along at far below the optimum level of quality and efficiency. With today's competitive market can anyone afford to run with a process that is less than optimal?

Suggested Reading

Hunt, Dennis. "Rapid Mesh Tensioning Proves Successful." *Screenplay,* February 1995, pp. 26–29.

Johnston, Fred. "The Economics of Rapid Tensioning." *Screen Graphics,* May 1996, pp. 12–16.

Peyskens, Andre. "Mesh Conceptions: A Practical Look at Tensioning." *Screen Printing,* February 1996, pp. 42–52.

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