Predicting Comfort of Flame-Resistant Clothing

Comfort has rapidly become a key factor in the selection of flame-resistant (FR) and arc-rated (AR) protective clothing. In fact, recent research shows it is more important to wearers and specifiers than any single factor. This article reviews what is known about comfort and clears up several common misconceptions.

Quantifying Comfort

Comfort cannot be reliably predicted by any single lab test of a fabric or by any series of different fabric tests. This is because comfort is inherently subjective; it is entirely a perception in the mind of the individual wearer and thus defies objective, quantified analysis. This perception differs from person to person, day to day and sometimes even moment to moment. To see real-world evidence, take a look around the next meeting you attend with at least 8 to 10 people who were free to dress in whatever they prefer. Although the environmental conditions are the same for everyone in the room, chances are you will observe some people wearing one shirt, others wearing a t-shirt and shirt and some wearing a t-shirt, shirt and jacket, vest or other third layer. You will probably also see long sleeves and short sleeves, knits and wovens, heavy fabrics and lighter fabrics, etc. Despite identical conditions, there will likely be almost as many fabric weights, layers and styles as there are people in the meeting.

Two fabric “comfort” characteristics that are routinely and significantly misunderstood are breathability and weight.

Breathability

Breathability matters because people dissipate heat first by radiation and secondly by sweating; sufficient air permeability to accomplish this is important. However, once this threshold permeability has been reached, small and medium differences in air perm data are not generally noticeable to a wearer. Significant differences may be meaningful but only when all other properties are identical (such as with a fiber type and fabric brand); they are usually lost in the myriad of differences across other fiber types and fabric brands.

When wearers talk about “breathability” of an FR or AR fabric, they are generally thinking about a combination of many fabric and garment characteristics that, in sum, mean they “feel too hot,” “feel okay” or “feel good.” Air permeability quantifies only one of many relevant characteristics and should not be mistaken as categorically measuring what wearers mean by breathability. In fact, a longstanding and effective FR fabric has a high air permeability rating and yet consistently scores at or near the bottom of wear tests for comfort. It is almost always rated well below other fabrics in “breathability” by wear test participants, despite having much higher air permeability data than many of the other fabrics in the studies. How can this be?

When wearers are asked in follow-up research for rationale behind this rating, the most common answer is one version or another of “the sweat rolls down my
back and puddles in my boots.” The wearer’s perception is that if sweat is not evaporated, it must be due to poor breathability. However, this is really more reflective of the fabric’s inability to absorb moisture than it is the textile definition of air permeability.

The second most common explanation was that the wear test participants questioned the protection of the lightest garments, wondering how effectively they would insulate against a hazard. They were more comfortable when they felt more protected.

In a similar vein, two garments made of the same fabric brand and weight, and therefore possessing the same air permeability number, were given significantly different breathability ratings by wear test participants who only knew the fabrics as A and B. After interviews, it became apparent they rated fabric A as hotter than fabric B, and therefore their perception was that it was less breathable. The only actual difference was that fabric A was much darker in color than fabric B. Darker colors feel hotter in the sun.

Breathability means something different, and something more, to wearers than it does to textile scientists in lab testing and is thus essentially impossible to homogenize or objectify. The quantification we have (air permeability) has been oversold as a differentiator (assuming a sufficient base level), and even large changes are often overwhelmed by other differences between compared fabrics.

**WEIGHT**

If air permeability is not predictive of comfort, what about weight? The popular misconception is that lighter is better in hot weather, but again, wear tests clearly demonstrate otherwise. In the majority of objectively administered blind wear tests of common FR and AR garments, fabrics that are rated as most comfortable are 1 to 2.5 oz. per square yard heavier than the lightest fabrics in the tests. Conversely, the lightest weight fabrics are frequently at or near the bottom in ratings of overall comfort. People who choose FR and AR garments primarily based on the expectation that light weight equals comfort usually select the lightest shirts on the market, which are generally 4.5 oz. synthetics. It is particularly ironic that many feel it necessary to wear 100% cotton t-shirts underneath for softness and/or sweat absorption that lightweight synthetic FR does not provide; at 4.5 oz. per square yard, t-shirts effectively double the total shirt weight.

If light weight were predictive of comfort, we would not expect to look around that meeting room and see people choosing to wear one, two and even three layers. We would not expect people to choose 14 oz. jeans instead of 9 oz. slacks or 6 oz. shirts over 4.5 oz. shirts, but they do. And they do so sometimes even within a fabric brand, where the only difference is weight. A wear test conducted by a major U.S. utility in a tropical environment, where the temperature and humidity are high year round, rated a 7 oz. shirt as more comfortable than an otherwise identical 5.5 oz. shirt. When the results were questioned prior to writing a specification, the predominant reason given by the wear test population was that lighter shirts stuck to the body once they got sweaty, making it harder to move around and climb poles, while the slightly heavier fabric was not nearly so prone to do so and was otherwise equally comfortable.

Like air perm, lighter weight rarely correlates to overall comfort across multiple fiber and fabric types because comfort is not a single-issue characteristic and because there are so many other differences. It might seem reasonable to combine characteristics and identify a fabric that has both. However, even this combination approach fails to have predictive value.

A matrix was created ranking fabrics by a combination of light weight and high air permeability. The fabric brands were not named, but the data were from the most popular FR and AR fabrics on the market, plus a surprise entry; there was a single woven fabric that had the best numbers by a wide margin in both categories and overall—and it was a window screen.

There is much we do not fully understand about comfort and more that is widely misunderstood. Weight and breathability are just two of a number of these characteristics; this makes intuitive sense when you consider the inherently subjective, individual and dynamic nature of what makes someone feel “comfortable.” Some of these characteristics are indefinable, others are not objectively measurable and the complex interplay between so many variables multiplies the considerations exponentially. Comfort cannot be judged from across a desk or from graphs and charts. It eludes simple quantification. There is only one reliable, proven method for predicting comfort of FR and AR clothing. There is simply no substitute for a properly conducted, and objectively administered, blind wear test.

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