Milliken®

Amplitude®

Flame Resistant Fabric

WHITE PAPER

Predicting Thermal Comfort of Garments by Measuring Fabric Properties

Milliken™

Please Note: Amplitude fabrics are innovative, high-tech, flame resistant materials intended to be used in garments that supplement personal protective equipment that reduce the flammability risks of momentary exposure to electric arc flash and flash fire hazards. They may be used as a layer of, but are not intended for use as the primary protection in fire fighting garments or other products subject to repeated or extended exposure to heat or flame except for Amplitude fabrics that are explicitly certified in writing to meet NFPA 1977 for use in wildland fire fighting garments. Use caution near sources of flame or intense heat and do not launder with bleach or fabric softeners. Amplitude flame resistant fabrics technology is left for the life of the garment when washed according to care instructions. As each customer's use of our product may be different, information we provide, including without limitation, recommendations, test results, samples, care/labeling/processing instructions or marketing advice, is provided in good faith but without warranty and without accepting any responsibility/liability. Each customer must test and be responsible for its own specific use, further processing, labeling, marketing, etc. All sales are exclusively subject to our standard terms of sale posted at www.milliken.com/terms (all additional/different terms are rejected) unless explicitly agreed otherwise in a signed writing.

INTRODUCTION

In selecting flame resistant garments for workers, thermal comfort has been receiving an increasingly large amount of scrutiny. This is due both to a heightened awareness of the dangers of heat-related stress and the probable reality that workers are more likely to comply with PPE requirements if the garments are comfortable. Wear trials are a great tool to gauge the comfort of garments in specific work environments, but using wear trials alone can become extremely time-consuming and expensive, particularly if multiple fabric choices are under evaluation. In order to gather accurate information during a wear trial, the trial needs to be of adequate duration and size and span the range of environmental conditions and activity loads that are expected for each job. With the rapid growth of flame resistant workwear over the last several years, many new fabric suppliers and new fabric options have become available to service the large number of new users in an increasingly diverse hazard environment. Methods for screening garments based on fabric properties must be employed to reduce the wear trial scope and focus on the garments that are likely to be best suited for the environment. Measuring a single fabric property may not always be an accurate predictor of thermal comfort. However, by using a combination of fabric properties including weight, air permeability, heat loss, and moisture management properties, a reasonable comparison can be made of candidate fabrics prior to constructing garments for wear trials.

Milliken & Co. is a 2012 member of NFPA, ASTM, NSC, and IEE

HEAT LOSS MEASUREMENTS

Heat loss is one the fundamental fabric properties that drives thermal comfort. It measures the ability of the fabric to pass heat from the wearer to the environment. Fortunately, simply measuring the air permeability, which measures the volume of air that will pass through the fabric at a standard pressure (ASTM test D737-04) and the fabric weight (ASTM D3776), can provide a reasonable approximation of thermal heat loss properties of a fabric. In general, lighter weight fabrics with higher air permeability will trap less heat and provide greater comfort in warm environments and in jobs with a high metabolic demand.

There are more advanced measurements that can be conducted to gain a deeper understanding of the thermal heat loss properties of fabrics, particularly during strenuous activities or in high-heat environments. For example, the permeability index (I_m) indicates the ability for moist heat to pass through the fabric. The values range from 0 (totally impermeability) to 1 (totally permeability). Fabrics with higher values will generally be more comfortable in sweating conditions. A combined measurement that takes into account both the dry and evaporative (sweating) heat loss through the fabric is termed the total heat loss (Q_t). Measured at 100% wet skin conditions, it predicts the amount of activity that a wearer may sustain and still remain comfortable. Higher values indicate that a more strenuous level of activity is possible without creating heat stress. Both of these tests are described in ASTM test method F1868C.

MOISTURE MANAGEMENT PROPERTIES

Another major contributor to comfort is the ability of the fabric to transport moisture (sweat) from the inside of the fabric to the outside where it can evaporate and provide cooling. The absorbent capacity of the fabric, although important, should not be considered alone. The ability of the fabric to release moisture through evaporation is a much better indicator of comfort in high-heat environments. Heavier fabrics tend to absorb more moisture (think flannel or denim), but also tend to retain that moisture longer, potentially leading to a saturation condition where the sweating rate exceeds the evaporation rate. The evaporation properties of fabric can be determined by measuring two key parameters: the percent evaporation (E_p) and the drying time.

The percent evaporation is the ratio of the amount of moisture evaporated to the amount of moisture absorbed during a 1000 second (approximately 17 minutes) test. In this test, water is supplied from a reservoir to the fabric through a porous test plate. The water is wicked into the fabric laterally while it is simultaneously evaporating. At the end of the test period, the amount of water consumed from the reservoir is compared to the amount of water remaining on the fabric. The difference is the amount of water evaporated during the test. Higher values in this test indicate a greater ability of the fabric to disperse and evaporate moisture. The drying time is a good measure of the ability of the fabric to cool the wearer if it were to become saturated. It is simply a measurement of the amount of time required for the fabric to go from completely wet to completely dry in controlled conditions.

EXAMPLE COMPARISON OF FABRICS

As an example, two commercially available 88/12 cotton/nylon flame resistant fabrics were submitted to North Carolina State University to measure these thermal comfort parameters. Each of these fabrics is certified to NFPA 2112 and both are HRC2 rated and have identical arc ratings at 8.7 Cal/cm^2. Although the flame protection properties of these two fabrics are virtually the same, the thermal comfort properties predict a clear distinction in comfort.

	Amplitude®	Market Fabric	% Change
Weight (ounces per square yard)	6.6	7.8	15% lighter
Air permeability (cfm) Higher values indicate greater air flow through the fabric	120	30	400% more air flow
Permeability index (I_m) Higher values indicate greater ability to transport moist heat away for the body	0.76	0.56	26% more permeability
Total Heat Loss (Qt) (Watts/sq. meter) Higher values indicate that more strenuous activity can be performed without heat stress	767	653	15% more heat dissipation
Evaporation % Higher values indicate better ability to transport and evaporate sweat for evaporative cooling	34%	29%	14.7% more evaporation
Drying Time Lesser values indicates faster drying time	13 min	16 min	19% faster drying

The Amplitude® fabric is designed and manufactured by Milliken & Company using patent-pending technology that allows the fabric to be lighter weight and more breathable without sacrificing protection. The thermal properties of air permeability,

permeability index and total heat loss indicate that the Amplitude® fabric will be better able to transport moist heat away from the user than the competitor fabric and that more strenuous activity can be performed while remaining at a comfortable temperature. In addition, the moisture management properties of the evaporation percentage and drying time demonstrate that Amplitude® will have a greater ability to transport and evaporate moisture.

Naturally, other factors need to be considered when selecting fabrics. Other comfort parameters, such as fabric "hand," which is a combination of softness, stiffness and stretch, will also contribute to overall comfort. If the primary concern is thermal comfort, however, the comparison of the basic fabric properties of permeability, weight and the ability to transport moisture is an excellent method to help determine the best fabric/garment solution for your worker's environment.

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For more information, visit www.millikenfr.com.