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PPE Update

Does firefighter PPE need another breathability test?

With a test measuring total heat loss accepted, is there room and need for a test measuring evaporative resistance?

Apr 19, 2016

Over the past two decades, firefighting protective clothing has transformed from being relatively heavy with rubberized layers to being more sleek, form-fitting and lighter.

Some of this transformation came about because years ago stress-related fatalities and injuries were the number one risk facing firefighters. And that partly came about due to the excessive weight and bulk of the gear.

Those involved in the turnout clothing business evolved new materials and gear designs to lessen those burdens without sacrificing protection. In the 1980s and 1990s, turnout gear took the form of multi-layered clothing that consisted of the primary layers of an outer shell, a moisture barrier and a thermal barrier.

The outer shell layer provided the principal physical and flame protection by being rugged and resistant to the effects of moderate duration high-heat exposure.

The moisture barrier actually started out as a vapor barrier. It was intended to prevent water, hot and cold, and lessen steam penetration to the inner thermal barrier, which was the primary insulating layer against heat.

Most fire department buying decisions were based on the newly introduced material composite thermal protective performance (TPP) test that indicated clothing's overall thermal insulation. The argument was that firefighter protection was improved with increasing TPP values.

However, this had significant penalties in that it created severe burdens on the firefighter. While it provided protection during structural firefighting, it encumbered firefighters on the way to the first scene or in other non-structural firefighting activities.

The extra stress that this heavy clothing imposed created a significant physiological impact on firefighters and became a hazard to their overall health and well-being.

Seeking balance

It soon became recognized that the industry needed some balance between TPP and ways to minimizing this stress.

The International Association of Fire Fighters conducted a detailed field study with the support of DuPont and W. L. Gore & Associates. The study ran a series of experiments that measured the physiological impact of similarly designed turnout clothing with different types of material composites.

Several firefighters from the Indianapolis Fire Department went through simulated engine and ladder company exercises while their body core temperature, heart rate and skin temperatures were telemetrically recorded. Firefighter sweat rates were also measured and the firefighters answered detailed questionnaires about their perceived comfort and stress.

As a result of this study, IAFF was able to relate a new material composite test method called total heat loss (THL). This test method measures how heat can be removed from the body by the combination of sweating and conduction, the two principal forms of heat loss possible while wearing encumbering clothing.

The study showed that THL could reasonably predict the heat stress produced by wearing heavy clothing. As a consequence, THL testing was introduced into the NFPA 1971 standard on protective clothing and created an upper boundary on preventing overly heavy and bulky clothing.

Thus, fire department purchasing practices focused on tradeoffs between heat loss and thermal protection.

Enter evaporative resistance

There are certainly limitations to any test method, whether TPP or THL, in being able to set universal requirements for some level of performance deemed critical to firefighter health and safety.

For example, TPP is intended to measure the PPE's thermal insulation when exposed to flashover or backdraft. Yet, most firefighters never experience those circumstances.

However, they can still be burned under a variety of thermal exposures, particularly by being in prolonged radiant heat or making contact with hot surfaces. For this reason, there are supplemental tests such as stored heat energy and conductive/compressive heat resistance that are applied to turnout gear.

For gauging thermal comfort, THL has been the only test in the NFPA 1971 standard since it was introduced as an optional test in 1991. Understanding why evaporative resistance is a concern is based on the same rationale why one test cannot completely characterize needed product performance.

Total heat-loss testing has had a dramatic impact on fire service clothing materials and to a lesser extent clothing design. Many fire departments have learned how to balance thermal insulation with heat stress relief in their clothing choices using TPP and THL values for the material composites.

Prolonged protection

Yet, there can still be differences in how clothing systems perform and the perception of the firefighters who wear them. Some argue that THL really does not make any difference because in the heat of fire, any system is going to be overwhelmed.

This argument falls short because PPE is worn leading up to the fire and in many non-structural fire events where improved breathability can afford less physiological stress. That means that when the time of greater exertion does occur, their bodies are less apt to be overcome by large increases in core temperature and heart rate that can alter judgment, endurance and overall health status.

If THL is accepted as a bona fide measure for the stress effects of clothing on firefighters as demonstrated by the IAFF study, then it follows that other types of measurements may supplement THL just as other thermal insulation tests must be used to demonstrate protection against heat.

Evaporative resistance is not a new test and has been used in several industries, although primarily outside the United States. As a test property, it can measure the intrinsic breathability — the ability of moisture vapor arising from sweat to be passed through clothing material.

This is important because sweating is one of the primary ways the body sheds heat. If the outside temperature is warmer than body temperature, it can be the only way the body can lose heat. Therefore, this measurement can provide utility for assessing turnout clothing's impact on firefighter physiology in ways that are not determined by THL testing.

Confusion and clarity

Unfortunately, introducing a new test requires educating the fire service for its usefulness and providing an understanding for how to interpret the results. Although it is an established test, it's mandatory for firefighter clothing in Europe, some have been trying to spread confusion by misrepresenting information about the test.

For example, one claim is that the IAFF Indianapolis study already looked at the use of evaporative resistance and concluded that it did not correlate with physiological measurements. That of course is untrue. Having run that study and preparing its report, we can definitively vouch for the specific conclusions that were reached.

There has also been an attempt to indicate that evaporative resistance is already part of the THL test. This is misleading since a different form of evaporative resistance is measured in THL testing, as is thermal resistance to create a combined measurement.

The reality is that both tests represent different measurements, which is why they have separate individual procedures.

One problem is that the units of measurement for evaporative resistance are not as intuitive as they are for total heat loss — lower values are better than high values, the reverse of TPP and THL.

Another challenge is that THL is established and evaporative resistance is not, and that nothing is to be gained from adding a new test other than additional expense to already costly turnout clothing.

We encourage you to look at the data that is being presented over the next several months. Judge for yourself whether evaporative resistance ranks clothing material composites differently than THL and if you believe this type of test data allows you to make an informed decision for overall safety and health.

About the author

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Jeffrey and Grace Stull are president and vice president, respectively, of International Personnel Protection, Inc. They are members of several NFPA committees on PPE as well as the ASTM International committee on protective clothing. Mr. Stull was formerly the convener for international work groups on heat/thermal protection and hazardous materials PPE as well as the lead U.S. delegate for International Standards Organization Technical Committee 94/Subcommittees on Protective Clothing and Firefighter PPE. They participate in the Interagency Board for Equipment Standardization and Interoperability and have authored the book, "PPE Made Easy." Send questions or feedback to the Stulls via email.

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