

FIREFIGHTER SAFETY

NFPA 1851: KEY TO TURNOUT GEAR PURCHASING AND MAINTENANCE

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Firefighting is dangerous work. Proper turnout gear is necessary to ensure that firefighters are protected. *Photo courtesy of Globe*



ABOUT THE COVER:

Fire departments and manufacturers work together to ensure that firefighters have the personal protective equipment they need to do their jobs as safely as possible.

Cover photo by Glen E. Ellman

NFPA 1851: Key to Turnout Gear Purchasing and Maintenance

Best practices for procuring
personal protective equipment

Putting together a set of turnout gear is a lot like putting together a puzzle. There are many components and pieces and how they fit together will determine what the final ensemble will look like and how it will perform.

Manufacturers of fabric used in bunker coats and pants work tirelessly to use the latest technology and science to protect firefighters, and getting the most out of this gear requires that the fire departments assess their needs.

The National Fire Protection Association (NFPA) has developed standards to help departments through the turnout gear selection process, and fire departments across the nation are buying into that process. NFPA 1851: Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting is the industry standard for the fire service.

Firehouse® Magazine spoke with fire departments throughout the country that are using the standard in order to get their advice on best practices for procuring personal protective equipment (PPE). In this article, three fire officers –

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“Make sure it’s what you want”

Dan Bossio, of the Hanover County Fire Department, comes from a long line of firefighters in North Carolina. He knows the importance of selecting the proper turnout gear to get the job done. He’s in charge of making sure 175 members of his department in eight stations have the proper turnout gear. “If you are going out to bid on a set of gear, make sure it’s what you want and fits the climate,” Bossio said. “Then you have to sell it to the chief.”

Once Bossio became the go-to guy for turnout gear, he spent 2½ years evaluating everything from the very fabrics and material used in the coats and trousers to performance and fit to warranty and repair issues. “I became known as the turnout gear god,” he quipped.

It was a well-deserved title, as Bossio and his committee members traveled to several fabric and gear manufacturers’ plants, including Globe Manufacturing Co. in New Hampshire, the company which the department ultimately selected as its gear provider. Bossio used the NFPA 1851 standard in conducting an assessment of the department’s needs and looked at things like the Thermal Protective Performance (TPP) of the material composite they were selecting as well as the Total Heat Loss (THL). The committee also looked at gear designs, flame testing, abrasion testing and seam strength as well as after-sale service. Another consideration was the ease of repair should something become damaged during the gear’s lifetime.

Bossio developed a two-hour PowerPoint presentation that he used to sell the chiefs on the need for high-quality gear that was a bit more expensive than that of other bidders.

“We had to educate them about what it all means...and it paid off big time,” Bossio said. By the time the research had been complete and the presentation digested, all of the chiefs and budget committee decision makers were well educated and embraced the need for quality gear that would get the job done and protect the firefighters.

The purchasing group not only included the county department, but the City of Wilmington and a neighboring volunteer fire department, all of whom appreciated Bossio’s work.

Bossio said he was also able to convince the department to go with black gear, which can cost more because of the dyeing process. “We looked at the gold gear and the black gear and we found the trim contrast with the black gear made everyone more visible,” Bossio said.

Once the vendor had been selected, a five-year contract was awarded and Bossio said the department will be evaluating the turnout gear during that time with an eye toward improving the process and continuing to ensure firefighters are getting the best gear available for the demands of their job.

“Trying to get everyone educated with the whole program is a lot of work, but I am very happy we did it,” Bossio said.

“The value of the risk assessment”

Joel Bodenman, from the Kirkland Fire Department in Washington, became involved in the specification of turnout gear about seven years ago when his department had a cancer-related line-of-duty death.

“Dirty gear is a possible link to cancer and we decided to take a look at NFPA 1851 to see if there was anything we could do to improve our turnout gear purchasing and maintenance,” Bodenman said. That journey led the department to become one of

Fire departments in need of turnout gear use NFPA 1851 to conduct a full assessment of their protective clothing needs.

Photo courtesy of Globe

Captain Mike Bardwell of the Denton, TX, Fire Department; Lieutenant Joel Bodenman of the Kirkland, WA, Fire Department; and Lieutenant Dan Bossio of the New Hanover County, NC, Fire Department – share their combined decades of experience in evaluating, selecting and purchasing turnout gear.

All three officers are unanimous in their recommendation that fire departments in need of turnout gear do a full assessment of their respective department’s turnout gear needs. For instance, a fire department that operates primarily in warmer climates has very different needs than the department that works more often in cold weather. And, some departments that primarily fight fire outside buildings have different needs than those departments that launch aggressive interior attacks.

only a handful of fire departments in the nation verified to do advanced repairs and inspections on its gear, Bodenman said. “We took classes and we became verified,” he said. “For us, it was a matter of quality control.”

Kirkland’s PPE journey began with the NFPA standard requirement of a risk assessment of the department. “The value of the risk assessment is we are investing in a set of gear that’s made for the individual department needs,” Bodenman said. “Our turnout gear need is going to be very different here in the Northwest than it is for a firefighter in Phoenix... We do have some times that it’s freezing in the winter and then hot and humid in the summer.”

Bodenman said the department looked at all the fabric and material that goes into turnout gear, and even examined stitches per inch thread count and included that in the bid specification. To help them better understand how turnout gear is made and

“Buying turnout gear is like a puzzle,” Bardwell said. “You have to pick all the pieces and make them work for you.”

Bardwell, who has been a career firefighter for more than 26 years and the captain in charge of PPE, says one of the top criteria for his department is comfort. To achieve the maximum comfort, while focusing on the number one reason for having turnout gear – safety – Bardwell says he looks at all three components of the ensemble: the outer shell, the thermal barrier and the moisture barrier. All three have to work together, like a puzzle, to make the turnout gear work for the 170 firefighters he outfits, Bardwell said.

And Bardwell said his department is not afraid to mix and match the components to get what’s right for the department. Denton’s vendor of choice, selected by bid, is Globe and Globe has no problem providing a bunker coat of one style and trousers of a different style to meet custom-

“Manufacturers of fabric used in bunker coats and pants work tirelessly to use the latest technology and science to protect firefighters.”

what it is made out of, department representatives traveled to the fabric makers’ headquarters as well as the plants where turnout gear is manufactured. He said Kirkland then built a specification that was “performance based” using the information gleaned from the risk assessment as well as the factory visits. Ergonomics was also a big part of the equation, Bodenman said. “We pay these guys and gals a good deal of money to put their lives on the line,” Bodenman said. “The least we can do is to buy gear that provides a lot of protection, but is comfortable and flexible.”

Bodenman said his department looked at turnout gear from the fabric up and tried to balance performance with the kinds of calls the department handles and the conditions under which they do it. Because of the thorough examination of how the turnout gear is made, and the classes and certification members of the department have, Kirkland can do advanced repairs to all layers of the turnout gear ensemble. And, because the department has advanced turnout gear repair capabilities, it is 100% compliant with NFPA 1851 on maintenance, cleaning and repairs. “It’s definitely gotten notice,” Bodenman said, adding that the department has been trained at the Globe factory on how to make repairs. “Honolulu has made some calls to find out how we do what we do.”

Bodenman said his department has 200 sets of gear in service at any given time and staffers are making necessary repairs. Kirkland’s policy is to follow NFPA 1851 to the letter with routine testing and inspections. It’s also Kirkland’s policy to replace turnout gear every five years and keep the firefighter’s second set in service as a backup, should the primary set need to be cleaned, repaired or inspected.

“Buying turnout gear is like a puzzle”

Mike Bardwell is a captain with the Denton Fire Department in Texas. He’s also the person in charge of gear for the department, which is about 30 miles north of the Dallas/Fort Worth area.

ers’ needs. Bardwell said Denton has its own specification for turnout gear that covers everything from the outer shell material to the location of the radio pocket on the coat to the knee pads on the trousers.

The Texas Commission on Fire Protection has adopted NFPA 1851 and ordered that regulated fire departments must comply with it. Accordingly, Denton follows the NFPA standards for turnout gear and builds its procurement process around them. Part of those standards requires the PPE be cleaned regularly and as needed.

Denton has been sending its gear out to an independent service provider (ISP) for about seven years with good results, according to Bardwell. He adds the department does its own annual inspections and testing looking for any advanced repairs that may need to be made. Denton also has a policy of replacing turnout gear every five years, Bardwell said, stating that he sends out notices to firefighters who are up for new gear. Some of those firefighters respond back stating they have no immediate need for gear, he said.

“I might have a driver who says he doesn’t need new gear,” Bardwell said. “They’ll say it fits great, it’s broken in, it’s just been cleaned and repaired and it’s in great condition. The Velcro is all in place and it’s all good.”

If he gets that message, he will save the money and move on to another firefighter who needs replacement gear, Bardwell said, noting that gear that spends most of the time in its bunker bag or in the back of the truck while at the scene likely doesn’t need to be replaced as often as the gear used by interior firefighters.

“The 1851 program is a good program,” Bardwell said, adding that not only is it a national standard, Texas has made it its own, making it even more important that Denton follow the rules. “The way I look at it is it helps us use the gear the way it’s supposed to be used,” Bardwell said. ■

Firefighting is dangerous and fire departments want only the best for their members. Vendors in the fire service industry that provide fabrics and material components to turnout gear manufacturers are dedicated to the core mission of protecting the firefighter.

Photo courtesy of Globe

FIREFIGHTER SAFETY ■

Turnout Technology

Innovations in personal protective equipment

Materials used in firefighting turnout gear have evolved from rubber, cotton and corduroy into sophisticated, high-tech materials that require squads of chemists and engineers to develop.

We all know firefighting is dangerous and fire departments want only the best for their members. Vendors in the fire service industry that provide fabrics and material components to turnout gear manufacturers are dedicated to the core mission of protecting the firefighter. To get the latest on innovation and technology in the materials used for personal protective equipment (PPE), *Firehouse*® talked to several of the top fabric and material makers in the nation. Representatives from DuPont Protection Technologies, PBI Performance Products, Safety Components, Stedfast, TenCate Protective Fabrics and W. L. Gore & Associates shared information about the latest technology in today's turnout gear.

DuPont Protection Technologies

DuPont is one of the oldest names in flame- and heat-resistant material for turnout gear. Rich Young, a senior research chemist at DuPont and principal application investigator with the company's fire division, said, "DuPont has a long history in the making of flame-resistant fabric." Nomex, a DuPont product for more than 40 years, is an inherently flame-resistant fiber for firefighters and workers who need to rely on its flame-resistant properties for protection.

According to Young, DuPont makes products that are used in the outer shells of turnout gear, the most visible layer of turn-

out gear, including Kevlar which is blended with other fibers to increase strength. The three-layer construction of turnout gear is designed to trap air between each of the components, providing more protection for the user.

DuPont works with a variety of fabric and turnout gear makers to develop products designed for different uses. For instance, aviation flight suits are made to help the wearer escape high-temperature flash fires. Turnout gear, however, has to be heavier and constructed differently because it is designed to let the wearer work in extreme environments while also protecting from the quick, high-thermal event, Young said. DuPont works on making fibers and fabrics that won't melt and exacerbate, or prolong, the thermal event and cause injury to the user, Young said.

Because of the conditions in which firefighters are forced to work for 30 to 40 minutes at a time, the goal of any fiber and fabric manufacturer is to help make the lightest-weight, most breathable gear possible. "Kevlar, which is five times stronger than steel, and Nomex both make for more comfortable, lighter-weight gear," Young said.

Young said DuPont is continually working with fabric mills to develop more comfortable materials that hold dye better, displace heat and moisture more efficiently and better protect the firefighter. "We are continuously looking at new fibers and new technology," he said, noting that DuPont is motivated to reduce

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heat stress while improving flame and heat resistance.

Young said firefighters need to look at the entire ensemble when selecting turnout gear and learn what they can about the fibers and materials they are made out of and how each component interfaces with the other. “The hazards are well defined,” he said. “The object is to deny hazards access to skin. Turnout gear protects against that exposure.”

PBI Performance Products

Kim Henry, vice president of marketing and sales for PBI Performance Products, said PBI (polybenzimidazole) is a stable, organic fiber that provides thermal protection for high temperature applications. PBI is a fiber that is blended with other materials to make fabric used in turnout gear.

“We sell a fiber with a resistance to high heat and flame,” Henry said, noting that it is most often used for turnout gear outer shells. “We started in the late ’70s with Project F.I.R.E.S., started by the International Association of Fire Firefighters (IAFF).”

PBI is blended with Kevlar and Nomex to create the best fabrics for flame and heat performance. The company is currently manufacturing several products offering a variety of protection, according to Henry. PBI Gold is at the top of the list offering the best in protection, comfort and durability. Also in the fiber lineup is PBI Matrix, which combines the heat and flame protection of PBI Gold with high-strength filaments to reduce wear and tear. PBI Triguard fabric is a three-fiber blend that offers protection at a lower cost and a lighter weight, according to Henry. Triguard is used in gear manufactured for technical rescue operations.

Henry said firefighters should evaluate what they need for protection and pick the fibers and shells that provide the performance level and comfort that’s appropriate. “PBI fibers are not very rigid so they are comfortable and easy to move in,” Henry said.

Last year, PBI worked with Globe Manufacturing and other turnout gear manufacturers to develop a new PBI Lightweight Gold System in turnout gear that’s been well received in the fire service.

Henry said that PBI is continually working to develop new blends and fibers for the fire service market to improve comfort and protection. “We provide the highest-protection, lightest-weight fibers on the market,” Henry said.

Safety Components

Safety Components has spent the past few years developing new products with these in mind – increased comfort, flexibility and mobility in flame-resistant fabrics, said Guy Lucas, the company’s director of sales and marketing. Safety Components is one of the leading textile manufacturers in the world providing flame-resistant fabric solutions to the military and fire service, including turnout gear, urban search and rescue (USAR) gear, wildland clothing and flame-resistant stationwear.

“The fire service had come to expect excellent protection and durability with the different outer shells and thermal liners certified for turnout gear,” said Lucas, “but comfort, flexibility

and mobility were not words typically associated with flame-resistant materials.” Safety Components changed that with the development of Armor outer shell, PBI Max outer shell and Glide thermal liner, Lucas said.

“These new materials developed by Safety Components have one thing in common, Filament Twill Technology,” Lucas said, mentioning the trademarked material. “Filament Twill Technology is the breakthrough fabric design that incorporates DuPont Kevlar filament yarn and spun yarns woven in twill design.”

Lucas said one result of the design is a fabric that has super high tear strength due to the inclusion of a high percentage of filament Kevlar yarn, which is the same yarn used to make bulletproof vests. Another result of this fabric design is equal or higher thermal protection at a lighter weight, he said.

“Most important and most notable is the resulting comfort, flexibility and mobility experienced when these materials are utilized in turnout gear,” Lucas said. “For the first time, comfort, flexibility and mobility are possible.”

According to Lucas, Armor outer shell comes in two versions made up of Kevlar filament and Nomex/Kevlar spun yarns in a lightweight seven-ounce or 6.5-ounce twill design.

Lucas said the Glide thermal liner is specified by seven of the 10 largest metro cities because of its comfort and mobility. According to Lucas, Glide is offered in a variety of weights, depending on the batting, and uses a patented design of Kevlar filament and

40% Nomex/FR Lenzing spun yarns in a twill weave. “The result is easier donning and doffing, better moisture management, and increased comfort and mobility,” he said.

Stedfast

Stedfast is a maker of one of the most critical components of turnout gear, the moisture barrier. Sam Watts is the vice president of business development for the company and has been in the performance fabric business for more than 25 years.

“The moisture barrier is the most fragile and the most tested component in turnout gear,” Watt said. “That’s why it’s important to get the right one.”

Watts explained that Stedfast, which is one of the most recognized names in moisture barriers for turnout gear, makes three principal moisture barriers for the fire service. The first is Stedair 3000, a moisture barrier that offers the best overall value, Watts said, noting that it is an entry-level product that is still durable and meets all the standards. Next is Stedair 4000, which is a step up from the 3000 moisture barrier and features a Nomex woven substrate laminated to a breathable polytetrafluoroethylene membrane. At the top of the range is Stedair Gold. Watts explains the product incorporates PBI Gold and Kevlar in the blend woven substrate laminated to a breathable membrane.

Stedair Gold was developed for customers who want PBI Gold in each component of their gear, from the outer shell, through the thermal liner and the moisture barrier. “It’s for high-performance gear,” Watts said.

The trick to developing, and selecting, the proper moisture barrier is to understand what it is intended to do. Watts ex-



Today's personal protective equipment incorporates the latest technologies to protect firefighters. Photo courtesy of Globe.

plained that the more thermal protection performance (TPP) a moisture barrier offers, the less total heat loss (THL) is afforded. Departments must figure out how its members will fight fire and pick the appropriate moisture barrier.

Moisture barriers keep liquid and pathogens away from the firefighter while allowing internal heat to be dissipated, Watts said. He also said that all moisture barriers available to firefighters, including ones offered by competitors, do their jobs and protect firefighters. One of the biggest differences with Stedfast products is seam integrity, Watts said, noting that the company has perfected a method of making sure the tape used to cover the holes made by stitching the fabrics together is well adhered.

Watts said turnout gear makers have a lot of “moving parts” to

and soft comfort, with no break-in period. The fabric helps with the better management of sweat by pulling moisture away from the skin and reducing the physiological effects of heat stress.”

TenCate also introduced a new outer shell fabric in April called Kombat Flex that seeks to balance comfort and safety. Foley said the new product uses Kevlar, PBI and other fibers to create a material that is soft and flexible, but still has a high tensile strength and is tear and abrasion resistant.

“Each fire department has to figure out its own risks,” Foley said. “Every fire department doesn’t fight fire the same way. How you fight fire is going to be a big factor in the fabrics you need for your gear.”

“Vendors in the fire service industry that provide fabrics and material components to turnout gear manufacturers are dedicated to the core mission of protecting the firefighter.”

marshal to make their products, noting that they have to not only keep track of the different materials that go into the three layers of turnout gear, but keep track of the Velcro, cuffs, snaps, hardware, zippers, reflective trim and all of the options that firefighters demand. In turn, fabric manufacturers like Stedfast are continually working to perfect products to keep the firefighters safe.

“The material we used 20 years ago is vastly different than what we use today,” Watts said. “This is a science and science is a moving target. What we know now will be different than what we know four or five years from now. We continue to raise the bar. We are in the business of change.”

TenCate Protective Fabrics

TenCate is a multi-national company that develops and produces a variety of fabrics to protect people from the harmful effects of heat, flame and other related risks. Tom Foley, who is TenCate’s emergency response end use marketing manager, is a retired operations chief of CAL FIRE. He represented CAL FIRE on the National Fire Protection Association (NFPA) 1977 Standard on Protective Clothing and Equipment for Wildland Firefighters Technical Committee. In addition Foley retired as the chairperson of CAL FIRE’s Personal Protective Equipment Working Group.

As a marketing representative for TenCate, Foley now preaches the benefits of risk analysis for fire departments looking for turnout gear. “You need to understand your requirements for turnout gear,” Foley said.

Foley said as a fabric manufacturer, TenCate is always looking for material that affords a “balanced approach” between extreme protection and comfort. For instance, some fabrics may be very strong, but they are not good at resisting abrasions. Other materials may hold up to abrasions, but won’t hold dyes and color, Foley said.

“Your gear has to protect you from the thermal assault of a flashover, but it also needs to protect you from the heat generated from an aggressive interior attack,” he said. “That’s why TenCate has introduced its new Coolderm Technology fabric that features active moisture wicking, evaporative cooling effect

W. L. Gore & Associates

Jennifer Wise, a sales and marketing representative for W. L. Gore & Associates, said the company has three moisture barriers used in turnout gear and each has its benefits. At the top of the line is the company’s premium product, CROSSTECH 3-Layer, the company’s toughest barrier used by departments that want the best and most durable product available. Next is Gore’s CROSSTECH Black, a barrier widely used by metro cities all over the country, Wise said. Departments that want a high-quality moisture barrier for turnout gear that meets the standard select CROSSTECH Black, Wise said. Gore also offers a “performance-based” moisture barrier, Gore RT7100, that combines a high level of thermal protection and liquid penetration resistance.

At the core of Gore technology is the use of polytetrafluoroethylene (PTFE), a chemical relative of Teflon. The company developed a fiber used in the technical textiles industry to make its moisture barriers for the fire service.

“The moisture barrier helps manage heat stress,” Wise said. “Heat stress is one of the biggest concerns of the fire service.” Firefighters can be sidelined because of heat exhaustion and forced to drop out of the action, Wise said. Additionally, the moisture barrier helps keep chemicals and blood-borne pathogens away from the firefighter, Wise said.


While moisture barriers are important to keeping out chemicals, moisture and blood, they are also important to releasing heat generated by the firefighter. Wise said currently the industry focuses on the THL. Gore, on the other hand, is also looking at European testing called Resistance to Evaporative Transfer (RET). She explained that RET testing is done at 95 degrees as opposed to 75 degrees for THL testing. The difference to the firefighter is dramatic, she said, especially to those who work in warm climates.

Wise said it’s important for firefighters to pay attention to heat issues because any rise in core body temperature can cause serious physiological side effects like hearing loss, loss of motor skills and worse. “Having the right moisture barrier is more than just a comfort issue,” Wise said. “It’s about protecting the firefighter.”

—Ed Ballam

FIREFIGHTER SAFETY

By Barry Furey



Firefighters come in all shapes and sizes, so the days of building turnout gear that fits a “normal” range of firefighters are over.

Photo courtesy of Globe

Fit For Duty

How properly sized turnout gear enhances firefighter safety

“Fit for duty” is a phrase known to most firefighters. It is an indication that you have arrived at the station or at the scene of an emergency physically and emotionally ready to do your job.

Obviously, this lack of serious personal impediments improves your safety and the safety of those around you, but there is another less-focused-on area where “fit” also plays a role in your survival. That is the proper sizing of your turnout gear.

“Firefighters come in a remarkable range of shapes and sizes,” said Rob Freese, senior vice president of marketing at Globe Manufacturing Co. “When your gear really fits your body, it’s not just more comfortable; it enables you to perform your job to the maximum of your ability.”

As someone who is relatively short, the topic of correctly sized apparel resonates with me. Back in the early days, I, like many

volunteer firefighters, dressed on top of the hosebed while enroute to the call, grabbing our turnout gear from railings on the side of the engine. Despite our best efforts, we often wound up with ill-fitting gear that was both a nuisance and a danger.

While we have thankfully gotten past that point, dangers are still present. Consider that a review of the 2012 *U.S. Firefighter Injury Report*, published by the National Fire Protection Association (NFPA), reveals “the leading causes (of firefighter injury are) reported as overexertion, straining (27.5%) and falling, slipping and jumping (23.2%).” Although these injuries are not directly related to fit, they are illustrative of the movements that firefighters must typically perform.

This leads us to the question as to why properly fitting turnout gear is important. Firefighters are routinely tasked to

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work in hostile environments requiring physical exertion and rapid range of motion. We may be called upon to drag a hoseline, reach up to pull a ceiling or drag objects or victims. In the non-structural world, it may require climbing hills instead of stairs and ladders, and in the extrication environment to manage heavy or bulky tools in proximity to seriously injured people. Confined-space rescue is just that: carrying out critical maneuvers in extremely close quarters. With the odds already seemingly stacked against us, the last thing we should have to worry about is our personal protective equipment (PPE.) However, gear that does not fit can create some significant problems.

Ensuring a proper fit.

Bunker pants that are too long offer a tripping hazard and cause the expenditure of unnecessary energy. Sleeves that are too short can leave a gap between the turnout coat and gloves, exposing skin to mechanisms of injury such as cuts and burns, or if too long can bunch up at the wrist or elbow limiting the flexibility of the arms. Similarly, an ill-fitting coat can leave gaps or be so bulky as to be clumsy. Loose gear is not a good option as it increases the potential for catching or snagging

same sex. Best results are achieved by individual fittings.

Although major measurements are important, the knowledge of body dynamics comes into play. Gear must flex when you bend. It must cover when you reach. Given this, nothing beats an active try-on of the PPE in question. Think of every function that you may be required to perform, and put the suit through its paces. Don't forget relatively routine but repetitive actions such as getting on and off the rig. Is the gear comfortable? Does it move with you and flex as needed? Is any part too tight, too short, too long or too loose? During any of this dry run, does skin show due to loss of protective overlap of the components? That is why trying on the entire PPE system at the same time can prove beneficial.

Do your gloves and your sleeves operate as a well-matched protective envelope? Do you need a radio pocket or other accessories? Are you sure this is located where it will not interfere with your self-contained breathing apparatus (SCBA) harness? Can your lettering be read or is it covered by the cylinder? While the latter items may not be directly related to fit, they are most certainly related to function and safety.

Perhaps the most important consideration when trying on gear is to use the model and/or style of gear that you intend

“ Properly fitted turnout gear protects you from a number of hazards that can be encountered both on the fireground and in drill scenarios. ”

on objects at the scene, but neither is skin-tight apparel the best bet. While clothes that fit like a glove may be the choice of Olympians, turnouts require internal air circulation to provide the best possible protection. Therefore, a slightly relaxed, but not sloppy, proportion is recommended.

Given these requirements, how can you ensure you get clothing that fits you for duty? There are a number of considerations. For starters, consider that your PPE will be a couple of inches larger than your “normal” size since they will be worn over street clothing. Sleeves, chest, waist and all the common body factors will be taken into account. It is recommended that a manufacturer's sizing set be used for sizing rather than taking measurements by tape measure.

No “one-size-fits-all” option

While the gender-neutral term “firefighter” applies to both sexes, there is no denying that there are anatomical differences between men and women. And, without accounting for these differences, female firefighters cannot possibly achieve a proper fit. Women will typically have shorter arms than men, and this must be addressed. Similarly, turnout coats must sufficiently flare to fit at the hips, while still providing a proper interface with bunker pants. Their shoulders and torsos will be narrower than their male counterparts.

But whether the gear is for women or men, there is still no “one-size-fits-all” option. There will obviously be variations in height, weight, torso, trunk and leg proportions within the

to purchase. Just as there are different fits and styles in traditional suits, so too are there variations in turnout gear, with manufacturers making more than one product line. Be sure what you tried is what you buy.

PPE meets changing needs

Past generations of firefighters wore gear that was appropriate for past generations of tactics. Much consideration was put into keeping warm and dry. Reliance on external attacks did not place the focus on flame resistance and durability. As priorities changed and technology improved, lighter, flame-retardant materials came into widespread use. Fabrics such as Kevlar added strength and durability.

With the changing face of the fire service, in many communities response to fires represents a minority of the workload. PPE has also had to change to meet that need. Future gear will be impacted by both NFPA standards and user demands and expectations. There will be even more “miracle fabrics” on the horizon, and turnout coats will likely contain sensors that can relay firefighters' vital signs directly to the safety officer, who will be able to sense trouble before a Mayday has to be called.

Properly fitted turnout gear protects you from a number of hazards that can be encountered both on the fireground and in drill scenarios. But to get the maximum protection, it must be worn – and worn properly. Whenever PPE is required, make sure that you and your gear are both “fit for duty.” ■



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Knowing PPE The Limits of Your

Don't expect your PPE to always keep you from getting burned

The Occupational Safety & Health Administration (OSHA) requires fire departments to conduct a Risk Assessment as part of their personal protective equipment (PPE) selection process.

A lesser known fact, however, is that OSHA also requires departments to teach employees the limitations of their PPE and that each employee must demonstrate an understanding of those limitations.

Just as fireground tactics have evolved, personal protective clothing has evolved from single-layer rubber coats designed to keep firefighters warm and dry to high-performance, three-layer jacket-and-pant ensembles using the most technically advanced materials. Firefighters may be able to go into fire scenes deeper and stay in longer with this advanced protection, but the human body has not changed.

Globe started manufacturing firefighter protective clothing in the late 1800s and patented a unique three-layer turnout construction method in 1918. By the early 1980s, the International Association of Fire Fighters (IAFF) was concerned about heat stress associated with the traditional garments being worn by firefighters. The organization partnered with PPE manufacturers and the National Fire Protection Association (NFPA) to develop gear that would help to reduce firefighter stress. The three-layer ensemble developed more than 100 years ago is now found in every brand of turnouts on the market.

LIMITATION 1

Turnout gear components can break down after exposure

A typical turnout has an outer shell, a moisture barrier laminated to a substrate and then one, two or sometimes three layers of thermal material. It is in these layers and between these layers that air is trapped to insulate the firefighter from heat.

• **Outer shell.** The main purpose of the outer shell is to protect the firefighter from direct flame; it also contributes to abrasion and cut protection as well as some thermal protection. Flame resistance is commonly measured by the highest Limiting Oxygen Index (LOI), which is the amount of oxygen required to make the material burn. The higher the LOI value, the more flame resistant the material. Outer shells are blends of man-made petroleum products that have different LOI values.

Many outer shells are blends of Kevlar, which has a low LOI, and PBI or PBO, which have higher LOIs – the blend creating a synergy that enables it to work at a higher temperature. Different mills that manufacture the outer shell fabric from these products also engineer into their fabric additional attributes, like strength, flexibility and abrasion resistance.

Embrittlement is a total breakdown of the outer shell. Even with the highest level of flame resistance, an outer shell will eventually break down when exposed to flames and could result in serious burns.

Photo courtesy of Globe



Embrittlement is a total breakdown of the outer shell. Even with the highest level of flame resistance, an outer shell will eventually break down when exposed to flames and could result in serious burns.

Dye sublimation occurs when the dye in an outer shell fabric dissipates at about 450°F. This discoloration does not mean the outer shell is compromised, but it is a warning that all three layers of the garment must be inspected to validate whether it is safe to stay in service. The NFPA 1851 standard outlines how departments can test their gear after exposure.

MARK DOLIM
is National
Sales Manager
for Globe
Manufacturing
Company, LLC

Dye sublimation occurs when the dye in an outer shell fabric dissipates at about 450°F. This discoloration does not mean the outer shell is compromised, but it is a warning that all three layers of the garment must be inspected to validate whether it is safe to stay in service.

Photo courtesy of Globe

• **Moisture barrier.** The primary purpose of the moisture barrier is to protect the firefighter from water and what NFPA refers to as the “common liquids”: chlorine, battery acid, aqueous film-forming foam (AFFF), gasoline and hydraulic fluid. Then it is additionally tested for blood-borne pathogens. The moisture barrier must be resistant to these challenges for at least one hour. The other purpose of the moisture barrier is to allow perspiration to move away from the wearer, also referred to as “breathability.” The moisture barrier is typically a bi-component membrane,

or two layers, in different combinations of polyurethane and Teflon bonded to a substrate.

• **Thermal liner.** The thermal liner provides a majority of the thermal protection from the ambient heat in the room. The more thermal liner there is, the less heat the firefighter will feel. The less thermal liner there is, the more heat the firefighter will feel.

Thermal liners consist of a face cloth and batting. The face cloth can be spun fiber or a blend of spun and filament fibers. The filament adds slickness to the face cloth, which makes it comfortable to wear and work in. A spun fiber means that the mill converts bales of fiber by spinning them into yarns.

The yarns have random fibers protruding that wick moisture off the skin. The batting is typically Nomex and or Kevlar and can be a one-layer product like a felt, called needlepunch, or multiple layers of spun lace that’s made by using water jets to entangle the filaments of the fiber.

LIMITATION 2

Turnout gear is intended for escape when things go bad

NFPA 1971 has established minimum performance levels for PPE that are meant for the least effort a fire department is going to put forth in a structure fire, which might be defensive firefighting. However, most fire depart-

NFPA 1971 PERFORMANCE TESTS		
TEST	MEASURE	MINIMUM REQUIREMENT
TPP (Thermal Protective Performance)	Predicts time for convective and radiant heat to penetrate through three layers of ensemble to cause second-degree burn to human skin	35 w/m ²
THL (Total Heat Loss)	Measures ability of garment to allow heat to pass away from body through three layers of ensemble, also known as breathability	205 w/m ²
Flame Test	Specifies time to self-extinguish and allowable char length after 12 second exposure to direct flame	Afterflame of no more than two seconds with no melting or dripping Maximum char length of four inches
Heat & Thermal Shrinkage	Hot air oven test at 500°F for five minutes	No melting, dripping, separation, charring or ignition Maximum shrinkage 10% in any direction
CCHR (Conductive, Compressive, Heat Resistance)	Specifies minimums in protective insulation in high compression areas of knees and shoulders	25 seconds until second-degree burn
Trap Tear Resistance	Ensures fabric is strong enough to hold up in the field	Outer Shell – 22 lbs. Thermal Liner – 5 lbs. Moisture Barrier – 5 lbs.
Seam Breaking Strength	Sets a minimum strength to ensure that garment seams are strong	Major A Seams = 150 lbs. Major B Seams = 75 lbs. Major C Seams = 40 lbs.

ments in this country respond to hazmat situations, medical calls, motor vehicle accidents, extractions and confined space rescues – and many are capable of interior firefighting, the most dangerous and life-threatening scenarios encountered on the fireground. Any department that exceeds minimal firefighting tactics needs to evaluate and provide PPE that surpasses the standard by quite a bit.

Structural turnout gear must pass several performance tests outlined in NFPA 1971, a few of which are listed in the chart on page A13.

LIMITATION 3

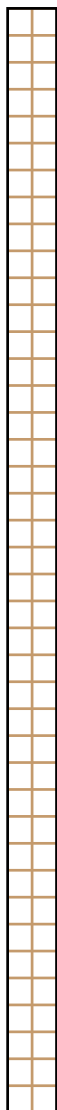
When things go bad, a firefighter has seconds – not minutes – to get out

All testing to the NFPA standards is intended to keep firefighters safe in perilous and volatile environments where conditions can change in seconds. One measure of turnout gear performance that many firefighters know something about is Thermal Protective Performance (TPP). That particular test simulates flashover and is tied to the Stoll Curve. Alice Stoll was a scientist in the 1960s who was given a contract by the U.S. Navy to confirm at what temperature human skin would burn. Sailors volunteered to be burned on their arms in order to get a weekend pass. From her study, she was able to provide firm data on how much energy and time would lead to the different burns.

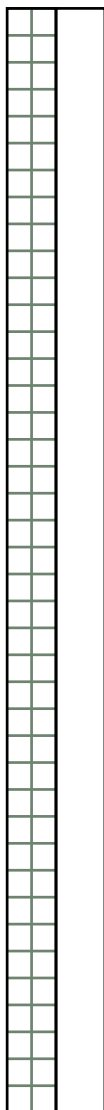
We know today that a first-, second- and third-degree burn is based on the amount of heat and the amount of time that passes as heat is conducted deep into the skin. It is not uncommon to see such burns in the fire service. NFPA keys on approximately 131°F because that is the temperature at which human skin will receive a second-degree burn.

If you take the TPP value of the gar-

OUTER SHELL



MOISTURE BARRIER



THERMAL BARRIER



A typical turnout has an outer shell, a moisture barrier laminated to a substrate and then one, two or sometimes three layers of thermal material. It is in these layers and between these layers that air is trapped to insulate the firefighter from heat.

ment composite and divide it in half, that is roughly the number of seconds before a second-degree burn would occur. With a minimum requirement of 35, anything beyond 17.5 seconds (minimum TPP value ÷ 2) is good.

But there's a problem with firefighters assuming they have 17.5 seconds to escape a flashover. TPP testing is conducted in a controlled laboratory environment with an ambient temperature of 70°F. When a firefighter has become trapped in a burning room, how hot

is that fire? How hot is it when crawling on the floor? It is literally hundreds of degrees and getting hotter by the second. Additionally, during the time the firefighter is in that room, the gear is absorbing heat. What happens in the real world, outside the laboratory environment, is that a firefighter in a flashover might have only one to three seconds before suffering second-degree burns because the gear is pre-heated and temperature in the room is constantly escalating.

What is really happening for the firefighter is that the second law of thermodynamics is in place. Rudolf Clausius was a scientist who, in 1850, presented the second law of thermodynamics: heat travels from hot to cold, always. Heat energy follows the path of least resistance so any clothing with a lower TPP rating, hoods for example, will allow the heat to pass through first. Ultimately, thermal equilibrium will be achieved. The room will come up to a temperature that is stable and everything in it will be at that same extreme temperature, including its contents and the firefighter. PPE buffers heat, but it cannot change the law of thermodynamics. In fact, a firefighter can be seriously burned at much lower temperatures as thermal equilibrium is achieved, and this can occur even with no visual damage to the turnout gear.

Train, train, train

There's a lot to consider when evaluating and purchasing PPE.

The Risk Assessment is critical in defining requirements as they relate to such things as types of duties performed, incident operations, frequency of use of the gear and geographic location and climate. But getting the right turnout gear for the department is just the beginning. Firefighters need training not only on the performance of their gear and proper donning and doffing techniques but also on the limitations of their gear. It's information that can save lives. ■

For more details on the selection, care and maintenance of PPE, go to www.PPE101.com.

Putting Your Best Foot Forward

Understanding the role of proper footwear

Of all the parts and pieces that make up personal protective equipment (PPE) footwear may be the component that receives the least consideration, yet it has a significant bearing on firefighter safety. Helmets, turnout coats, bunker pants, hoods, gloves and self-contained breathing apparatus (SCBA) would likely be listed first by those asked to name an item of protective apparel, yet it is footwear that provides a level of safety to our lower appendages. This lets us comfortably keep moving, crawling, climbing, lifting and all the other tasks that firefighters are required to routinely do.

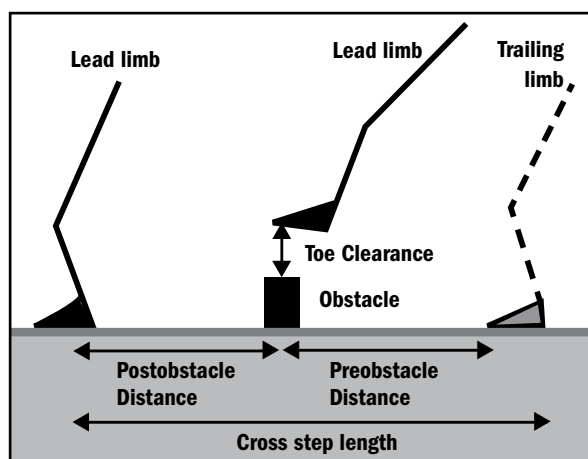


Illustration of step characteristics measures. Solid lines and black fill indicate the lead limb and foot. Dashed lines and gray fill indicate the trailing limb and foot.

As the needs of the fire service have changed, so has our gear; and boots are no exception. During the early years of my career, I wore three-quarter-length boots. The prevalent thinking was that your turnout coat was long enough to provide a protective overlap. Still and all, and depending upon your movement, there was often a significant amount of trouser leg exposed to surrounding hazards. This was especially true when your boots were folded down while you were climbing stairs or similar activities. These segued to “bunker boots” that worked in conjunction with bunker pants to provide a more coordinated system. Some began to resemble work boots or combat boots more than traditional firefighter gear, but improved on safety and performance. As women entered the fire service, new challenges of proper footwear were added.

In 2008, the National Institute for Occupational Safety and Health (NIOSH) began a study of firefighting boots. During the previous year, National Fire Protection Association (NFPA) figures suggested that about half of firefighter injuries were related to overexertion and falls.

As part of the NIOSH study, firefighters were asked to perform tasks replicating typical activities while wearing

rubber boots, leather boots and safety shoes. It was found that while rubber boots cost less than leather, they weighed more. Observations tended to indicate that heavier boots led to changes in the way test subjects walked, adjusting their gait to adapt. There was also an increase of oxygen use and expenditure of energy, as witnessed from the monitoring of vital signs. During obstacle crossing, significant 5-6% decreases in metabolic variables were observed in more flexible soles. This and other test results showed the flexibility is also important. Overall, female firefighters were observed to take shorter steps than their male counterparts, meaning that gender has a bearing on footwear performance.

On April 5, 2011, Dr. Nina Turner presented the results of the Centers for Disease Control (CDC/NIOSH) work to the NFPA Technical Committee on Structural and Proximity Fire Fighting Protective Clothing and Equipment. Dr. Turner further acknowledged her research partner Dr. Sharon Chiou. Committee notes, as well as Dr. Turner’s presentation, offer the following summary information:

- Boot characteristics in addition to weight, such as sole flexibility, may influence physiological and biomechanical variables, ultimately affecting fatigue and risk of trips/falls
- The effects of such boot characteristics as weight and sole flexibility may depend on task and gender
- NFPA 1971 technical committee will consider these findings as they update boot standards

The full presentation can be viewed at: http://www.nfpa.org/Assets/files/AboutTheCodes/1971/FAE-SPF_ROC-Minutes_04-11.pdf

For this article, Firehouse* interviewed Dr. Turner, who consulted with Dr. Chiou for these answers:

Firehouse*: How did you get involved in this study?

Dr. Turner: In 2005, the NFPA 1971 Technical Committee on Structural and Proximity Firefighting Protective Clothing and Equipment was in the process of updating the 1971 standard. The committee was very interested in including recent, objective data on the physiological and biomechanical effects of firefighter boot weight and design for men and women in future standard revisions and specifically requested the assistance of NIOSH, Division of Safety Research, Protective Technology Branch, in conducting and interpreting this research.

Firehouse*: Personal protective equipment is obviously a system made up of several components. How do boots fit into this system?

Dr. Turner: Firefighters are required to wear protective ensembles that are designed to provide a high level of protection against extremely adverse environments. Nevertheless, the use of PPE may pose an additional load on the firefighters, restricting their movements and impeding the job performance.

Firefighters have traditionally worn heavily insulated rubberized boots as protective footwear. These boots can add 10 pounds (4.4 kg) of extra weight to a firefighter. There are sev-

FIREFIGHTER SAFETY

eral general types of certified structural firefighting boots in use today: rubber bunker boots 30 cm to 40.6 cm (13 in. to 16 in.) and leather or leather-fabric “hybrid” boots 20.3 cm to 40.6 cm (8 in. to 16 in.). Leather boots are now produced with either stitched (less flexible) or cement (more flexible) soles.

Rubber boots are generally heavier than leather boots, while leather boots cost more. A 6% to 10% increase in oxygen consumption per kg of weight added to the foot was documented in the literature; however, the increase may depend on gender, task, ankle fit and whether subjects are wearing additional protective clothing or equipment. Since firefighters’ boots are heavy and bulky, they may change firefighters’ gait patterns and limit effective locomotion on the fireground. The effects of boot weight and sole flexibility on male and female firefighters’ metabolic variables, gait patterns and ability to negotiate obstacles were unknown prior to the NIOSH firefighter boot study.

Firehouse®: *From a layman’s perspective, what did your studies find?*

Dr. Turner: A 1-kg increase in boot weight caused a 5-6% increase in energy expenditure in men and a 3-5% increase in women during treadmill walking; however, increases were not statistically significant during stair climbing. Thus, heavier boots could lead more quickly to fatigue than lighter boots. Boot weight and task duration affected firefighters’ gait performance in negotiating obstacles. Firefighters were more likely to trip over obstacles when wearing heavier boots and after walking for a period of time.

Firehouse®: *Why should firefighters understand this body of work?*

Dr. Turner: Firefighting is one of the most dangerous and

physically demanding jobs in the United States, with the work-related injury rate exceeding those of most other occupations. The intensity of energy expended by firefighters performing firefighting tasks is generally agreed to be in the heavy-to-very heavy range. Further research of this type will be used by the NFPA 1971 standard committee to update their standards, which encourages boot manufacturers to continue to improve the design of firefighter boots.

Firehouse®: *Were any surprises found?*

Dr. Turner: When most people think of personal protective equipment, they immediately think of respirators, protective garments and gloves. The importance of protective footwear as one of essential components of personal protective equipment is often neglected. Boots worn by firefighters can unintentionally add extra stresses to firefighters.

Firehouse®: *Is there anything else we should know?*

Dr. Turner: NIOSH researchers are working on additional publications on firefighter boots.

Nina L. Turner, Ph.D., is the co-project officer for this project. Dr. Turner’s major area of education and training is applied physiology. She has extensive training and experience in conducting cardiopulmonary exercise testing and interpretation of exercise test results. She has been a principal investigator conducting human performance and personal protective equipment research at NIOSH for 25 years. Dr. Sharon S. Chiou is a health scientist at the Division of Safety Research, NIOSH, in Morgantown, WV. Her research focus areas include postural stability, slips and falls, gait analysis and ergonomics. She has been conducting traumatic injury and human performance studies at NIOSH for 14 years.

—Barry Furey

The Future of PPE? Real-Time Monitoring of Physiology and Location

The InterAgency Board (IAB) has had two critical problems on its research and development priority list for a long time: Emergency Responder Body Worn Integrated Electronics System Development and 3D Indoor Tracking of Personnel. Now there appears to be a technology that provides an integrated solution – WASP, the Wearable Advanced Sensor Platform.

Firefighters experience extreme physiological stress during the course of their duties. According to the U.S. Fire Administration (USFA), stress and overexertion account for 50% or more of firefighter line-of-duty deaths. Factors that affect firefighter physiological responses include exertion of work performed, elevated thermal environment, wearing heavily insulated protective clothing and carrying heavy equipment, as well as individual health status, fitness level, medication and hydration level. Firefighters are also exposed to extreme hazards during the course of emergency response.

WASP provides a tool for incident commanders to track the location of team members to improve situational awareness and potentially

shorten the time needed for a rapid intervention team to rescue a downed firefighter. WASP is a body-worn system that provides instructors at training academies or incident commanders on scene with mission essential situational, real-time awareness of both physiological status and location of personnel to aid in decision making.

WASP provides a tool for incident commanders to track the location of team members to improve situational awareness and potentially shorten the time needed for a rapid intervention team to rescue a downed firefighter.

The physiological sensors that track heart rate, heart rate variability, respiration rate, activity levels, posture and other physiological factors are mounted on a strap embedded within a flame-resistant, base-layer T-shirt. The location unit is worn on a belt at the waist and provides indoor location data in 3D in GPS-denied environments. The combined WASP system collects, transmits and displays integrated user data in real time over

Motorola APX radios, Android cell phones or Wi-Fi networks at a command station.

Globe Manufacturing Co. led a multi-discipline team consisting of Zephyr Technology (physiological monitoring), TRX Systems (location tracking), Propel (textile development), Skidmore College Health and Exercise Sciences (physiology

science) with support from the U.S. Army Natick Soldier Research, Development & Engineering Center (NSRDEC) to develop this integrated system. Field trials of WASP during development provided invaluable firefighter feedback that was incorporated into all phases of development, design and production.

For more details or to download a WASP brochure, visit www.PPE101.com.

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