

Burn injuries vs. heat stress

1 Introduction

On January 1st, 2009 firefighters of the city of Diksmuide are called to a fire in a single family dwelling (see figure 1). They arrive on scene and perform a size up. Construction workers were applying spray foam insulation in the attic when they suddenly smell something burning.

Two captains take a look inside to measure up the situation. The ground level shows no signs of fire. Access to the attic is through a hatch with a folding ladder. The attic is very small and narrow. When they are on the ladder, they can poke their heads in and take a look around (see figure 2). At that moment they decide to go back and order a thorough sweep of the attic to be done by two firefighters in full PPE. The officers in charge make a well thought and professional decision at that point. After all, it is unclear what the possible risks are of a full sweep. And of course, it would have been much easier operating without BA in such a small and narrow area.



figure 1 Firefighters on scene at the house in Diksmuide. This picture was taken long after the time of arrival. (Photo: Fire service Westhoek – station Diksmuide)



figure 2 View from the ladder into the attic. The photo shows how narrow the attic space is. (Photo: Fire service Westhoek – station Diksmuide)

Two firefighters don themselves in full bunker gear and put on their BA. The mask up three minutes after the time of arrival, so very little time was lost with the initial size up of the two captains. The captains made a quick assessment of the situation. When the search crew enters the attic, there is nothing showing. So they continue their sweep of the attic. When they reach the end of the attic space, they are at the spot where according to the construction workers, they should find the source of the fire. That is the spot where the construction workers were spraying insulation when they suddenly smelled something burning. The crew finds nothing though. They decide to turn around to search the other end of the attic. *Maybe the smell is coming from over there? Maybe something is wrong at that end?* They are moving away from the initial search spot indicated by the construction crew towards the other end of the attic. Still, there is nothing showing. The search crew is about two minutes into their search and so far, nothing seems

to be going on here. It looks like it is going to be yet another one of those calls that turn out to be nothing. Suddenly the crew is overtaken by a greenish smoke. The senior firefighter of the search crew immediately realizes something is not right. He tells his partner that they have to get out of there, but it is too late. Within seconds, the smoke ignites and the crew finds itself in the attic engulfed in flames. Both firefighters manage to find the open hatch and are caught by their colleagues at the bottom.

Both firefighters are badly burned. Their bunker gear has been severely damaged (see figure 3) and is removed on scene. First aid is applied and they are rushed off to an emergency care burn victim facility. There they will start a lengthy rehabilitation process.

It is clear that the bunker gear in combination with a BA, saved the lives of these firefighters. Thanks to the prudence of the captains, who decided that BA was necessary for the search, two LODD's were avoided that day.



figure 3 This is the turnout jacket of one of the firefighters. It has been heavily damaged. (Photo: Fire service Westhoek – station Diksmuide)

Several years ago, a fire started in a warehouse in a large city. The fire service dispatched two fire engines. Upon arrival, firefighters face a heavy fire deep inside the building. It is immediately clear that two engines will not suffice for this kind of fire, so the officer in charge requests additional units to the scene. Aside from the fire itself, there is another factor complicating matters that day: the temperature outside. It is summer and the city is in the middle of a heat wave. Outside temperatures are running up to and past 35 °C. This means firefighters are already severely sweating while riding out towards the incident. Donning their bunker gear and putting on BA, is enough of a physical activity to start sweating. Firefighters arriving on scene are not feeling 100% even before having to start their operations.

The crews are physically tasked while fighting the fire. Firefighters are switched out regularly. Most of them are exhausted and are in need of rest before being able to go back in. A rehab area is designated where the crews can cool down, drink something, ... Such an area is essential to take care of the firefighters.

Suddenly, a firefighter exiting the burning building, collapses. He has come out from the building after taking his turn on the hose line, just as many of his colleagues before him. However, unlike the others he falls unconscious once outside. He is immediately caught by his fellow crew members. They remove his gear. His body feels very warm to the touch. However, there are no visible burns or any other injuries. Necessary measures are taken to cool him down and an ambulance rushes him off to the hospital. Two hours later, doctors declare him dead. He died of heat stress.





figure 4 Fine example of a rehab area. This fire service has set up a tent where BA crews can take off their gear. They can then have something to drink or eat while resting in the shade. During winter, this tent could be heated. The photo dates back from 2011. Nowadays, decontamination would be part of the rehab measures as well. (Photo: Yoni Casteleyn, Fire service Zone 1 - station Torhout)

2 Heart of the matter

The cases above describe two different kinds of risks to which firefighters are exposed on the fire ground: burn injuries and heat stress.

2.1 Burn injuries

Burn injuries are generally well known in the fire service. Every firefighter gets basic first aid training which covers burns. We all know that burn injuries occur when our skin is exposed to high temperatures. When the severity of the burns (and the surface area involved) is too great, a life threatening situation ensues. Very large burns, as was the case for the colleagues of Diksmuide, have serious consequences. Victims generally have to stay hospitalized for a long time. They also often have a long rehabilitation after that and will have scar tissue for the rest of their lives.

The fire service has anticipated and responded to this particular risk. Over the past 30 years, our protective clothing has improved immensely. It was the turnout gear that kept the Diksmuide firefighters alive during the incident.

Some years back, the fire service started placing emphasis on under garments. Adequate under garments provides two additional protective layers for the skin:

- The under garments themselves are a protective layer.
- The air between the under garments and the inside of the turnout gear forms an additional protective layer. Air is, after all, a very good heat insulator.

Belgian law regarding personal protective equipment (PPE) from 2013, states that clothes worn inside turnout gear have to have long arm sleeves and long pant legs. Some fire

departments invested in overalls for their firefighters. Others bought long sleeved polo shirts. And some chose to buy pajama type under garments. These last ones are also often used in CFBT live fire training. As explained above, under garments protect firefighters against burn injuries. It is commendable that the fire service as an organization is taking this into account and investing money into this issue.

However there is a problem with wearing these under garments in the field. A lot of voluntary firefighters are often wearing short sleeve t-shirts when they arrive in the station. They are reluctant to put on another set of clothes before donning their turnout gear. After all, they have an emergency situation they need to respond to. During summer, they often wear shorts. Even in career stations, the crews on shift often have on a short sleeved shirt or polo. So for many years, there has been a discrepancy between the regulation that demands long sleeves and pant legs, and the reality in the field.

2.2 Heat stress

Some firefighters would rather not change clothes before putting on their turnout gear, because they do not want to waste time. In Brussels, the situation is often as follows: firefighters are on shift wearing Nomex type uniform pants and a polo shirt. More often than not this is a short sleeved polo shirt. Only during the winter do a lot of firefighters put on long sleeved polo shirts. Only then are those people following regulation strictly speaking. However, whenever there is a fire call, the following happens: firefighters rush towards the garage from all over the station. They slide down the poles and hurry to their designated vehicle so they can head out. Next to the vehicles, there are often clothing racks. There, many firefighters will take off their boots and remove their uniform pants. Next they put on their turnout trousers over their bare legs. These experienced and seasoned firefighters deliberately choose to remove a protective layer! They choose to have less protection from burn injuries. This seems odd at the very least. *Why would you do such a thing? Something that reduces your overall protection?*



figure 5 Exhausted firefighters recovering on the fire ground. (Photo: TSL Hulpdienstfotografie)

These firefighters obviously have their reasons for doing this. They have experienced firsthand that the extra protective layer causes their bodies to rapidly heat up. They may be well protected against burn injuries, but they are finding that their core temperature is rising too fast, especially during the summer time. The Brussels fire department regularly has exhausted firefighters on the fire ground. These men and women show signs of heat stress. Once, a Brussels firefighter suffering from heat stress had to be hooked up to an IV drip and a total of 3,5 liters

of fluid was administered by the emergency medical crew on scene. In fact, several IV lines were used simultaneously for this. *How close did we get to another LODD as in the case described above in the introduction?* Considering all this, the actions of the Brussels firefighters do not seem all that farfetched any more.

3 Scientific research

Other countries have done some research into the impact of under garments in relation to heat stress. McLellan performed a study on 24 firefighters from Toronto Canada. He looked at the impact of long vs. short pant legs on all kinds of firefighter interventions. He concluded that short pant legs reduced heat stress effects by 10 to 15% when performing continuous "light labor" (defined as walking at 4,5 km/h).

David Prezant also did a (larger) study on this topic at the New York fire department. He looked at a total of 29.094 fires over a period of four months each in different years. The New York fire department had changed its PPE twice during that period. During the first period (1993), they wore traditional (older) style turnout gear. During the second period (1995) they wore more modern bunker gear comparable to what we wear in Belgium. They combined their turnout gear with long arm sleeves and uniform pants, similar to what Belgian law dictates. During the third period (1998) the New York fire department switched to short pants and short arm sleeves underneath their turnout gear. Prezant concluded that modern turnout gear significantly reduced the risk for burn injuries. The number of days a firefighter would be on medical leave due to burns, dropped by 89%. He also found that there was no notable difference between modern turnout gear combined with long sleeved shirts and uniform pants compared to modern turnout gear in combination with short sleeved undergarments. However he did conclude that short sleeves and short pants significantly reduced heat stress symptoms.

So there is scientific research indicating that the fire service made the correct choice in switching towards modern turnout gear. Modern turnout gear provides a much better protection against burns. However, it seems that the fire service also made a mistake in holding onto long sleeves and uniform pants. This set of under garments (= burn injury protection) increases the risk of getting heat stress. *The Brussels firefighters are being validated in their choice by researchers doing work in the field of burn injuries and heat stress.*

We must also realize that the fire service in general thought it was doing the right thing when it mandated particular under garments. They were convinced it would offer an important piece of protection on scene. The study done by Prezant negates this though. Of course, we have to be careful when we only have results of one single study. However, it was a rather extensive study so it definitely has some merit.

4 What about other countries?

How are things done in other countries? What is their view on the issue of under garments? Does everyone mandate long arm sleeves and uniform pants as is the case in Belgium? A quick poll yielded the following results:

- Argentina: there are no regulations
- Australia: turnout gear has been tested standalone. You could theoretically be naked underneath your turnout gear. So the protection provided is also adequate when wearing shorts and t-shirt. Standard on duty uniform is short sleeved.
- France: short sleeves are allowed



- Italy: short sleeves are allowed
- Austria: there are no regulations
- Poland: follows instructions set out by the manufacturer of the turnout gear
- Portugal: there are no regulations
- Spain: there are no regulations
- Turkey: following manufacturer's instruction which do neither mandate long pant legs, nor long arm sleeves.
- US: no federal regulations. Many fire departments have short arm sleeves.
- Sweden: there are no regulations mandating under garments. They use manufacturer's instructions.

Legislation of a country is usually only available in the language of that specific country. That is why the answers above are not the result of some thorough study but come from a simple question being posed to different firefighters. It does seem that Belgium is somewhat of an exception in mandating long arm sleeves and pant legs.

5 Other aspects

Are there other relevant aspects that have not yet been discussed in this article? Of course. Our work space is evolving and becoming ever more complex.

5.1 Live fire training (CFBT)

Over the last decade, live fire training (CFBT) has become an integral part of the basic and annual training of firefighters. During that training, everyone is wearing some type of under garments. What is the difference between live fire training and fire interventions?

Some CFBT exercises are designed to study fire growth. So some of the training goals are only reached by exposing the participants to high temperatures for a longer period. Everyone involved in the training knows beforehand that the risk for burns is higher. After all, the training requires a hot environment so that we can learn from it. And again, the exposure to those hot temperatures is much longer than would be the case in reality. On the fire ground, firefighters would knock down the fire as soon as they find it. In a situation where fire development is being studied, the fire will grow while firefighters are being exposed to the radiant heat. This means the heat gets to penetrate deeper into turnout gear than in reality.





figure 6 A firefighter involved in a training run for studying fire gas ignitions. When he opens the door at the back end, the smoke layer at the ceiling ignites due to the exiting flames. The firefighter is subject to a very high radiant heat during this training. (Photo: Stijn Hermans)

In that context, it seems logical to choose a higher level of burn injury protection. This kind of observational training is usually very static. Participants are seated and have to watch the environment. They do not have to lug around hose lines or climb staircases before facing the fire, as would be the case in a real scenario. This means their core temperature is also lower to start with than on a real fire. The chance of getting heat stress seems somewhat less. Hence the choice of wearing long sleeved undergarments. CFBT instructors are also taught during their instructor course, to be mindful at all times of heat stress. It seems that the fire service has succeeded over the past decade in creating a safe way of performing live fire training.

5.2 Health & hygiene

An additional problem that has arisen over the last years is that of health and hygiene in the work space. More and more people are asking necessary questions on the effect of smoke on the human body. In the past, debriefings were done while still wearing turnout gear. Nowadays, a hot, warm and cold zone is set up and all contaminated turnout gear is taken off. On training days in which there is a burn session in the morning as well as in the afternoon, it is a best practice to shower at the end of each of these sessions. All of this is done so that we are better protected against both burn injuries and heat stress, and also to reduce to possible risks of smoke exposure over longer periods of time.

So we can also ask ourselves the following question: do undergarments provide an extra layer of protection against smoke exposure? We could easily reason that because it is an extra layer, it is therefore an extra level of protection. However, this reasoning could prove to be false. The protective effect could be minimal at best. Time will tell.

6 The future?

What does the future look like in terms of PPE? In Swedish fire academies, students are always given two sets of gear. One of these is a set of turnout gear that is only used for live fire training. This gear offers excellent protection against burns and has to be decontaminated after use. We also know that the decontamination process after fire is not 100% effective and some substances stay in the gear. This is also the case for gear used on busy highways. The large amounts of exhaust fumes gets stuck in our gear in the same way that smoke does. After all, modern society is full of all kinds of chemical agents. The students also receive a set of clothing comprised of trousers and jacket and a Petzl helmet. This set of gear is well insulated against cold. In Sweden it can be quite cold during the winter. The second set of gear is used for all other types of interventions.

The fire service of London also has multiple sets of gear. Their turnout gear is comparable to what Belgian firefighters use. This gear is heavily insulated against high temperatures, so there is a risk of getting heat stress. Again, heat insulation to protect against burns equally increases the risk of getting heat stress. London firefighters also have a second set of gear for technical interventions. This gear does not have the increased insulation which lowers the chances of getting heat stress. On top of that, it is often easier to perform technical work while wearing lighter protective clothing instead of heavy turnout gear. Another thing to consider is that the *technical clothing* is much easier to wash and to perform maintenance on without any health risks. That is not the case for turnout gear that has been used in a fire.

In Belgium, we already have a lot of fire departments that are using two different sets of gloves: one set for fire and one set for technical incidents. The fire gloves are heavy and have a thick layer of insulation which severely hinders fine motor skills. It is very difficult to perform precision tasks while wearing fire gloves. The technical gloves offer protection against other types of risk (not heat) and allow for precise control.

Maybe in the future, the Belgian fire service can make the switch to two sets of gear as well: one for fire (combined with short pants and short arm sleeves underneath) and one for other incidents.

7 Bibliography

- [1] Prezant DJ et al. (2000) *Impact of a design modification in modern firefighting uniforms on burn prevention outcomes in New York City firefighters*, *Journal of Occupational Environmental Medicine*, Vol 42 (8), 827-834
- [2] McLellan TM et al. (2004) *Heat stress while wearing long pants or shorts under firefighting protective clothing*, *Ergonomics*, Vol 47, 75-90
- [3] Beernaert J & Sansen B, *personal talks*
- [4] *Belgian law: Koninklijk Besluit van 30 augustus 2013 tot vaststelling van de minimale normen betreffende de persoonlijke beschermingsmiddelen en de bijkomende uitrusting die de hulpverleningszones en prezones ter beschikking stellen van hun operationeel personeel*, *Belgisch Staatsblad*, 19 september 2013

Karel Lambert

