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# MILITARY TEXTILE MATERIALS FOR EXTREME WEATHER CONDITIONS

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***Abstract:*** *Despite the leaps in technology in warfare and modern weaponry, the human soldier remains the most important aspect of a competitive army. Military textile materials are an essential, yet often neglected, factor that protect the soldier and enable his or her actions in varying fields around the globe. The participation of most countries in larger military or peacekeeping organisations like the NATO and the UN involves the extension of the geographical areas of activity in environments varying greatly from the soldiers' country of origin. Protection from the varying weather conditions and comfort are important factors for the optimal operational ability of a person in humanitarian actions or at combat field. Research in performance textiles has given rise to various forms of multilayered clothing and functional membranes with several commercial tradenames. These performance textiles aim at specialized sports and recreational activities as mountain climbing, hiking and cycling, among others. Additional advancements involve even more specialized function like the incorporation of microelectronics monitoring of vital signals of the human body or for the control of equipment.*
*The incorporation of such technological advancements is a current challenge for the national and international military forces that inherit a set of strict procedures. These procedures involve standardization, detailed technical descriptions, cost and of course customs particular to each force. On the other hand, the advancements cannot be neglected and the numbers of soldiers involved are significant to enable the need for change. Current paper is concentrated on the clothing and fabric developments relating to the protection of the soldiers from extreme weather conditions.*

***Key words:*** *Military textiles, multi-layered clothing, body insulation, membranes, waterproof fabrics, shell fabrics.*

## 1. INTRODUCTION

Despite the leaps in technology in warfare and modern weaponry, the human soldier remains the most important aspect of a competitive army. Military textile materials are an essential, yet often neglected, factor that protect the soldier and enable his actions in varying fields around the globe. Protection and comfort are important factors for a soldier that delivers its best. In this article, current developments in military textiles are examined. These developments enable soldiers to perform in varying weather conditions.

## 2. HISTORICAL PERSPECTIVE

The weather conditions and seasons of the year have always been considerable factors in warfare strategic planning. Often, they proved to be critical or even fatal for the outcome of important missions. For instance:

- In 1812 when Napoleon withdrew from Prussia, 250.000 of his soldiers died due to cold weather.
- In WWI, the British army suffered 115.000 injuries related to cold.
- In WWII, the German losses in the East Front were around 100.000.

Each age and time has its relative clothing systems that affect and are affected from the rules of combat. Additionally, they are naturally influence by the available technology of each period. Terrorist attacks and actions of modern era, and missions in Iraq and Afghanistan, lead to the development of novel clothing systems especially suited for urban combat [1].

## 3. SHOLDIER PHYSIOLOGY FOR PRESENT – DAY CLOTHING SYSTEMS

Soldiers' bodies often face extremely varied weather conditions that consequently affect the body temperature balance. Additionally, soldiers in the field operate in conditions producing high metabolic rates, therefore generating additional heat that often must be quickly dissipated. These are challenges for the development of military textiles that are currently designed taking into consideration a complex system consisting of the human body, the textile material and the weather conditions [2].

The clothing system should be designed in such a way that it will maintain the body temperature in the natural state of 37˚C. The underlying concept in hot weather conditions is that moisture levels of the system should remain minimal while excess heat produced by the body should be quickly and efficiently dissipated to the environment. The moisture dissipation is a key factor since it helps sweat evaporation from skin which is the mechanism used by the human body to cool.

On the other hand, in cold weather conditions heat is normally transferred from the human body to the environment, which is undesirable. In this case the textile system should provide insulation but simultaneously let the moisture produced leave the body. If moisture is trapped between skin and the material, it tends to form concentrates and reduce comfort, therefore soldier performance. Additionally, moisture concentrates reduce the insulation level that is also undesirable.

Military clothing systems nowadays are brilliantly designed to be part of the complex system body, material and environment.

## 4. MULTILAYERED CLOTHING SYSTEMS FOR COLD WEATHER

Most contemporary military clothing systems, for cold weather, used in the field are multilayered variants. They consist of a series of compatible clothes that are used in layers according to specific needs. The multilayered clothing has significant advantages over the conventional approach where one material provides the desired functionality in a monolithic way. They permit the soldier to individually adjust the level of performance and insulation by wearing more layers or by removing excess ones according to environmental and physiological conditions. Additionally, each individual layer is designed in such a way so that it fits the body more comfortably than a single thick cloth [3].

A basic structure of a multilayered military outfit consists of 3 layers namely [4]:

1. **Underwear layer**: It is the layer that has as a main function the removal of sweat from skin surface. This takes place via a strong wicking effect and by the function of breathability. Currently, this layer has also antimicrobial properties allowing the suppression of odour and resulting in increased comfort and hygiene. The underwear layer is designed to have optimal fitness on the body allowing comfort and enabling easy addition of the other layers.
2. **Middle layer**: this layer's function is wicking, breathability but mostly insulation. Insulation is mainly obtained by fibrous structures trapping a relatively high volume of air.
3. **Outer layer**: this layer is subjected to the environmental conditions and it is probably the one that faces most challenges. Its functions vary widely. In terms of weather protection usually it must be *waterproof*, yet *breathable*. It should also be *windproof*. The other functions may be *camouflage*, *bullet proofing* and *chemical protection*, among others.


***Fig.1:*** *A three – layer system for cold environment (©Polartec)*

Insulation is not only necessary for the main body of the soldier. It is important to insulate the ending parts like hands, feet and head. This is of course obtained with gloves, footwear and head covers among other materials. Since the whole soldier uniform is regarded as a system, the additional materials should remain compatible with the system so that altogether they perform optimally. For example, the sleeves of the jacket may be compatible with the gloves so that when the soldier uses the latter the connection between the materials will be without gaps that will allow air flow and decrease of performance.

Modern military textile materials designed for cold weather are based on the multilayer approach usually have the 3 layers described above, but they are enhanced with other layers of specific function. This ability for customization allows the soldier to operate in cold conditions ranging from -40°C to +4°C. For example, the third generation *3G* or *GEN III Extended Climate Warfighter Clothing System* used by the US military consists of 7 layers and 12 components.

## 5. MEMBRANES

Membranes are polymeric materials that have hundreds of millions of pores on their surface. They are placed on the top of the textile materials and act together as a system. On one hand the textile material supports the membrane and on the other hand the membrane gives to the fabric waterproof and windproof properties [5].

The porosity of the membrane allows it to be breathable, therefore permitting the body moisture to dissipate into the environment improving comfort. The pores should have an adequate diameter for this to happen. This diameter however should be small enough to resist its penetration by water, like rain for instance, from the outside of the system. The size of the pores is therefore optimized under these two constraints. Membrane technology used in outer clothing in past decades is often referred to as hard shell because it makes the fabric harder to the touch. This was a side – effect most often undesirable.

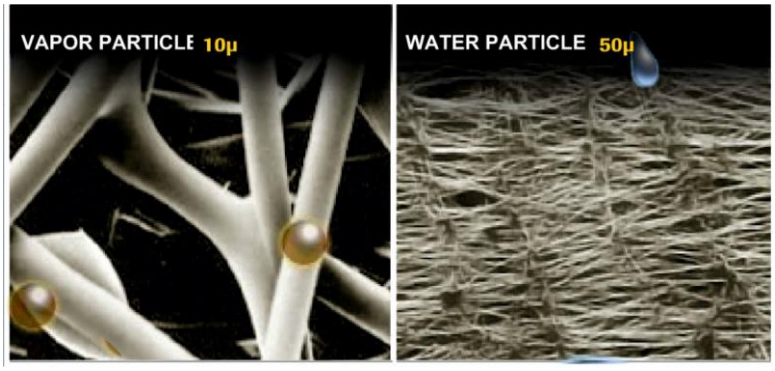


***Fig. 2:*** *The porous system of a membrane (© Gore-tex)*

Technologies are developed a technology where the membrane film is more flexible therefore giving it the description as *soft – shell.* The *soft – shell* technology is so flexible that can be used in the middle layers of the clothing system. This technology combines a weatherproof outer surface with a fleece inner therefore producing fabrics with a combination of properties including insulation, water resistance and breathability, among others. The water resistance specifically in *soft – shell* is lower to that in the *hard –shell* alternatives yet it can be improved by additional finishing processes on the outer surface. The most important element in the *soft – shell* technology is the flexibility and the resulting comfort of the fabrics produced via this technology. Often the consumer and user of such materials is pleasantly surprised upon their utilization because traditionally he perceives that protection is combined with a *hard – shell* fabric. The *soft – shell* fabrics fit well and their use is very much widespread in modern military clothing.

## 6. SMART MATERIALS

*Smart* materials belong to a whole family of modern textiles with a wide array of characteristics. They do range from materials with unconventional properties to fabrics that include electronic sensors. *Smart* materials for adaptation to extreme weather conditions are those that have some sort of interaction with the environment adjusting to changes of temperature and moisture [6]. Due to such properties, smart materials can often be

considered as heating elements since due to their chemistry and physical structure, when temperature drops they provide some heat and better insulation than otherwise. This occurs automatically, without the soldier's intervention. *Smart* materials, for the particular application, are:

- *Shape memory* materials
- *Phase changing* materials

The *shape memory materials (SMM)* can change their shape according to the environment, i.e. they react to changes of temperature or moisture, for example. Their main categories are *polymer SMM* and *gel SMM*. The *polymer SMM* can store heat in the warm environment and give it back when the environment gets cold. Additionally, in the warm environment they allow moisture transfer whereas in the cold environment they reduce moisture transfer imparting good insulation. The *gel SMM* are an even more advanced technology where they react to temperature, pressure and moisture, among others, changing their whole volume by capturing and releasing water molecules. *Gel SMM* can change their volume 1000 times more when swollen to their un-swollen condition and this process is reversible. The *gel SMM* are readily applied over textiles.

*Phase changing materials (PCM)* have also the ability to store and release heat in larger quantities than the *polymer SMM*. The material is changing from solid to liquid or gel when it absorbs heat and recovers to its solid state when it releases heat. These materials are usually in the form of microencapsulates and in this form, they are embedded in the textile material.

## 7. THE MULTI-CLIMATE PROTECTION SYSTEM

The *multi – climate protection system* for military applications was developed in the US Navy and has the components mentioned:

1. **Inner layer**: it consists of the underwear that are made in such a way as to be light wear and absorbent, allowing moisture dissipation from skin via the wicking effect. Currently, it is often required to have flame retarding properties.
2. **Moderate insulating layer**: this is used over the underwear in moderate environmental conditions. It has insulating properties, flame retardancy, moisture transfer and wind proofing.
3. **Heavy insulation**: it consists of the top, pants and the full – body outfit. Has similar properties to the second layer, mentioned above, yet it focuses on more extreme conditions therefore its insulation properties are more advanced.
4. **Jacket and fleece vest**: they are treated to have 2 times the air resistance of conventional materials while maintaining moisture transfer ability and flame resistance.
5. ***Hard – shell* jacket and pants**: they are used as additional outer layers providing heavy waterproof protection and flame retardancy.
6. **Face mask**.

## 8. CONCLUSIONS

The human component of a modern army remains a significant asset in most combat situations. The unfortunate evolution of terrorist acts and the resulting transfer of military actions in urban environments lead to the development of novel clothing systems for all armed and police forces. These clothing systems provide protection against several kinds of attack and a wide range of environmental conditions. Present article focused upon the protection relating to the climate conditions where the materials used provide protection and comfort simultaneously and it is part of an onward research by specialized comittees of the military forces, working on the technical descriptions of advanced uniforms. Novel uniforms will enable the optimal performance of soldiers, while protecting them in extreme cold conditions, that have proved to be fatal for a battle outcome but also on peacekeeping missions, where soldiers offer invaluable protection of civil population or provide vital service in natural disasters.

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