Coolpac: Cooling Device for Firefighters

Project Proposal

Team 2:
BME: Jaspreet Mankoo, Kerri Blanc
ME: Nedim Begovac, Sean Meehan

Sponsor: Createc Consulting LLC
Sponsor Advisor: Hans Almqvist, 203-215-6824, HAcaretec@aol.com
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Executive Summary

This proposal outlines the validation testing and mechanical modifications of the CoolPac cooling device for firefighters. This project is being done for Createc Consulting, headed by Mr. Hans Almqvist, who has created a prototype cooling sleeve which must be tailored for commercialization. The driving goal for this project is to provide firefighters with a physiologically efficient cooling sleeve that will help maintain their core body temperature under adverse conditions and ultimately prevent heat related injuries. In order to meet this goal extensive testing will be done both on the cooling device, as well as individuals wearing it, in order to validate the proposed value this product brings to the target group. Mechanically an emphasis will be put on redesigning the physical functionality of the product for comfort and safety. Also it will be important to have an in-depth analysis of the mechanical heat transfer between the product and the wearer, as well as the product with its surrounding environment on its own. Further specific requirements regarding the testing and design modifications will be outlined later in the proposal.

The concept of creating a general cooling device for firefighters has been explored in industry to a great extent, yet these ideas have been implemented with moderate success. A description of some of these devices will be provided within this proposal in order to highlight their strengths and weaknesses with respect to the proposed characteristics of CoolPac. The patents for the aforementioned devices and other projects will also be outlined so that the final product does not infringe upon any current patents in the market.

Following the review of other products in the same market, an in depth account of the project and its requirements will be given. This will further explain the objectives of the project as well as the unique stipulations surrounding both the validation testing and mechanical redesign aspects of the project. Finally a preliminary budget for prototype modification and testing is included in the proposal, but only represents an estimate based off of costs of the current prototype.
1. Introduction

1.1 Background

Firefighting is a physically and psychologically demanding profession and a potentially hazardous occupation. This is largely because it involves performing strenuous muscular activity in a hot and hostile environment while wearing heavy and restrictive equipment. As a result of this combination of stressors, firefighters experience heat stress. Heat stress, and the corresponding elevation in core body temperature, has numerous effects on the human body. Most critically these include hastening the onset of muscular fatigue, increasing cardiovascular strain, and compromising cognitive function. Figure 1 effectively shows the trickle down effects of heat stress relating to firefighter injuries.

Since heat stress can severely compromise the performance of a firefighter in their critical line of duty, there has arisen the demand for a cooling device or piece of protective gear that is effective in regulating temperature for firefighters and is user-friendly.

Createc Consulting has identified this demand and has developed a prototype product, the Coolpac cooling sleeve, which addresses the aforementioned problem but requires testing in a controlled environment to validate its functionality. The CoolPac project is being headed by Mr. Hans Almqvist, who has years of experience designing and marketing personal safety equipment for firefighters, divers, and industrial workers. The company’s main customers are local and
central governments and agencies, as well as certifying agencies. Previous successful designs include the S.C.U.B.A breathing system for divers, hazmat suits, and face shields for firefighters. One can see that many of these products have become the standard in terms of safety in their field and the company is hoping for the same result for the CoolPac cooling sleeve.

1.2 Purpose of the Project

The overarching goal of the project is to build upon the CoolPac prototype and eventually come up with a product that is ready for commercialization. The first sub-component will involve testing the CoolPac cooling sleeve in terms of its thermoregulation capabilities. The product will either be worn or applied in a designed apparatus that will involve applying heat stress settings. Physiological data and vital signs will be taken in order to compare its effect on the body in comparison to a subject without the CoolPac under the same conditions. Furthermore, testing conditions will be designed as to adequately simulate physical performance in combination with the layers of protective gear worn by firefighters. This aspect of the project is vital because the company needs concrete scientific evidence in the form of physiological data that proves that the cooling sleeve does indeed work in order to successfully market the product. On a similar level, testing on the current phase change material and alternative materials will help provide maximum cooling to firefighters in harsh conditions.

The second sub-component of the project will involve redesigning CoolPac from a mechanical perspective and will be aimed towards making the sleeve more universal with respective to size. This would make the product more marketable and easier to manufacture. Expansion of the cooling sleeve to the calves will also be explored and tested for effectiveness and practicality. Likewise emphasis will be given to making the sleeve as comfortable as possible without reducing its cooling capacity. Overall the purpose of redesigning is aimed towards making the final product as ergonomically efficient as possible without compromising its intended purpose. In an effort to do so, local fire department professionals will be consulted in order to generate a design that will be truly geared towards the target group. By doing so, the final CoolPac design could have not only great potential for financial success, but also for allowing firefighters to better perform their jobs.
1.3 Previous Work Done by Others

1.3.1 Products

There are a variety of cooling devices on the market that have been developed by various companies which try accomplishing the goal of cooling firefighters. One of the most notable of these is the KoreKooler Rehab Chair designed by Total Fire Group. In terms of its general design, KoreKooler is a modified folding chair with arm reservoirs that contain plastic bags filled with ambient temperature water. Like the CoolPac, KoreKooler stresses the concept of limb immersion as the primary method of cooling. Essentially its functionality relies on the fact that under heat stress, the dominance of blood flow within the body is shifted to the extremities and skin in order to facilitate heat loss. The KoreKooler relies on direct contact of the skin with a large volume of water, thus heat is transferred from the comparatively hotter hand to the troughs. Figure 3 shows the structure of the product in practical use by a firefighter.

One of the most positive aspects of this design is that water has high emissivity, high thermal mass, and being a fluid adapts to every centimeter of the firefighters hands for maximum cooling. One can see that although this product is fundamentally sound in its design, it has several limitations that restrict its use. This is because although firefighters can use the KoreKooler during breaks in their rotation system, the product doesn’t help reduce heat stress during the critical period when firefighters are physically exerting themselves. As previously mentioned firefighters operate in environments of immense heat and have to wear protective suits. These suits prevent metabolic heat from escaping the body, thus heat stress and its effects are most prevalent when they are actually performing with their gear on. In addition reservoir bags must be replaced after a period of time. The total cost of the product is approximately $300, in addition to addition reservoir bags which are $30 per bag.

Another popular product on the market is the portable environmental control system (PECS), which is a cooling vest designed by the Triangle Research and Development Corporation and
sponsored by the Navy. The PECS is geared towards preventing heat stress for firefighters and other professionals by encapsulating phase change materials within the vest in order to keep the user’s core body temperature below the heat stress levels. The advantage of the product is that it does not require batteries, pumps, or circulating fluids to provide body cooling. In addition PECS utilizes a non-toxic paraffin PCM that changes phase at a higher temperature so it can be thermally rejuvenated just below 70 degrees Fahrenheit. Due to the fact that blood flow decreases from the torso to the extremities during period of increased stress, the product is not physiologically efficient. Thus by putting the vest on, one is adding approximately 5 lbs of weight to the body and not exploiting the full potential of the human body. For firefighters who already carry 60 to 70 lbs of equipment in the field, managing cost-benefits of additional weight is critical because it should not compromise their physical ability to their job.

CoreControl is a unique device designed for both athletes as well as fire emergency responders. CoreControl is a cooling glove that operates by manipulating core body temperature and accelerates the body's natural heat dissipation process. Like some of the aforementioned devices, CoreControl enhances heat extraction from the extremities by amplifying local blood flow using a proprietary and scientific combination of carefully controlled temperature settings and slight vacuum. However it must be noted that the “glove” is very bulky and requires electrical components, thus is impractical for use in the field.

1.3.2 Summary

Overall one can see that although there are a variety of cooling devices in the market, each having their positive and negative aspects. CoolPac emphasizes many of the positive aspects of these products such as being physiologically efficient, using phase change material for cooling, and having a self-recharging capacity. Perhaps the most important aspect that distinguishes CoolPac is its potential for use during the most stressful periods of physical exertion rather than periods of rest like many of the aforementioned products.
1.3.3 Patent Search Results

Patent search results for other cooling sleeves or garments produced very limited search results. Interestingly the one patent for “Cooling Garments Containing Phase Change Material in its Extremities” was published by our client, Mr. Hans Almqvist. Figure 4 shows a preliminary sketch of the concept within the patent document.

![Figure 3. Cooling Garment Concept from Patent US 2006/0064147 by Hans Almqvist](image)

Therefore since the general concept behind the project has already been patented, the team can openly proceed to modifying the prototype sleeve as well as exploring testing possibilities. Other patents included products such as the cooling vests mentioned earlier, however they should not infringe upon the scope of this project.

2. Project Description

2.1 Objective

The Coolpac device is designed to be worn comfortably under the fireman’s suit in order to decrease the risk of heat related injury in the field. A study of the heat flow from the human body suggests that most of the endemic heat generated radiates from the appendages, and given this information the initial prototype has been designed for use on the forearms. The forearms are a good place to start with such a device, since there is a substantial amount of blood flow just
beneath the skin. By removing heat from this part of the body, the core body temperature can be regulated and thus reduce the danger of heat stroke and other injury.

The current prototype consists of three major components including the sleeve, the phase-change material (PCM), and a fastening device to hold it in place. All of these components can likely be altered in order to enhance both the performance and the comfort aspect of the device. The sleeve consists of a light, non-stretchy polyester material. It is very basic, with twelve small pockets sewn in it for the PCM samples to fit in. The twelve pockets are in a 3 x 4 grid on the material, each a small rectangle that just fits the PCM sample sizes in use so that they are snug and do not easily fall out. It is approximately a foot square sheet of material. The PCM samples rest in the sleeve’s pockets and sit flat while at room temperature, but begin to conform to the wearer’s arm over time since the melting point is low at 28°C. On either side of the material are the elements of the fastening device. On one side there are two small, rectangular metal rings, and the other has two strips of Velcro. In order to make the device wearable, the Velcro is slipped through the metal rings and tightened around the wearer’s arm, then overlapped on itself to make it secure. Figure 4 shows the CoolPac in its prototype state.

The PCM has a melting point of 28°C, a latent heat of 35 W·h/kg and an optimum temperature range of 25-32°C for functionality. At this point in time, any tangible information as to the exact chemical composition and properties of the PCM are unknown. However, based on research on the uses and properties of other PCMs, as well as information from our sponsor, some information can be confirmed. The PCM in the device is a salt hydrate because the material is inorganic, and therefore inflammable, and the production of the salt hydrate is relatively
inexpensive for the manufacturers. Our sponsor is in the process of receiving an MSDS sheet on the PCM from the company, TST Sweden, which distributes the material. The sleeve consists of a light, non-stretchy polyester material.

In order to implement this design and enhance its performance there are a few preliminary steps that have been drawn out. The first is to verify the properties of the PCM in use, as well as to research possible others that may work better. It is important that the PCM operates as intended, since it is the core workhorse behind the model. Testing will be performed to verify the melting point and latent heat values of the materials to ensure that the samples obtained are of good quality and will work reliably over time. Following the testing and possible selection of a new PCM, initial physical tests will be performed with the current prototype in order to verify the validity of the idea so that redesign of the prototype is worth the time. Options are currently being investigated as to how to perform good scientific testing of the prototype, and some thoughts include using the exercise facilities in Gampel Pavilion, discussing the product with the UConn Fire Department with regard to their potential needs, or a lab with the necessary exercise resources in Farmington. Subjects will perform 300 W of work both while wearing the prototype and without it, while data is taken with regard to core body temperature and other important parameters. If the idea can be proven beyond a reasonable doubt that it works, as it should in theory, then steps will be taken to begin redesigning the prototype for marketing.

3. Budget

For this project a concrete budget has not yet been established with Createc in terms of ordering the necessary supplies, equipment, and services to complete the project. Funding will be given based on an analysis of what modifications, tests, and PCM alternatives the team presents to the company and is deemed acceptable. Because this project is testing based several design alternatives will be presented, where the one with the best balance of test results and cost efficiency will be chosen. This document shows the necessary expenses for the first prototypes of the CoolPac.

<table>
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<tr>
<th>Phase Change Material Units</th>
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<tr>
<td>Production Costs</td>
<td>$100.00</td>
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<td>Firefighter Gear/ Simulation Equipment</td>
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Potential testing facilities for validation experiments include the UConn Health Center, athletic training center in Gampel Pavilion, or the Fire Fighter State Training Facility. Potential expenses for testing are to be determined as the team continues to contact the aforementioned sites.

4. Conclusion

With the completion of this project, we will be able to provide a new method to of regulating the core temperature of firefighters as well as other professions that are at risk of heat stress and heat stroke. This is done with one of many PCMs which, when used in these situations, absorbs heat from their surroundings and thus cause the heat to dissipate. Existing cooling devices have generally focused on diffusing heat from the torso or have incorporated stationary designs to cooling off the outer extremities, including both the forearms and legs. However these cooling devises have either proven to have little effect in regulating the core temperature of the body, or are unable to be used while actively carrying out a task due to a lack of mobility. Currently what sets apart the CoolPac from other products is its capability to be used while in action as well as its effectiveness to regulate the core body temperature of its wearers. The application of the PCMs to the outer extremities of the body rather than the torso results in increased mobility of the wearer; and based on the results from thermal imaging of the body also increases their effectiveness. Eventually this cooling device will set the standard for firefighters nationwide and make their difficult job easier.

There are many aspects and possibilities to this device. Many chemical and material science concepts will be integrated into the success of the final CoolPac devices. In turn these advancements will help future generations in their lines of physically demanding positions. Many athletes, construction workers, firefighters and even women going through menopause will one day have use for this product and hopefully this product will be the breakthrough that we expect it to be for both present and future generations to come.
5. References


