A review of options to protect your head and neck against prolonged heat exposure: the new KALIS Dry Cooling System as the optimal choice in Personal Protective Equipment (PPE).

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PERSONAL COOLING

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Contents

Background to current options

This paper first discusses the problems associated with managing heat within occupational PPE. It then goes on to examine various cooling methods and introduces a new dry cooling system from Centurion Safety Products, an innovative and first to market alternative to wet cooling designed for improved performance, health and cost advantages.

Wearers of PPE who perform heavy work in hot and humid conditions face risks of reduced concentration, productivity and safety. Major factors contributing to heat stress are the weather, work rate, clothing and the individual. There are also hidden factors that contribute, these include isolation, culture, control and education. Over 93% of workers experience heat stress on the job*. Heat stress may also result in sickness or injury, while heat stroke – the most severe heat-related illness – can cause death if the symptoms are not treated early. Despite this, every year there are more instances of heat-related illness among PPE wearers globally. This is likely to increase further due to climate change, especially for workers in outdoor occupations with high workloads. In a 2015 study published by the International Journal of Environmental Research and Public Health, 96% of surveyed Indian employees within construction, transport, metal fabrication and other sectors said that their health was affected by occupational heat stress. More than half (57%) reported productivity losses.

Previously, wet cooling systems were the best available solution to equip workers with added head and neck protection against heat, humidity and direct sunlight. The less expensive wet cooling methods involve wetting the product (e.g. a pad or fabric), wringing it out, then wearing it as evaporation takes effect. More costly products use ice or cooling tubes. Yet, generally, wet cooling systems have presented issues in service. These problems typically arise because wet technologies must be immersed in water, so can never be 100% dry which creates potential discomfort for the wearer and risks of contamination. Evaporative wet cooling is also effected by high-humidity leading to shorter cooling lifecycles. In addition, available wet cooling systems are generally poorly compatible with certain types of PPE.

The requirements for a cooler, cleaner and longer-lasting solution drove Centurion to partner with Inuteq in developing the innovative new KALIS Dry Cooling System. Designed to be comfortable, durable and anti-bacterial, the system keeps the wearer cool well below the 'best performing comfort zone' of 22 °C (71.6 °F) and 100% dry for longer periods. The product is more universally compatible with PPE, performance tested and approved for use with all Centurion helmets.

Figure 1
KALIS Dry Cooling System product examples, the helmet pad and helmet sweatband.

*USA CDC survey 2015

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An introduction to a comparison between 'wet' and 'dry' cooling

The KALIS Dry Cooling System is shown to keep the wearer 15°C (27°F) cooler than ambient temperature and completely dry. It remains cool for up to four times longer and offers superior comfort when compared to wet cooling technologies.

The principle of the KALIS Dry Cooling System is that water is inserted into the pad and held between two layers of material that keep the wearer both cool and 100% dry. The product is also anti-bacterial to be more hygienic. These qualities contrast wet cooling where the product is dipped into water, remains wet and uncomfortable on the wearer's skin and is prone to potential contamination. The advantages of dry over wet cooling are shown in Figure 2.

Figure 2
System comparison, KALIS Dry Cooling V wet cooling

	The problem wet cooling technologies	The solution Dry Cooling Technology
1	They are immersed in water and therefore feel wet to the skin and uncomfortable	Centurion Dry Cooling Technology is 100% dry and therefore totally comfortable for the wearer
2	They only provide a cooling benefit for a few hours (depending on the humidity)	Dry Cooling lasts for 1-3 days because of the inner and outer membranes
3	Can only be activated 100 times* so, if reactivated twice per working day, only last approximately 2-3 months	Can be activated 750 times, so lasts up to 5 years dependant on how often it is reactivated
4	They provide only between 6-12 °C (48.2-53.6 °F) cooling benefit for the wearer	Can provide up to 15 °C (59 °F) cooling benefit for the wearer
5	Are usually specified to be hand washed (with a brush and soap)	Dry Cooling can be machine washed
6	Are generally not anti-bacterial, so can get contaminated and dirty	Dry Cooling is anti-bacterial

*Depending on the brand used

Thinking ahead: five-year cost calculator

The patent-pending improvements of the KALIS Dry Cooling System over competing wet cooling technologies are designed to go beyond comfort and performance.

Certain advantages of KALIS, such as four times longer cooling and up to five times longer overall performance, can greatly benefit operators from an investment standpoint. It is also possible to halve the cost per use with each dry cooling. Figure 3 summarises the significant cost advantages of Inuteq DRY® technology, the basis of KALIS Dry Cooling Systems, against competing wet cooling technologies. The data illustrates why dry cooling is an attractive value proposition.

Figure 3
Wet vs. Dry, the five-year cost calculator

	Competing wet cooling product	Centurion Kalis Dry Cooling System
Number of activations	100*	750
Estimated lifetime	1 Year	5 Years
Cooling duration	5-10 hours claim	1-3 days
Cost per use of each dry and wet cooling	£0.08	£0.04
Estimated price (£GBP) over a 5 year period**	£194.40	£30.00

*Applies to most competing brands
**Based on 150 activations per year from Centurion and Inuteq research

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How does KALIS Dry Cooling technology work?

Water is a vital ingredient both in wet cooling and the KALIS Dry Cooling System, but with very different results. By the tendency of water to evaporate in hot environments, KALIS can achieve a maximum cooling output that lasts for up to three days, versus only five to ten hours with wet cooling.

The KALIS Dry Cooling System is designed for environments where cooling is desired and resources are limited. To activate the technology, the user applies a limited quantity of water to the pad. As shown in Figure 4, the water is then stored between two membranes: the outer layer is semi permeable and allows water vapour through; while the inner layer is impermeable to protect the wearer's skin and keep it 100% dry.

The KALIS system cools the wearer by utilising energy from the water inside the pad. The water vapour escapes through the porous material and evaporates, cooling the user. The KALIS Dry Cooling System therefore works best in humid environments; the more airflow, the better the cooling effect.

More specifically, the KALIS system is a 'heat sink' activated by the tendency of water to evaporate when it combines with energy (heat) from the local environment. As water has among the highest levels of thermal capacity (4.184 J/g/°C) and latent heat of evaporation (2,260 KJ/kg), it is an innovative and effective choice to internally activate the product. Water is also safe, environmentally friendly and generally available so the KALIS Dry Cooling System can be refilled easily and at no additional cost.

When water has been added to activate the KALIS Dry Cooling System, the rate at which it cools the wearer depends on two factors. The first is the size of the holes (or pores) on the semi permeable membrane, which acts like a 'gate'. Bigger holes mean that water vapour can move more quickly through the gate, and provide faster cooling for the wearer.

The second factor is how the ambient relative humidity (RH) reacts with the air flow over the product. When the difference between the inside of the pad (retaining 100% RH) and the ambient atmosphere (including how fast the air is moving) is greater, this in turn creates a greater driving force for evaporation and will increase the rate of cooling. The Kalis helmet pad from Centurion will perform better in vented helmets.

An advantage of the KALIS Dry Cooling System is that it requires only a small quantity of water to achieve a maximum cooling output. However, this also means there is a limited amount of water in the product and therefore only finite cooling power.

To better understand water movement with respect to humidity, upon which the inner activation of the KALIS system depends, it is useful to imagine the process as a park slide. Because water movement will always flow naturally from the high end of the slide to the low end, a steeper slope will create a bigger differential in the relative humidity.

Figure 4
Dry cooling membranes.

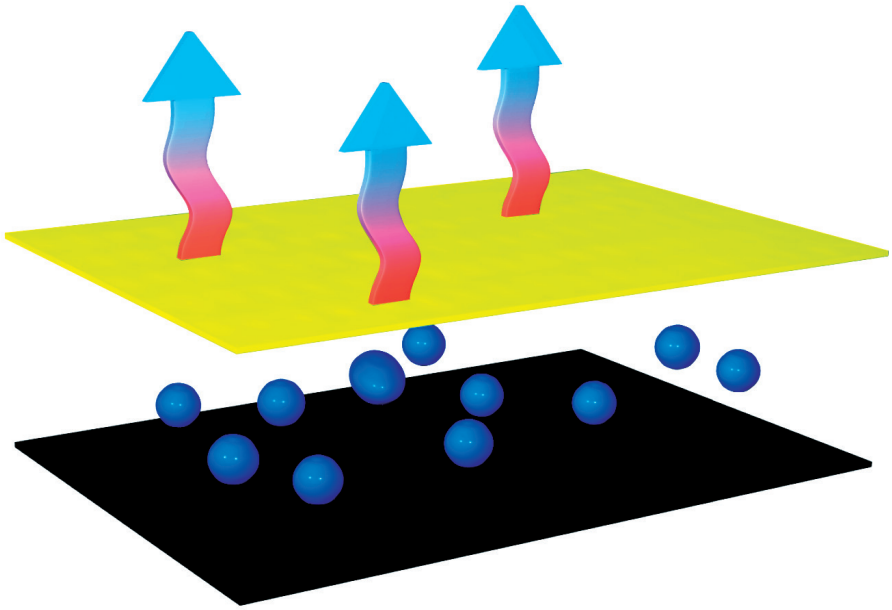


Figure 5
Water movement with respect to humidity.

How the KALIS Dry Cooling Technology performs

What might matter to end users of head or neck cooling protection?

Extensive research with users and specifiers clearly highlighted four requirements of the product.

a) Cool the wearer to a sufficiently low temperature

b) Cool quickly and for a 'reasonable' length of time

c) Be comfortable to wear and remain dry on the skin

d) Be anti-bacterial and easy to wash

Centurion design and make the world's most advanced and intuitive head protection systems. The patent-pending Kalis Dry Cooling is the result of an innovative collaboration on design and usability with Inuteq – world leader in personal cooling technologies and products. This partnership followed extensive user consultation that demonstrated the issues with existing industrial cooling systems.

To fully assess the effectiveness of the Centurion KALIS Dry Cooling System as an improvement over existing wet cooling products, the Inuteq DRY® technology on which the system is based was subjected to extensive testing in a controlled and stabilised climate condition of 21 °C (69.8 °F) at 50% relative humidity (RH). At the University for Applied Sciences in Munich, Germany, thermoregulation assessments were conducted to measure the live climate conditions between the human skin of the wearer and the technology itself over time, both during physical activity and in resting stages.

The test occupant was male, aged between 45 to 55, 185 cm tall and weighed around 90 kg with moderate physical fitness and prior experience of thermoregulation assessment. The occupant underwent an identical test process twice, in a time period totalling 45 minutes, each time wearing Inuteq technology in the form of head cooling protection. The test process itself 10 of pause, 10 of activity equalling 80 work (W) on a bike ergometer, followed by a further five of pause to end the session. A break of two hours occurred between both tests to return the subject to 'normal' condition.

The special Inuteq DRY® dry cooling technology operated with a water soaking inlay to provide evaporative cooling, once soaked, both within and around the product's textile layers. Without adding the water necessary to activate the dry cooling technology, the product functioned without any cooling properties. Because of this, the first test cycle assessed the occupant wearing the product 'with water load' and the other 'without water load' to examine fully the influence of liquid on the dry cooling process.

With an applied water load, the Inuteq technology was confirmed as being 'very comfortable' by its wearer. The occupant also reported no sensation of the technology being 'too cool'. This was not the case with the product tested without water load. Figure 6 illustrates the differences in temperature (T) between both products during the overall 45 mins test period.

Figure 6

Temperature (T) differences between both caps during the overall 45 mins test period

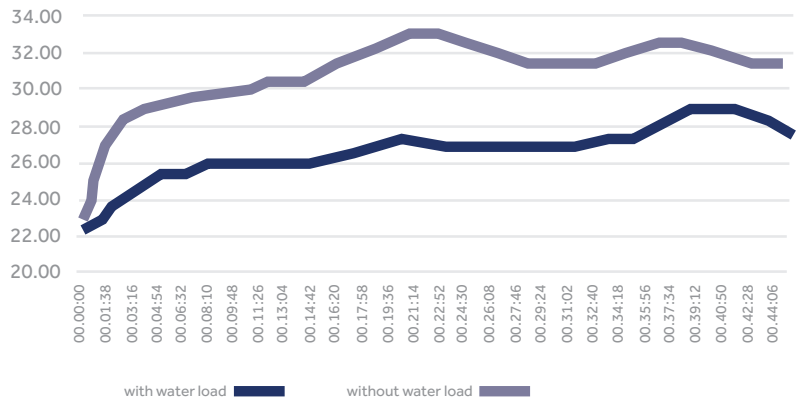
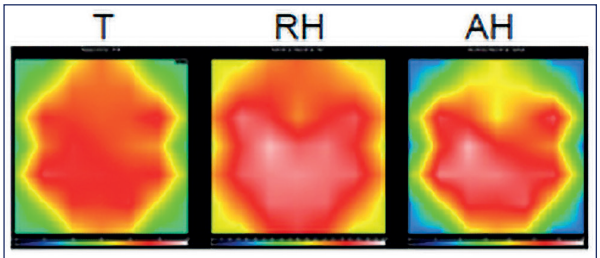


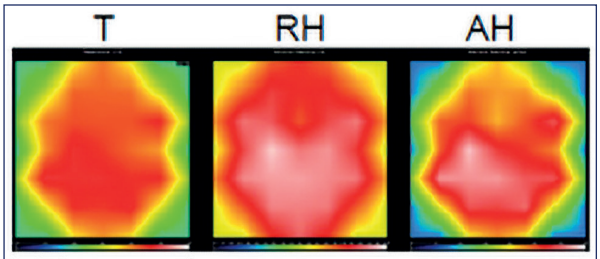
Figure 7

Thermal images visualising the cooling effect of evaporation and its impact on human thermoregulation activity.

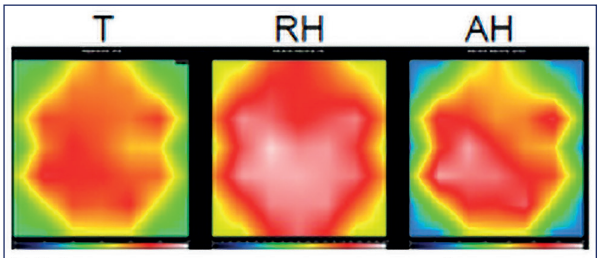
With Water



With water after 25 min.

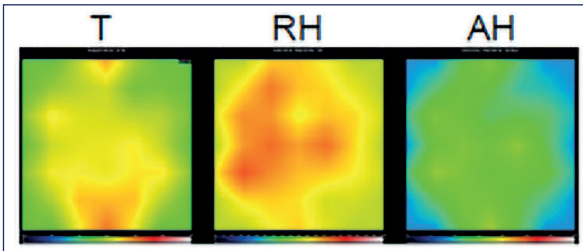


With water after 35 min.

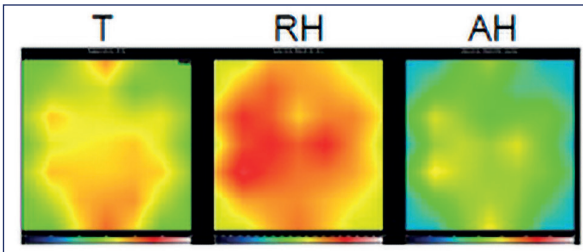


With water at measurement end.

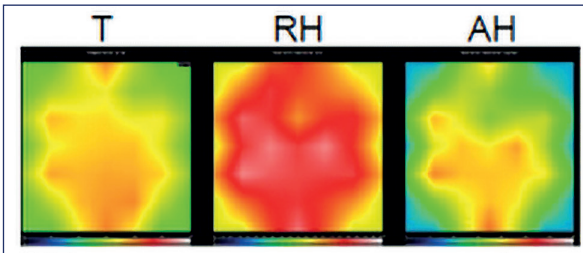
Without Water



Without water after 25 min.



Without water after 35 min.



Without water at measurement end.

The thermal images in Figure 7 visualise the cooling effect of evaporation and its impact on human thermoregulation activity. The climate development between human and test object was tracked with a THG BodyView 14 sensor unit and a three-sensor unit to measure and conduct temperature (T), relative humidity (RH), and actual humidity (AH) data over the testing time period.

The thermal images track, in real time, the climate change between the product worn during each test and the wearer's head, and depict the head area as if looked upon from above the forehead. The colour scale is measurable and goes through black (meaning cool/dry), blue, green and yellow to red and white (hot/humid).

Each row visualises the changing climate condition during the test, measured at the start time and then at intervals of 10, 25, 35 and, finally, 45 minutes. The left column (T) shows thermal development in °C, the middle column measures RH as %, and the right column shows the AH in g/kg.

So which material would you specify to protect against heat exposure?

The utilisation of water evaporation in the KALIS Dry Cooling System is not only innovative but also enables comprehensive and tangible operational benefits. The system is equipped to keep the wearer 15°C (27°F) cooler than ambient temperature and remains cool for up to four times longer when compared to wet cooling technologies. It is 100% dry and offers superior comfort. Together with the cost of ownership benefits and Centurion system approvals, these factors make KALIS a clear choice for more comprehensive levels of head and neck protection within PPE.

Because the KALIS Dry Cooling System is new to the above-the-neck PPE market, its full potential has yet to be realised. What is sure is that the technology is the first of its kind to offer such reliable protection for workers above the neck. The product can help improve concentration and performance, reduce sweating and perspiration, and avoid heat stress symptoms. Furthermore, its compatibility with all helmets is unrivalled which includes performance testing to ensure compliance with all Centurion helmets. While wet technology products are relatively inexpensive at the point of purchase, when it comes to safeguarding employees against the considerable productivity and health implications of heat-related illnesses, our recommendation is to invest the little bit extra in dry cooling to exceed standards and maintain higher standards of peace of mind for all.

REFERENCES:

Venugopal, V., Chinnadurai, J., Lucas, R. and Kjellstrom, T. (2016). Occupational Heat Stress Profiles in Selected Workplaces in India. International Journal of Environmental Research and Public Health 2016, [online] Volume 13(89), pp.1-13. Available at:www.mdpi.com/journal/ijerph [Accessed 25 Apr. 2018].

www.hse.gov.uk, (2013). Health and Safety Executive (HSE) – Heat stress in the workplace, a brief guide. [online] Available at: www.hse.gov.uk/pubns/indg451.htm [Accessed 25 Apr. 2018].

Inside Climate GmbH. (2018). Evaluation of "dry cap" - Microclimate measurement between human skin and test objects over time under physical activity. University for Applied Sciences, Munich, Germany. Research commissioned by Inuteq International B.V.

AUTHOR MR ROD KING

Rod is a fully qualified Mechanical Engineer starting his professional career within the Ministry of Defence working in many diverse areas such as aviation, hydraulics, fuel systems and filtration.

He then moved onto work as a Senior Test and Development Engineer responsible for Condition Monitoring within many business sectors such as aviation, hydraulics, power generation and off-shore oil and gas. It was within these industries that he became head of product testing to ISO standards including CE and ATEX product certification together with new product development. Rod was a representative within the British Fluid Power Association (BFPA) Technical Committee TC6 'Contamination Control' contributing to and improving British Standards and Directives.

Since joining Centurion, Rod has become the technical representative within many new project developments for 'above the neck safety systems' and is responsible for the testing within these project teams. He is also a committee member of PH2, the UK committee for eye and face protection.

DIRECTOR / CO-OWNER AT INUTEQ INTERNATIONAL B.V. MR ERIC PELLIS

INUTEQ® is a Dutch based, world leading company in developing & manufacturing innovative personal cooling technologies.

Creating the best possible solutions to keep people & animals comfortable and cool, is at the core of INUTEQ's DNA.

Eric is an experienced hands-on international sales & operational manager, responsible for custom projects within INUTEQ. Eric has over 10 years' experience in cooling fabrics.

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