

# Bulletin n°20

## Veille thermique

### Période : juillet 2024

#### Objectifs :

L'INRS est de plus en plus sollicité sur des questions concernant les activités en entreprise par forte chaleur : les activités en extérieur, l'été en période de canicule, mais aussi les activités en intérieur, dans des lieux aux conditions thermiques extrêmes. L'objectif de cette veille est de se tenir informé sur ces thématiques, dans une période où la problématique thermique croît avec les changements climatiques.

*La bibliographie extraite de la base de données INRS-Biblio, permet la consultation des ressources en version PDF.*

*Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.*

*La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS.*

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## **EPI, matériaux protecteurs/refroidissants**

M. J. Pan, X. Y. Lu, Y. H. Lu and G. L. Chen.

### **Development of protective fabric systems with spacer fabric and performance evaluation upon hot pressurized steam.**

INTERNATIONAL JOURNAL OF OCCUPATIONAL SAFETY AND ERGONOMICS. 2024.

<https://doi.org/10.1080/10803548.2024.2371206>

*Developing new fabric systems with excellent thermal protective performance is essential to protecting workers from hot pressurized steam hazards. In this study, a laminated fabric was selected and a weft-knitted spacer fabric was developed for steam protective fabric systems. Effects of the configuration of the fabric systems and heat setting of spacer fabric on performances were investigated. The results demonstrate that the developed spacer fabric significantly prolonged skin burn times compared with controls. However, heat setting of spacer fabric had a negligible effect on improving thermal protective performance. Spacer fabric provided superior thermal protection while ensuring thermal comfort and enhancing air permeability, especially for spacer fabric after heat setting. Generally, a fabric system composed of a laminated outer shell and a spacer fabric is the best choice for steam protective clothing. The findings help develop a novel thermal liner to decrease energy transfer and provide better protection from pressurized steam.*

S. Maurya, A. Das and R. Alagirusamy.

### **Effect of Orientation of Test on Radiant Protective Performance of Outer Layer of Multilayer Thermal Protective Clothing.**

FIRE TECHNOLOGY. 2024.

<https://doi.org/10.1007/s10694-024-01601-0>

*Thermal protective performance of protective clothing is greatly affected by structural parameters of fabric, air gap, and orientation of testing. This paper used Box-Behnken design experimental design to see the influence of pick density of shell (outer) layer, air gap, and orientation of test on thermal protective performance in terms of protection time. The testing was done at constant radiant heat flux. Thermal protective performance was measured in terms of second degree burn time using Stoll's curve. The model showed F value of 72.98 and p-value 0.0001 which shows that model was significant. It was also found that there was significant effect of pick density, air gap, and orientation angle on thermal protective performance. There was positive effect of pick density and air gap but negative effect of orientation angle. This was also observed that effect of pick density was more when air gap increases. The study can help in development of thermal protective clothing for different parts of body.*

M. Kajiki, N. Yamashita and T. Matsumoto.

### **Effects of fan cooling with an air-perfused rucksack on physiological and perceptual strains in young men while running in uncompensable hot environment.**

JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS. 2024.

<https://doi.org/10.23736/S0022-4707.24.15948-8>

Cooling devices reduce thermal strain during pre-, between-, and postexercise. However, their efficacy during moderate/ intensity runs in hot conditions with airflow equivalent to the running speed remains unclear. This study assessed physiological and perceptual responses to neck and upper back fan-cooling through an air-perfused rucksack under such conditions. Ten young men ran at 60% (sic)  $\dot{V}O_2$  peak for 30 min in 35 degrees C, 50% relative humidity with (FAN) and without (CON) air-perfused rucksacks with a hood in a randomized order. Headwind equal to running speed was provided in both conditions. The fan-cooling trial consisted of upper back and neck fan cooling with airflow at 4-5 m/s via two fans attached on either side of the rucksack. Rectal and skin temperatures, whole-body thermal sensation, thermal comfort, and changes in body mass were measured. Upper back skin temperature and thermal sensation were significantly lower throughout the exercise in the FAN than in the CON, whereas thermal comfort was significantly higher at 15-40 min in the FAN (all  $P \leq 0.05$ ). Heart rate elevation during 30 min of running was attenuated in the FAN compared to that in the CON ( $P \leq 0.05$ ). No significant differences in rectal and mean skin temperatures, or total body mass loss were observed between the two trials. These results indicate that additional fan-cooling on the upper back and neck during running in uncompensable hot conditions with a headwind had limited physiological benefits. However, whole-body-based thermal sensation and comfort are partially improved with the use of an air-perfused rucksack.

S. Dwivedi, R. Srivastava and P. K. Roy.

### **Exploring the potential of dual-metallized PET towards improving the efficiency of outermost reflective layer in fire proximity clothing.**

FIRE AND MATERIALS. 2024.

<https://doi.org/10.1002/fam.3229>

The outermost layer of a fire proximity suit needs to conform to a strict requirement of radiant protection performance (RPP)  $\geq 20s$ , which is indicative of its ability of offering a protection for at least 20s duration from second degree burn upon radiant heat exposure (84 kW/m<sup>2</sup>). Typically, this layer is fabricated by laminating a single-side metallized PET (SMPET) layer with glass fabric. However, upon erosion of the deposited metal, this laminate is rendered unsuitable due to loss of reflectivity. Here, we explore the possibility of replacing the SMPET with its dual-metallized analogue (DMPET) and determine the effect of increasing the optical density (OD) on the adherence and protection level. Metallized films with OD varying from 2.2 to 4.8 were laminated with glass fabrics of twill, satin and plain weave pattern using a silicone adhesive. The peel adhesion strength of laminates prepared using DMPET was found to be higher (1.01 +/- 0.03 N/mm), as compared to SMPET (0.63 +/- 0.03 N/mm) and the resulting films did not undergo delamination during flexing. Laminates prepared from satin woven glass fabric exhibited lowest flexural rigidity followed by twill and plain woven glass fabric. Protection offered by the laminate from convective heat was quantified in terms of the thermal protective performance (TPP), and the abraded laminate prepared using DMPET (OD-4.8) was found to meet all the mandatory requirements of proximity clothing, offering an RPP of 27 s and a TPP of 62 cal/cm<sup>2</sup> s. In comparison, SMPET laminates exhibited lower level of adhesion and offered an RPP of only 7.5 s.

Y. P. Zhang, X. K. Cui, C. L. Li, M. G. Hu and H. H. Hao.

### **Research on the Impact and Parameters of Liquid-Cooling Garment on Thermal Comfort.**

HEAT TRANSFER ENGINEERING. 2024.

<https://doi.org/10.1080/01457632.2024.2378560>

*Liquid-cooling garment (LCG) can alleviate heat stress and improve thermal comfort in high-temperature environments. This study conducted human experiments to assess the impact of the LCG on physiological parameters and subjective evaluations during heat stress. Then, a numerical parametric study was performed to examine the effect of environmental temperature, inlet temperature, and flow rate on LCG performance. The results demonstrate a significant inhibition of physiological parameter escalation compared to the absence of protective measures. Specifically, skin temperature exhibited a reduction ranging from 1.6% to 4.9%, whereas heart and core temperature rise rates experienced respective decreases of 27.5% and 24.2%. Additionally, there was a notable reduction of 20.76% in sweat production. Elevated skin temperature was associated with heightened thermal sensation and diminished thermal comfort. Moreover, applying the LCG resulted in a noteworthy decrease of 28.5% and 14% in the physiological and perceived stress indexes, respectively. Adjusting inlet temperature better reduces skin temperature than flow rate when environmental temperature and labor intensity increase. Lowering inlet water temperature improved LCG performance. An inlet temperature of 20 degrees C and a flow rate of 500 mL/min were optimal for moderate labor.*

Y. Wang, B. H. Zhao, H. X. Zhu, W. Yang, T. P. Li, Z. Cao and J. Wang.

### **Vests with Radiative Cooling Materials to Improve Thermal Comfort of Outdoor Workers: An Experimental Study.**

NANOMATERIALS. 2024;14(13).

<https://doi.org/10.3390/nano14131119>

*This study focuses on improving human thermal comfort in a high-temperature outdoor environment using vests with a radiative cooling coating. The effects of coating thickness on the radiative cooling performance were first evaluated, and an optimal thickness of 160  $\mu$  m was achieved. Then, six subjects were recruited to evaluate the thermal comfort in two scenarios: wearing the vest with radiative cooling coatings, and wearing the standard vest. Compared with the standard vest, the coated vest decreases the maximum temperature at the vest inner surface and the outer surface by 5.54 degrees C and 4.37 degrees C, respectively. The results show that thermal comfort is improved by wearing radiative cooling vests. With an increase of wet bulb globe temperature (WBGT), the improving effects tend to decline. A significant improvement in human thermal comfort is observed at a WBGT of 26 degrees C. Specifically, the percentage of thermal sensation vote (TSV) wearing the cooling vest in the range of 0 to 1 increases from 29.2% to 66.7% compared with that of the untreated vest. At the same time, the average value of thermal comfort vote (TCV) increases from -0.5 to 0.2.*

## Maladies liées à la chaleur

D. Bandiera, S. Racinais, F. Garrandes, P. E. Adami, S. Bermon, Y. P. Pitsiladis and A. Tessitore.

**Heat-related risk at Paris 2024: a proposal for classification and review of International Federations policies.**

BRITISH JOURNAL OF SPORTS MEDICINE. 2024.

<https://doi.org/10.1136/bjsports-2024-108310>

*Several International Federations (IFs) employ specific policies to protect athletes' health from the danger of heat. Most policies rely on the measurement of thermal indices such as the Wet Bulb Globe Temperature (WBGT) to estimate the risk of heat-related illness. This review summarises the policies implemented by the 32 IFs of the 45 sports included in the Paris 2024 Olympic Games. It provides details into the venue type, measured parameters, used thermal indices, measurement procedures, mitigation strategies and specifies whether the policy is a recommendation or a requirement. Additionally, a categorisation of sports' heat stress risk is proposed. Among the 15 sports identified as high, very high or extreme risk, one did not have a heat policy, three did not specify any parameter measurement, one relied on water temperature, two on air temperature and relative humidity, seven on WBGT (six measured on-site and one estimated) and one on the Heat Stress Index. However, indices currently used in sports have been developed for soldiers or workers and may not adequately reflect the thermal strain endured by athletes. Notably, they do not account for the athletes' high metabolic heat production and their level of acclimation. It is, therefore, worthwhile listing the relevance of the thermal indices used by IFs to quantify the risk of heat stress, and in the near future, develop an index adapted to the specific needs of athletes.*

## Travail dans une ambiance thermique extrême

M. J. Fan, H. F. Cheng, M. T. Nian and S. Q. Xie.

### Performance Study of Intermittent Heating Mode Combining Air-Source Heat Pump with Radiator in Hot Summer and Cold Winter Zones of China.

ADVANCES IN CIVIL ENGINEERING. 2024;2024.

<https://doi.org/10.1155/2024/1661363>

*An intermittent heating mode combining air-source heat pumps and radiators (ASHP-R) was proposed to meet the time-sharing heating demand of office workers' residential buildings in hot summer and cold winter zones. Taking Hefei City as an example, the heating performance of the ASHP-R system under intermittent operation was experimentally studied from January 18 to 21, 2017. Based on the data on a typical day (January 19), the variation characteristics of thermal parameters and thermal comfort of heating rooms were analyzed, and the economic and environmental benefits of the ASHP-R system were evaluated. The results show that the water supply temperature of 60 degrees C at the startup stage can rapidly increase the indoor air temperature; in the stable stage, the water supply temperature is 40 degrees C, the indoor air maintains a suitable temperature and relative humidity, and the indoor thermal environment is basically unaffected by the change in outdoor temperature and humidity; the inner surface temperature of the envelope (except the window) presents a similar trend to the indoor air temperature, which reduces the asymmetry of the thermal radiation field around the human body. The air temperature distribution in the human activity area is uniform, and the indoor PMV is in an acceptable, comfortable, and satisfactory state; compared with all-day continuous heating with an air-source heat pump, the expense can be saved by 24.4% (by 21.5 yuan/m<sup>2</sup>) in each heating season, and the system can reduce the emissions of CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub> by 988, 29.73, and 14.86 kg/year, respectively. Therefore, the system exhibits good environmental performance and economic performance.*

L. Tsoutsoubi, L. G. Ioannou, U. Ciuha, J. T. Fisher, C. Possnig, L. L. Simpson, A. D. Flouris, J. Lawley and I. B. Mekjavic.

### Validation of formulae predicting stroke volume from arterial pressure: with particular emphasis on upright individuals in hot ambient conditions.

FRONTIERS IN PHYSIOLOGY. 2024;15.

<https://doi.org/10.3389/fphys.2024.1398816>

*During heatwaves, it is important to monitor workers' cardiovascular health since 35% of those working in hot environments experience symptoms of heat strain. Wearable technology has been popularized for monitoring heart rate (HR) during recreational activities, but it can also be used to monitor occupational heat strain based on core and skin temperatures and HR. To our knowledge, no devices estimate the cardiovascular strain directly based on stroke volume (SV) or cardiac output (CO). In addition to the hardware, there are limitations regarding the lack of suitable algorithms that would provide such an index based on relevant physiological responses. The validation of the formulae already existing in literature was the principle aim of the present study. We monitored the cardiovascular responses of our participants to a supine and 60 degrees head-up tilt at the same time each day. During the test, we measured blood pressure derived by finger photoplethysmography, which also provided beat-by-beat measures of SV and CO. Afterwards, we compared the SV derived from the photoplethysmography with the one calculated with the different equations that already exist in*

*literature. The evaluation of the formulae was based on comparing the error of prediction. This residual analysis compared the sum of the squared residuals generated by each formula using the same data set. Our findings suggest that estimating SV with existing formulae is feasible, showing a good correlation and a relatively small bias. Thus, simply measuring workers' blood pressure during breaks could estimate their cardiac strain.*

## Page(s) web

**Les coups de chaleur, comment les prévenir ?, Irsst.qc.ca, 19 juin 2024.**

<https://www.irsst.qc.ca/publications-et-outils/publication/i/101209>

*Document d'information pour les milieux de travail sur la survenue de plus en plus fréquente des vagues de chaleur et à favoriser la prise en charge des risques reliés à la chaleur à l'aide d'un aide-mémoire. Il s'adresse aux préventionnistes, aux intervenants et intervenantes en santé et sécurité du travail, aux gestionnaires, aux superviseurs et superviseuses, aux représentants et représentantes des travailleurs et travailleuses et à tous ceux et celles qui ont un intérêt dans la prise en charge des risques reliés à la chaleur.*

**Travailler à la chaleur... Attention !, 4<sup>e</sup> édition, Cnesst.gouv.qc.ca, juillet 2024.**

<https://www.cnesst.gouv.qc.ca/fr/organisation/documentation/formulaires-publications/travailler-chaleur-mesures-preventives>

*Mise à jour de ce feuillet qui permet aux travailleurs d'évaluer le risque auquel ils sont exposés lorsqu'ils travaillent à la chaleur. Il contient les principales mesures préventives à prendre pour éviter le coup de chaleur et la marche à suivre lorsqu'un travailleur présente des symptômes ou des signes qui annoncent un coup de chaleur. Dans cet outil on retrouve de nouveaux facteurs de correction pour l'ensoleillement ainsi que la durée des pauses prises chaque heure qui augmente en fonction de la température de l'air corrigée. La durée de la pause peut être moins élevée si elle est prise dans un endroit frais ou climatisé.*

**Heat Stress Toolkit, Ohcow.on.ca, juillet 2024.**

<https://www.ohcow.on.ca/heat-stress-toolkit>

*La page web présente un ensemble d'outils sur le stress thermique, dont l'objectif est d'aider à comprendre les conditions de chaleur sur le lieu de travail, à évaluer le risque de stress thermique et à prendre des mesures pour protéger les travailleurs. Plusieurs ressources sont présentées : vidéos, calculateur de stress thermique, un plan d'intervention, des guides de référence sur les aspects techniques de la gestion du stress thermique sur le lieu de travail, affiches, infographies, etc.*

**HEAT STRESS CALCULATOR and RESPONSE PLAN, Ohcow.on.ca, juillet 2024.**

<https://www.ohcow.on.ca/resources/apps-tools-calculators/heat-stress-calculator>

*L'article présente la mise à jour 2024 de l'outil de calcul du stress thermique et le plan d'intervention.*

**Growing Trends for Lone Worker Safety This Summer. Gen Handley, Ohsonline.com, 26 juillet 2024.**

<https://ohsonline.com/Articles/2024/07/26/Growing-Trends-for-Lone-Worker-Safety-This-Summer>

*L'article présente les dernières tendances à surveiller cet été en matière de sécurité des travailleurs isolés.*



## Actualités juillet 2024

- **Travail par fortes chaleurs et périodes de canicule**

*Chômage-intempéries dans le BTP : la canicule intègre la liste des risques éligibles.* Liaisons sociales Quotidien (Presse, p.A2-A3), 03 juillet 2024

[Canicule : le droit du travail s'adapte aux épisodes de chaleur.](#) Francetvinfo.fr, 09 juillet 2024

[France : le Code du travail intègre la canicule comme motif de chômage technique dans le BTP.](#) Mind.eu.com, 09 juillet 2024

[Travail sous la canicule : Ce gagne-pain forcé !](#) Lapresse.tn, 11 juillet 2024

*Une chaleur à ne pas prendre à la légère au travail.* Le Canada Français (Presse, p.A20), 11 juillet 2024

[BTP : le travail sur les chantiers en extérieur désormais interdit en cas d'alerte à la canicule.](#) France3-regions.francetvinfo.fr, 12 juillet 2024

[Les morts de chaleur au travail, un défi pour le prochain gouvernement.](#) Lopinion.com, 14 juillet 2024

[Canicule : À Athènes, il fait trop chaud pour visiter l'Acropole, qui ferme en pleine journée.](#) 20minutes.fr, 17 juillet 2024

[La chaleur excessive au travail a fortement augmenté en Europe et Asie centrale \(OIT\).](#) Mediapart, 25 juillet 2024

[Iran: fermeture des banques et autres établissements à cause de la canicule.](#) fr.timesofisrael.com, 28 juillet 2024

[Canicule : salariés, voici vos droits au travail lors d'une vague de chaleur.](#) Capital.fr, 29 juillet 2024

*Canicule : que dit le Code du travail ?* La Nouvelle République du Centre-Ouest .com (Presse, p.6), 30 juillet 2024

[Travailler dans le BTP en pleine canicule : « Les salariés doivent être écoutés sur l'organisation du travail ».](#) Nouvelobs.com, 30 juillet 2024

*Canicule, fortes chaleurs : quelle est la conduite à suivre pour prévenir les risques au travail ?* Liaisons sociales Quotidien (Presse, p.A2), 30 juillet 2024

[Décret canicule pour le BTP : « J'ai l'impression que tout le monde s'en fout ».](#) Libération.fr, 30 juillet 2024

*Le BTP s'adapte à la chaleur.* La Nouvelle République du Centre-Ouest (Presse, p.3), 31 juillet 2024

*« Le cerveau perd des facultés de décision au-delà de 30 °C ».* Libération (Presse, p.7), 31 juillet 2024

[How to stay cool at work during southern Interior heat wave.](#) Infotel.ca, 04 juillet 2024

[Oregon heat rules aim to protect workers as temperatures soar. Here's what's required.](#)

Oregonlive.com, 05 juillet 2024

[Heat is a legitimate health hazard.](#) Lasvegassun.com, 07 juillet 2024

[How employers are taking steps to safeguard workers from extreme heat.](#) Thecanadianpressnews.ca,  
24 juillet 2024

- **Travail dans une ambiance thermique extrême**

[Conditions de travail : comment s'adapter face aux fortes chaleurs.](#) Lagazettedescommunes.fr,  
11 juillet 2024

[2 firefighters treated for heat exhaustion while fighting flames at Richmond home.](#)

Ottawa.ctvnews.ca, 16 juillet 2024

- **Outils et capteurs de mesure**

[Ce thermomètre « comestible » équipe des astronautes et des athlètes des JO.](#) Leparisien.fr,  
22 juillet 2024