14 Auxiliary cooling and cooled drinking water supplied by a system operated on limited power

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Providing an adequate micro-environment and supply of cooled drinking water are two essential factors for the relief of heat stress. A refrigeration unit was developed to provide sufficient cooling to 4 subjects and to keep 30 liters of drinking water at 16°C. The compact system (30 x 30 X 60 cm) was designed to operate under a very limited source of energy (<600 Watts, 24VDC) under extreme climatic conditions. The effectiveness of the system to alleviate heat stress for prolonged periods was studied under two stressful environmental conditions: 38°C, 69% relative humidty (rh) and 45°C, 49% rh.

Cold water was supplied to the 4 cooling vests (ILC Dover), and through a heat exchanger, to the 30 liter drinking water tank, by two identical refrigeration systems; one handled three vests and the other, the remaining vest and the water container, Operating parameters of the refrigeration units were continuously monitored. These included refrigerant pressures and temperatures, electrical power consumption of compressors and water pumps, and flow rates and temperatures of the water distribution system. The system was tested on 8 heat acclimated subjects, dressed in coveralls and boots, who were exposed for 4 hours to each of the climatic conditions, alternately with and without auxiliary cooling. The physiological monitoring included heart rate (HR), skin and core temperatures (T_{sk}, T_{re}), fluid balance, and sweat rate (m_{sw}), and a thermal strain index was calculated as: $SI = \Delta HR/100 + \Delta T_{re} + m_{sw}$. The subjects' metabolic rate was estimated as ~100W. in addition, the subjects' sensations of thermal comfort were recorded, using a 5 point scale.

The average electrical power needed to operate the cooling vests and to cool the 30 L drinking water was 554 W, out of which 484 W were needed for the cooling vests. With this amount of electrical power, 442 W of heat was absorbed by the 4 cooling vests (110 W per vest). The efficiency of the system was thus ~92%. Only slight differences were found between the two climatic conditions. The physiological responses, and rating of discomfort with and without auxiliary cooling (mean ± S.D.) are summarized in the following table:

	38°C/69% rh			45°C/49% rh		
	N.C.	C	P	N.C.	C	P
E_{req} (W)	112.4±9.2	126.6±15.5	N.S.	163.8±9.0	166.3±11.6	N.S.
Heat storage (W)	37.2±7.0	2.9±7.2	<.001	65.5±9.0	11.8±8.5	<.001
dehydration (%)	12	0.6		2.6	0.5	
SI (units)	2.72±0.17	1.33±0.71	<.005	3.22±0.22	1.70±0.09	<.005
Thermal Comfort	3.84+0.19	1.84+0.12	<.001	4.16+0.17	2.16+0.08	<.005

E_{req} = The amount of heat to be dissipated: the sum of metabolic heat production and dry heat gain

N.C., C., N.S. = No cooling, Cooling, Not significant, respectively.

The system described was proved to be very effective in removing excessive heat fmm the body, and in supplying cooled drinking water when operated under very limited energy supply, Furthermore, the potential of the system to supply conductive cooling was greater than that needed in the study. Thus, the system described might be effective in alleviating heat stress in subjects engaged in heavier work loads (higher metabolic rate) than administered in the present study.