APPLICATION OF MULTIMAN LIQUJD COOLING SYSTEM

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INTRODUCTION

The human body is like an internal combustion engine because it produces heat in the process of convering food into energy. The internal combustion engine eleminates heat by means of its radiator and cooling system. The human body must also be able to rid itself of excess metabolic heat in order to prevent overheating which **decreases** performance efficiency and threatens health. Therefore, people who must wear protective garments and work in a hot, hazardous environment, need an auxilary cooling system to maintain the body's thermal equilibrium. During the past decade, various personal liquid and air cooling systems have been developed and studied (4,5).

Because human-mounted cooling units have the disadvantage of increased weight burden and modest physiological cooling capacity (1,3), the concept of intermittent microclimate cooling (IMC) during rest periods **has** been developed (2). IMC decreases the logistical and ergonomic problems associated with personal cooling systems. **By** using either liquid or air upper body cooling during scheduled rest periods, work times are lengthened, physiological stress is reduced, and personal comfort is improved as compared **with** uncooled control trials **(2,4)**.

To expand the application of intermittent microclimate cooling, a portable, compact multiman liquid cooling system (MLCS) was developed. This system can generate enough power to drive the system and produce an adequate amount of cool liquid for ten people. The MLCS has been identified as U.S. Air Force Invention No. 18,882. Its design **has** also **been** approved by the Patent Office and will be issued as a US Patent in the **near** future. This paper describes the development and application of the MLCS for use in a hot, hazardous environment.

METHOD

Svstem Description

In this study, a multiman liquid cooling system was designed and fabricated at the **USAF** Armstrong Laboratory, Brooks AFB, Texas, to provide intermittent cooling. It circulates a sufficient amount of cool liquid through a torso garment to maintain thermal comfort. This integrated MLCS is composed of three major functions and associated parts: 1) Power Generation: 8 Horsepower (HP) gasoline/diesel engine, or electrical motor; 2) Cooling Capacity: two-ton compressor and condenser; 3) Liquid Distribution: reservoir, pump, ten line connectors.

When the temperature of the liquid in the reservoir is higher than the preselected temperature, the thermal sensor in the reservoir will direct the system to activate the compressor which is energized by the engine. The thermostat *can* be adjusted for the temperature necessary to meet the mission requirement. The pump will circulate the liquid between the cooling vest and the reservoir through a heat exchanger for recycling when the engine is running. The cool liquid will absorb and remove heat from the human body, while the warm liquid flows to the heat exchanger for recycling. The MCLS can **run** indefinitely and supply cool liquid to users continuously as long as necessary.

Svstem Validation

Validation tests of the MCLS have been conducted with human subjects at the **USAF** Armstrong Laboratory. The thermal chamber was heated in two conditions: warm ($32^{o}C/90^{o}F$, 80% RH) and hot ($38^{o}C/100^{o}F$, 50% RH). The prototype unit which was evaluated in such thermal conditions used 220 V to energize the compressor and 110 V for the pump circulation and control. The MLCS was turned on to produce cool liquid (a solution of 50% glycol and 50% water) five minutes before the subject took rest for cooling. In order to maintain a liquid temperature of 15°C at the vest outlet, a reservoir temperature of 10°C was selected to activate the compressor.

Six military volunteer subjects, who continuously wore the liquid vest over a cotton T-shirt, battle dress uniforms, and chemical protective garments, completed a series of 3:1 and 1:1 work/rest cycles. They walked on a treadmill at **4.8** km/h and a **6°** incline for **45** or 30 minutes and alternated with 15 or 30 minutes of seated rest. The liquid cooled garment was a snug-fitting upper torso vest covering approximately 0.5 m^2 of body surface. Cool liquid was circulated through small-bore Tygon tubing at a rate of one liter per minute with an inlet temperature of approximately 15°C. Additionally, an engine-driven prototype has been built and demonstrated in a 38°C/100°F outdoor environment at Brooks AFB in San Antonio, Texas, to verify its cooling capacity.

RESULTS

Without cooling the body core temperature of test subjects operating in a 32°C (90°F) and 80% RH warm environment for **45** minutes of work and 15 minutes of rest cycles rose from an initial temperature near 37.2°C to a peak temperature of about 38.6°C . Then, it fluctuates between 38.3°C and 38.6°C during the alternating work and rest cycle. When cooling was applied, body temperature decreased approximately 0.5°C and showed more stability. It revealed that a worker *can* complete the 45 minutes work 15 minutes rest cycle for at least four hours and still maintain core temperature about 37.8°C $\pm$ 0.2°C in the last cycle.

The subjects also conducted similar work under more extreme conditions of 38°C (100°F) and 50% RH for a 30-minute work 30-minute rest cycle. Without cooling the subject's core temperature reached a threatening 39°C level within three hours. When the MLCS was applied to cool the subject during the 30-minute rest cycle, the subject's core temperature was easily limited to values below 38.25°C over a 6-hour cycle of 30-minute work and 30-minute rest. The test results indicated the core temperature variations of about 0.6°C were actually experienced between the work and rest cycles with cooling.

CONCLUSIONS

Individuals can connect the cooling supply line of the MLCS to the liquid vest after a work period to maintain thermal equilibrium as well as improve personal comfort. The enginedriven unit generates sufficient power to produce an adequate supply of cool liquid and charge the battery. This battery is used to control liquid temperature and flow rate adjustment in order to meet personal needs and mission requirements. The MLCS is a portable, compact, cooling apparatus which provides both the necessary cooling capacity and power source for use in this intermittent cooling approach. Moreover, it can be transported by military or commercial vehicles to anywhere cooling is needed, and a power source is not available.

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