DEVELOPMENT OF A PORTABLE MULTIMAN AIR COOLING SYSTEM

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INTRODUCTION

Thermal stress to personnel working in a hot contaminated environment is a critical problem in industry and the military (1). During the past decade, various personal microclimate liquid and air cooling systems which can remove stored heat and therefore reduce body core and skin temperature to improve personal comfort have been studied and developed (2,3).

Since human-mounted cooling units have the disadvantage of increased weight carriage and modest physiological cooling capacity (4), the concept of intermittent microclimate cooling has been investigated (5). Use of either air (20°C, 20 cfm) or liquid upper-body cooling during scheduled rest periods lengthened work times, lessened the associated physiological stress, and improved personal comfort when compared with uncooled control trials.

To expand these intermittent microclimate cooling applications, the use of an individual open loop air cooling apparatus was conceived since it can provide adequate cooling capacity and has its own power source. Using this approach, a portable multiman air cooling system (PMACS) has been developed and incorporated with a U.S. Army air vest (6) to provide cool, clean air at the necessary pressure to cool personnel wearing protective garments. The PMACS has been identified as a U.S. Air Force Invention No. 19,871 and a patent request has been processed by the U.S. Air Force. This paper describes the technical development and mechanical testing of the PMACS in a hot environment.

METHOD

System Description: In the current study, a prototype PMACS was designed and fabricated at the USAF Armstrong Laboratory Brooks AFB TX. The integrated PMACS is composed of three major parts: 1) cooling capacity: compressor, condenser, evaporator, remote thermostat; 2) power source: 10 horse power gasoline/diesel engine or electrical motor; 3) air distributor: vacuum/pressure blower, U.S. Army M-48 filter, air speed control. The 10 horse power engine provides adequate power to drive the compressor, condensing fan, vacuum blower, and alternator. For chamber testing, an electrical prototype of the PMACS was built to prove the concept since it is difficult to test a gasoline/diesel engine unit in a sealed thermal chamber. A vacuum/pressure blower pumps 100 cubic feet per minute (cfm)/2,832 liters per minute (1/m) of air through a U.S. Army M-48 filter, an air vest, and an MCU-2/P mask with a C-2 filter which together create up to 11 inches of water resistance. Since the vacuum blower is equipped with a speed control, air volume is adjustable. Also, the remote thermostat is used to control air temperature to meet each user's requirement and application. Hot ambient air is pumped through a double layer-cooling coil in the evaporator which removes more water from the air. Therefore, air pumped into the air vest is clean, cool and dry. The PMACS has five outlets and each one supplies 20 cfm of air, 17 cfm to the body and 3 cfm to the face.

System Test: The chamber was heated in a series of four 2.8°C (5°F) steps from 32.2°C (90°F) to 40.5°C (105°F). The cooling unit evaluated in this chamber test used 220 V to energize the compressor and 112 V for the vacuum blower. The PMACS was turned on to produce cool air after the chamber was heated up to 32.2°C. To obtain an air temperature of 15°C at the vest outlet, an evaporator surface temperature of 1.7°C (35°F) was set to activate the compressor. The unit was operated in the 32.2°C, 35°C, and 37.8°C environments for 30 minutes and in the 40.5°C for 1 hour. Temperature probes were set in the manifold of the unit, the outlet of the air vest, the outlet of mask filter, and in the condenser. These data were collected and stored by a Squirrel data logging device for later analysis.

RESULTS & DISCUSSION

During testing of the PMACS, it was noted that the unit operates in consistent on-off cycles. The "off" cycle time is the same in all environmental temperatures. However, the hotter the chamber, the longer the unit functions in the "on " cycle in order to cool the air down to the set temperature.

When the environment was 32.2°C, the air temperature of the outlet on the manifold cycled to between 9.6°C and 16.2°C. Air from the manifold flowed through 6 feet of insulated hose which connected it to the air vest. At the outlet of the vest, the air temperature was between 11.8°C and 16.6°C. Three cfm of air were diverted through a connector to the mask where air temperature at the outlet was measured between 17.1°C and 21.6°C. Air flowing through the condenser was 40.2°C (104°F). When the chamber was heated to 40.5°C (105°F), air flowing through the condenser was 50.4°C. Therefore, regardless of the environmental conditions, the temperature of air flowing through the condenser increased by only about 10°C when the compressor was operating. Since this increase in condenser temperature is consistent, it appears that the unit has adequate cooling capacity to keep operating under stable conditions no matter how hot the environment for as long as there is power to the unit.

In the 40.5°C environment, the air temperature in the outlet of the manifold cycled between 12.3°C and 17.7°C. The air temperature in the outlet of the air vest was between 14.0°C and 18.9°C, while the air temperature fluctuated between 21.5°C and 26.8°C in the mask. Therefore, in all environments, the temperature increased approximately 2°C in the air vest and 6°C to 9°C in the mask above the manifold temperature. The fact that the air to the mask flows through an additional 4 feet of rubber hose and a filter, explains why the air temperature of the mask was 5°C to 7°C higher than out of the air vest.

CONCLUSION

Thermal chamber testing of the PMACS with human subjects is presently being conducted at USAF Armstrong Laboratory, Brooks AFB TX. The preliminary data indicated that use of the PMACS in a 40.5°C (105°F) environment can effectively reduce body temperature and extend work time.

Since previous studies have shown that air cooling using 20°C air at 20 cfm, similar to that provided by the PMACS, produced adequate body cooling (5), it is concluded that the PMACS can supply filtered air at the volume and temperature necessary to cool people. Therefore, individuals can connect the cooling supply line of the PMACS to the air vest they are wearing and obtain cool air after a work period to maintain thermal equilibrium.

Based on the configuration and testing of the PMACS, it is the only portable, compact unit currently available which includes both the necessary cooling capacity and its own power source for use in this intermittent cooling approach. Moreover, it can be transported by military or commercial vehicle to wherever cool air is needed and a power source is unavailable.

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