APPLICATION OF A COMPACT THERMAL CONTROL SYSTEM IN ADVERSE ENVIRONMENTS

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INTRODUCTION

Conditioned air is utilized to maintain comfort for humans living in an enclosed space or to create an advantageous environment for production or commercial processes. The use of air conditioning has also made it possible for people to exist in adverse climate environments (1). The air conditioner (A/C) is an environmental control system that has changed our life style, as well as improved our living, working, and entertaining standard. Advanced industrial and medical processes can not be accomplished without this technology. Air conditioner systems are designed to produce cool air by circulating approximately 80% of the return air while introducing 20% ambient air from the local environment. Thus, A/C systems cannot function as primarily designed when the surrounding ambient air is contaminated or polluted.

When people wear chemical protective garments and work in hot hazardous areas, such as in the military and industry, thermal stress is always a critical problem (2,3). During the past decade, scientists at the USAF Armstrong Laboratory have investigated and developed various cooling systems (4,5,6,7) which provide cool liquid or air to maintain thermal equilibrium, increase work performance, and extend work time. However, when people are required to remain in such environments without wearing protective garments, a survival shelter must be provided to protect them from harmful chemicals or contaminants.

Based on the present living standard and advanced technology for constructing a survival shelter (8), a compact thermal control system (CTCS) needs to be developed and integrated into this shelter to keep it cool, clean, and protected. A complete and comfortable shelter can be furnished to protect humans from thermal stress as well as harmful chemical substances. The CTCS is a portable, self-powered, and filtered air conditioning system built with a gasoline/diesel engine, operational control, and chemical-agent-removal filter. It can supply pressurized cool, clean, and dry air to a shelter and maintain it free of toxic substances. This paper describes the application of a CTCS to create a protected and comfortable facility for people to work and rest in when they must be located in a hot and contaminated environment.

MATERIALS and METHODS

In the current study, a concept of the CTCS was developed to be integrated with a survival shelter to provide comfort in hazardous environments. The CTCS was modified from an existing Portable Multiman Air Cooling System (PMACS) (6) which was designed, fabricated, and tested at the USAF Armstrong Laboratory Brooks AFB, Texas. The PMACS has been identified as U.S. Air Force Invention No. 19,871 and U.S. Patent No. 5,386,823. The PMACS was originally designed to provide cool, clean and dry air to people who wear chemical protective garments and work in a hot contaminated environment.

The integrated PMACS was composed of three major parts: 1) cooling: compressor, condenser, evaporator, remote thermostat; 2) power: 10 hp gasoline/diesel, engine or electrical motor; 3) air distributor: vacuudpressure blower, U.S. Army M-48 filter, air speed control. The ten hp engine provided adequate power to drive the compressor, condensing fan, vacuum blower, and alternator. For chamber testing, an electrical prototype of the PMACS was built for proof of concept since it was difficult to test a gasoline/diesel engine unit in a sealed thermal chamber. **A** vacuudpressure blower pumped 100 cubic feet per minute (cfm) [2,832 liters per minute (l/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 created up to 11 inches of water resistance.

Since the vacuum blower was equipped with a speed control, air volume was adjustable. Also, the remote thermostat was used to control air temperature to meet each user's requirement and application. Hot ambient air was pumped through a double-layer cooling coil in the evaporator which removed water from the air. During testing of the PMACS, it was noted that the unit operated in consistent on-off cycles. The "off' cycle time was the same in all environmental temperatures. However, the hotter the chamber, the longer the unit functioned in the "on" cycle in order to cool the air to the selected temperature. The PMACS had five outlets and each one supplied 20 cfm of air, 17 cfm to the body and 3 cfm to the face. Air pumped into the body and face through the air vest and mask was clean, cool, and *dry* (15-20°C, 35-50% RH).

The seven military subjects wore the Army air vest over a cotton T-shirt, under the battle dress uniform. Then, they put on the military chemical defense ensemble (2.5 clo) including jacket, pants, rubber glovers, with cotton liners, and an MCU-2P mask with a hood and C-2 filter. The physical task used for all test procedures consisted of walking on a treadmill at 4.8 Km/h up a *5%* grade. Subjects worked in a thermally controlled chamber under hot conditions (40.5°C *dry* bulb temperature, 80% relative humidity) until they reached a core temperature of 38.5°C. Then, the subjects rested until their core temperature decreased to 38°C while using tlie PMACS hooked to **an** air vest to cool the body and face. Core and mean skin temperatures, along with heart rate were continuously monitored and recorded. During tlie cooling period, subjects were allowed to drink water through a drinking tube without taking off the **mask.** All subjects completed three work/rest cycles. They felt cool and coinfortable during tlie rest period. Tlie preliminary data froin tlierinal chamber testing with human subjects indicated that use of the PMACS in a 40.5°C/105°F *dry* bulb and 80% RH environment could effectivelyreduce body temperature and extend work time.

RESULTS and DISCUSSION

Tlie CTCS developineiit applied tlie concept of PMACS to generate and pump cool, clean, and dry air into the shelter and to constantly maintain it pressurized and decontaminated. Tlie design was introduced and developed on tlie basis of tlie PMACS concept that 100 percent ambient air is pressurized, decontaminated, then, cooled and dried before it is puinped into tlie shelter or **an** enclosed space.

To employ this technology in a survival shelter, the CTCS must be equipped with a 25 horse power engine, 3-ton (36,000 BTUH) A/C compressor, 3-stage adjustable centrifugal blower, and two U.S. Army KMU-450 blower-filters. Larger coinpoiients are required if higher cooling capacity is specified. The centrifugal blower brings in as much hot ambient air as tlie system needs tlirougli tlie chemical-removal filter and a multi-layer evaporator. This process will generate 1,200 cfin of clean, cool air at 12 inches water pressure in the whole system.

Buffers are installed on tlie wall and entrance door of tlie shelter to balance pressure and maintain air pressurization in tlie shelter at a safe but coinfortable level. It would result in a positive pressure within tlie shelter of 1 to 2 inches water. Air pressure in the shelter is varied depending on the environmental conditions. Test results (6) indicated that tlie PMACS can be operated in a hot environment (40.5°C/105°F, 80% RH) and provide adequate cool, clean air to cool people working in that environment. Tlie testing process utilized for the PMACS can be used to test tlie CTCS to verify its cooling capacity and function.

Since the CTCS is equipped with mechanical components larger than those used for the PMACS, tlie CTCS should produce proportionally more cool air. Air puinped froin the CTCS into tlie shelter or enclosure can be chemically-filtered, dried, and cooled down to 10°C/50°F dry bulb and 30% relative humidity. Therefore, engineering design revealed that tlie CTCS generates an adequate amount of clean air for a shelter to continuously maintain it cool and pressurized. No polluted air will penetrate into tlie shelter, and clean indoor **air** can be controlled and conditioned as necessary (10-25°C, 30-50% RH).

CONCLUSIONS

With modifications, the PMACS technology can be applied to a system capable of servicing any size room or enclosed space, with no need for persons to attach individually to the system. Such a use of the PMACS technology has been successfully demonstrated with a multiman shelter by the CTCS design. In addition, the CTCS could be transported by military or commercial vehicles to any contaminated area as easily as PMACS.

Since the CTCS is a portable, compact, and self-powered environmental control system, the technology of integrating a CTCS into a survival shelter could be developed for use in a hot hazardous environment. *Also,* if an adequate gasoline or diesel engine is applied in the CTCS, no additional outside utility source would be required for the survival shelter, nor for the cooling system. Thus, the CTCS can supply cool and clean air at positive pressure to make a survival shelter function as a completely secure facility. This technical concept creates a protected and comfortable shelter for people to work efficiently and rest safely without the encumbrance of protective garments while located in an adverse environment.

REFERENCES

1. ASHRAE, Handbook -1989 Fundamentals, Physiological Principles, Comfort, and Health, 8.26-8.29
2. Hanane, R., Bittel, J., Viret, R., Morino, S. 1979, Thermal Strain Resulting From Protective Clothing, Aviat. Space Environ. Med., 50:599-609
3. Ramirez, T.L., Rayle, M.E., Crowley, P.E., Dervinger, C.V., Miller, S.D., Baker, P.D. 1988, The Thermal Effects of the Chemical Defense Ensemble on Human Performance, HSD-TR-88-015, Brooks AFB TX
4. Chen, Y.T., Bomalaski, S.H., Constable, S.H. 1990, A Light Weight Ambient Air Cooling Unit for Use in Hazardous Environments, Proceedings of the 4th Int'l Conf. on Environ. Ergon., Austin, Texas, USA, 186-187
5. Chen, Y.T., Bomalaski, S.H. 1993, Adaptation of Industrial/Commercial Air Conditioners for Use in a Thermally Stressful Environment, Journal of Thermal Biology (England), Vol. 18 No. 5/6, 683-686
6. Chen, Y.T., Bomalaski, S.H. 1992, Development of Portable Multiman Air Cooling System, Proceedings of the 5th Int'l Conf. on Environ. Ergon., Maastricht, The Netherlands, 232-233
7. Chen, Y.T. 1994, Application of Multiman Liquid Cooling System, Proceedings of the 6th Int'l Conf. on Environ. Ergon., Montebello, Quebec, Canada, 132-133
8. Kilian, J.P. 1990, Survivable Collective Protection System - Medical for Casualties Exposed to Neat or Thickened Simulant, USAF SAM-TR-89-25, Brooks Air Force Base, Texas