PROTECTIVE CLOTHING ENSEMBLE WITH TWO-STAGE EVAPORATIVE COOLING

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of and claims the benefit of priority under 35 U.S.C. 120 to International Application Number PCT/US11/30478 filed on Mar. 30, 2011, which claims priority to U.S. provisional patent application Ser. No. 61/319,070 filed on Mar. 30, 2010, both of which are expressly incorporated by reference herein.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured, used and licensed by or for the United States Government.

BACKGROUND OF THE INVENTION

Warriors, first-responders, and industrial workers are examples of personnel who may perform physically-demanding tasks with high rates of metabolic energy expenditures and metabolic heat production. These personnel may be equipped with protective clothing, for example, chemical, biological, radiological, nuclear, and explosive protective clothing, combat clothing, or other individual protective clothing ensembles. Normal mechanisms of dissipating excess metabolic heat, for example, through evaporative cooling in warm and hot environments, may be compromised by the insulation and resistance to water vapor permeation of known protective ensembles. Known protective clothing may increase metabolic heat production due to the metabolic cost of carrying and using the ensemble, and compromise metabolic heat loss by impeding evaporative cooling and dry heat dissipation through conduction, convection, and radiative heat loss. Reducing the thermal burden imposed by protective ensembles has long been, and continues to be, an important need for designers, manufacturers, and users of protective clothing.

Active cooling systems for protective ensembles are known. Active microclimate cooling systems may be thermoelectric systems, or compressor-based systems with a coolant that is circulated in tight-fitting vests, or, perhaps, blower systems that pass filtered outside air over the body and exhaust the air outside the protective suit. Compressor-based or thermoelectric systems may be power hungry, may be expensive, and may be heavy in weight. Air blower systems may be lighter in weight and more comfortable than compressor-based systems, but may be noisy, may have relatively high heat signatures (i.e., may be detected by infrared sensors), may require intake filtering of the air, and may have variable performance, depending on air inlet temperature and humidity. Air blower systems may be impractical in a chemically, biologically, and/or radiologically contaminated environment where filtering a large volume of inlet air may require a large filter capacity.

A long-felt but unsolved need has existed, and continues to exist, for lighter weight, more energy-efficient methods and apparatus to help reduce the thermal load of personnel equipped with protective clothing ensembles.

SUMMARY OF THE INVENTION

One aspect of the invention is a protective garment for an animate being. The protective garment may include an impermeable inner layer. A reservoir may be disposed interior to the inner layer, for collecting sweat from the animate being. The garment may include a pump for moving the sweat from the reservoir to a location external to the inner layer. The animate being may be a human.

The sweat collected in the reservoir may be unevaporated liquid sweat, and/or liquid sweat that has exuded or been excreted from the animate being, evaporated, and condensed on the inner layer. The pump may be disposed interior to the inner layer.

The garment may include a distribution system located external to the inner layer, for distributing the sweat on an exterior of the garment. Inlet tubing may have one end in fluid communication with the reservoir and another end connected to an inlet of the pump. Outlet tubing may have one end connected to an outlet of the pump and another end that passes through the inner layer. The outlet tubing may be operatively connected to the distribution system.

The garment may include an external reservoir disposed exterior to the inner layer and fluidly connected to the internal reservoir. The external reservoir may supply water to the internal reservoir for distribution inside or outside of the inner layer.

The distribution system may include wicking material and/or at least one fluid conduit. The distribution system may include at least one fluid conduit in fluid communication with the outlet tubing, and wicking material adjacent to at least one fluid conduit. The wicking material may be an external layer of the garment.

Another aspect of the invention is a method. The method may include providing an animate being with a protective garment and collecting sweat from the animate being in a reservoir. The method may include pumping the sweat to an exterior of the garment. The collected sweat may include sweat that has condensed on an inner layer of the garment. The collected sweat may include unevaporated sweat.

The method may include, after pumping, distributing the sweat on an exterior of the garment. The method may include, after distributing, evaporating the sweat from the exterior of the garment.

Water from a reservoir that is external to the inner layer of the garment may also be collected in the reservoir that collects sweat. One or both of water and sweat may be pumped to the exterior of the garment or distributed between the inner layer and the animate being.

The invention will be better understood, and further objects, features and advantages of the invention will become more apparent from the following description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily to scale, like or corresponding parts are denoted by like or corresponding reference numerals.

FIG. **1** is a schematic side view of one embodiment of a protective garment.

FIG. **2** is an enlarged, schematic, sectional view of portion "A" of FIG. **1**.

FIG. **3** is a schematic, cutaway, side view of one embodiment of a boot or shoe having a pump.

FIG. **4** is a schematic, cutaway, side view of one embodiment of a pump located near an elbow of a human.

FIG. **5** is a schematic front view of one embodiment of a pump located on a torso of a human.

FIGS. **6**A and **6**B are schematic fluid flow diagrams of a protective garment.