[0019] FIG. **4** is a schematic, cutaway, side view of one embodiment of a pump located near an elbow of a human.

[0020] FIG. **5** is a schematic front view of one embodiment of a pump located on a torso of a human.

[0021] FIGS. **6**A and **6**B are schematic fluid flow diagrams of a protective garment.

[0022] FIGS. **7**A and **7**B are side and ends views, respectively, of one embodiment of tubing for a distribution system.

[0023] FIGS. **8**A-B, **9**A-B, and **10**A-B are graphs of core temperature (FIGS. **8**A, **9**A, **10**A) and physiological strain index (FIGS. **8**B, **9**B, **10**B) versus time for varying temperature and humidity conditions, with (ACP2E) and without (MOPP-4) two-stage evaporative cooling. The physiological strain index (PSI) is a measure of thermal/work strain expressed on a scale of 1 to 10. Increases in heart rate and body temperature result in increased PSI levels. FIGS. **8**A-B, **9**A-B, and **10**A-B were generated using thermal-physiological modeling based on principles of physics and physiology.

[0024] FIG. **11** is a schematic fluid flow diagram of a protective garment that includes an external reservoir.

DETAILED DESCRIPTION

[0025] A two-stage evaporative cooling process and protective overgarment may reduce overheating and heat illness experienced by those who wear protective garments such as hazardous material suits. The cooling process and overgarment may be suitable for animate beings, in particular, humans. A first stage of evaporative cooling may include evaporation of sweat from the skin of a human, or evaporating sweat from an undergarment that is worn next to the skin. The undergarment may have multiple layers. The sweat vapor may condense on an interior surface of an inner, impermeable layer of the loose-fitting protective garment.

[0026] As used herein, "impermeable layer" means a layer of a garment that is at least impermeable to water vapor and water. Preferably, the impermeable layer may also be impermeable to a range of chemical, biological, and other types of hazards. Different chemical, biological, or other types of hazards may require the selection of varying materials for the impermeable layer. Examples of materials for impermeable layers of protective garments are well-known in the field of hazardous materials protection. Such materials may include PTFE (polytetrafluoroethylene, e.g., TEFLON®), Dupont™ Tychem® TK, impermeable Dupont™ Nomex®, Gore® CHEMPACK® Ultra Barrier, or other impermeable materials, such as cotton or nylon fabric coated with polyvinyl chloride (PVC), polyurethane (PU), or rubber.

[0027] A second stage of evaporative cooling may occur on the exterior surface of the protective garment, exterior of the impermeable layer. The second stage of evaporative cooling may help dissipate the heat of condensation generated on the interior surface of the impermeable layer. The second stage of evaporative cooling may include pumping condensed sweat from inside the garment to the exterior of the garment and then distributing the condensed sweat on the exterior surface of the garment for re-evaporation. The second stage of evaporative cooling may include pumping unevaporated sweat from inside the garment to the exterior of the garment and then distributing the unevaporated sweat on the exterior surface of the garment for evaporation. In some embodiments, the second stage may include pumping water from inside the garment to the exterior of the garment and then distributing the water on the exterior surface of the garment for re-evaporation.

[0028] FIG. **1** is a side view of one embodiment of a protective garment **10**. Protective garment **10** may be a unitary garment, or may have separate top (jacket) and bottom (pants) portions. Protective garment **10** may include removable gloves **12**. Or, gloves **12** may be integral with garment **10**. Protective garment **10** may include removable shoes or boots **14**. Or, shoes or boots **14** may be integral with garment **10**. Apparatus and methods for seals **22** around removable boots **14** and removable gloves **12** are known in the art. The degree of integrity of the sealing method that is required for boots **14** and/or gloves **12** depends on the nature or level of the chemical, biological, or other threat. As is known in the art, the composition of garment **10** may be different for different areas of garment **10**. For example, the composition of boots **14** and/or gloves **12** may differ from the composition of the remainder of garment **10**, particularly if boots **14** and/or gloves **12** are separately removable from the remainder of garment **10**.

[0029] In the embodiment of FIG. **1**, garment **10** includes an integral head covering **16**. Head covering **16** may include a transparent viewing portion **18**. Respiration may be variously accomplished via a backpack re-breather, a self-contained breathing apparatus, or a tethered system where air is supplied via a hose (not shown), as in the U.S. Army's Self-Contained Toxic Environment Protective Outfit (STEPO). Excess pressure may be released via one or more one-way exhaust vents **20**. Or, in lieu of integral head covering **16**, a gas mask with or without other head covering may be used. In some embodiments, water in expired breath may be condensed, captured and re-evaporated.

[0030] Garment **10** may be an overgarment, that is, the outermost component of a clothing ensemble. As such, garment **10** may be sized to be generally loose-fitting on the wearer of the garment, for example, to allow freedom of movement or to provide ample space for undergarments. Undergarments are not required with garment **10**, but may be used. For example, a T-shirt and shorts may be worn under garment **10**. For military use, an Army Combat Uniform (ACU) worn with undershirt and underpants may be worn with or without armor under garment **10**. Other types of garments may be worn under garment **10**. In general, garment **10** may not be pre-tensioned against the wearer, in contrast to elasticized, tight-fitting garments. But, in some embodiments of garment **10**, selected pre-tensioning may be used for protective purposes, for example, elastic sleeve cuffs, leg cuffs, neck band, etc.

[0031] FIG. **2** is an enlarged, schematic, sectional view of portion "A" of FIG. **1**. In FIG. **2**, a human **24** has an outer skin **26**. Optionally, an undergarment **28** may be juxtaposed with skin **26**. An air gap or space **30** may be adjacent undergarment **28**, or, if undergarment **28** is not present, air gap **30** may be adjacent skin **26**. Garment **10** may be disposed adjacent air gap **30**. The width of air gap **30** may vary on different areas of human **24** as human **24** moves around and/or changes position. At some times, in some areas of the human's body that are flexed (e.g., elbows, knees) or are supporting the weight of garment **10** (for example, shoulders), the width of air gap **30** may approach or become zero.

[0032] Garment **10** may include an impermeable, inner layer **32** having an inner surface **34** contiguous with air gap **30**. Garment **10** may include a moisture wicking, outer layer **36** disposed opposite impermeable inner layer **32**. Garment **10** may have an exterior surface **38**. Wicking outer layer **36** may be a wicking fabric, such as polyester, for example.