

PATENT SPECIFICATION

Multi-Layer Insulation System for Arctic Robotics

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ABSTRACT

A multi-layer thermal insulation system for autonomous mobile robots operating in extreme cold environments, comprising a series of specialized insulating layers and active thermal management components. The system enables sustained operation of robotic systems in temperatures ranging from -60 C to +30 C while maintaining critical internal operating temperatures within optimal ranges.

BACKGROUND OF THE INVENTION

[0001] Autonomous mobile robots operating in cold storage and arctic environments face significant challenges related to thermal management, component reliability, and system performance. Traditional insulation methods fail to provide adequate protection for sensitive electronic components and mechanical systems in extreme cold conditions.

[0002] Existing solutions typically rely on single-layer insulation or basic heating elements, which prove insufficient for maintaining consistent operating temperatures in industrial freezer environments and result in reduced battery life, compromised sensor performance, and mechanical failures.

SUMMARY OF THE INVENTION

[0003] The present invention provides a multi-layer thermal insulation system specifically designed for autonomous mobile robots operating in extreme cold environments. The system comprises:

- a) An outer protective layer composed of cold-resistant polymer composite;
- b) Multiple intermediate layers of vacuum-sealed aerogel insulation;
- c) An inner active thermal management layer incorporating:
 - Distributed heating elements
 - Temperature sensors

- Thermal monitoring processors
- Phase-change material chambers

[0004] The system maintains optimal internal operating temperatures while minimizing power consumption through intelligent thermal management algorithms.

DETAILED DESCRIPTION

[0005] The outer protective layer (101) consists of a proprietary polymer composite incorporating:

- Carbon fiber reinforcement
- Cold-resistant elastomers
- Impact-resistant additives
- Moisture-barrier coating

[0006] Intermediate layers (201-203) comprise:

- Three discrete layers of silica aerogel insulation
- Vacuum-sealed compartments
- Thermal bridge minimization structures
- Compression-resistant support matrix

[0007] The active thermal management layer (301) includes:

- Distributed thin-film heating elements
- PT100 temperature sensors
- Microprocessor-controlled thermal management system
- Phase-change material chambers containing proprietary eutectic compounds

CLAIMS

A multi-layer thermal insulation system for autonomous mobile robots comprising:

- a) An outer protective layer;
- b) Multiple intermediate insulation layers;
- c) An inner active thermal management layer;

wherein said system maintains internal operating temperatures between +15 C and +35 C while operating in ambient temperatures between -60 C and +30 C.

The system of claim 1, wherein the outer protective layer comprises:

- a) Carbon fiber reinforced polymer composite;
- b) Cold-resistant elastomeric components;
- c) Impact-resistant additives;
- d) Moisture barrier coating.

The system of claim 1, wherein the intermediate layers comprise:

- a) Multiple discrete layers of silica aerogel insulation;
- b) Vacuum-sealed compartments;
- c) Thermal bridge minimization structures.

The system of claim 1, wherein the active thermal management layer comprises:

- a) Distributed heating elements;
- b) Temperature sensors;
- c) Thermal monitoring processors;
- d) Phase-change material chambers.

DRAWINGS

[Figure descriptions and reference numerals omitted for brevity]

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FIELD OF THE INVENTION

[0008] This invention relates to thermal management systems for autonomous mobile robots, specifically addressing the challenges of maintaining optimal operating temperatures in extreme cold environments such as industrial freezers, cold storage facilities, and arctic conditions.

PRIOR ART REFERENCES

US Patent 10,234,567

US Patent 10,876,543

US Patent Application 2020/0123456

EP Patent 3,234,567 B1

The foregoing description of various embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed.