

PATENT SPECIFICATION

Thermal Insulation System for Robot Electronics

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ABSTRACT

A thermal insulation system for protecting electronic components in autonomous mobile robots operating in extreme cold environments. The system comprises multiple layers of active and passive thermal management components, including vacuum-sealed aerogel chambers, phase-change material (PCM) barriers, and microprocessor-controlled heating elements. The system maintains optimal operating temperatures for sensitive electronics while minimizing power consumption through adaptive thermal regulation algorithms.

BACKGROUND OF THE INVENTION

[0001] Autonomous mobile robots operating in cold storage environments face significant challenges related to electronic component reliability and battery performance at sub-zero temperatures. Conventional thermal management solutions fail to provide adequate protection while maintaining energy efficiency.

[0002] Existing solutions typically rely on constant heating or basic insulation, resulting in excessive power consumption or insufficient protection. There remains a need for an intelligent thermal management system optimized for cold-environment robotics.

SUMMARY OF THE INVENTION

[0003] The present invention provides a multi-layer thermal insulation system specifically designed for protecting robot electronics in extreme cold environments, comprising:

- a) A primary vacuum-sealed aerogel chamber surrounding critical electronic components;
- b) Secondary phase-change material barriers with transition points optimized for -40 C to +25 C operation;
- c) Microprocessor-controlled heating elements with zone-specific temperature management;
- d) Thermal sensors and control systems for adaptive power management.

DETAILED DESCRIPTION

[0004] Referring to Figure 1, the thermal insulation system includes:

Primary Insulation Layer

[0005] The primary insulation layer comprises a vacuum-sealed chamber filled with silica aerogel material having a thermal conductivity of less than 0.015 W/(m K). The chamber maintains structural integrity through a reinforced polymer framework while providing superior insulation performance.

Phase-Change Material Layer

[0006] A secondary layer containing proprietary phase-change materials engineered to:

- Absorb excess heat during peak operation
- Release stored thermal energy during idle periods
- Maintain stable temperatures across operating conditions
- Optimize transition points for cold storage environments

Active Thermal Management

[0007] The system incorporates:

- Distributed heating elements rated for 0.1-50W output
- Temperature sensors with 0.1 C accuracy
- Microprocessor control system with predictive algorithms
- Zone-specific thermal management protocols

CLAIMS

A thermal insulation system for robot electronics comprising:

- a) A vacuum-sealed chamber containing aerogel insulation material;
- b) At least one phase-change material layer;
- c) Multiple heating elements controlled by a microprocessor;
- d) Temperature sensors providing feedback for thermal management.

The system of claim 1, wherein the aerogel material has a thermal conductivity below 0.015 W/(m K).

The system of claim 1, wherein the phase-change material maintains thermal stability between -40 C and +25 C.

The system of claim 1, further comprising adaptive control algorithms for optimizing power consumption based on operating conditions.

DRAWINGS

[Figure descriptions and references omitted for brevity]

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CERTIFICATION

I hereby certify that this patent application meets all requirements for filing under 35 U.S.C. 111(a).

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[Additional standard patent boilerplate and legal declarations omitted]