

# **THERMAL MANAGEMENT SYSTEM ARCHITECTURE**

## **SPECIFICATION**

**Document No.: SPEC-TMS-2023-114**

**Version: 3.1**

**Effective Date: January 15, 2024**

**Classification: CONFIDENTIAL**

### **1. INTRODUCTION**

1 This Thermal Management System Architecture Specification ("Specification") is a proprietary and confidential document of Polar Dynamics Robotics, Inc., a Delaware corporation ("Company"), which defines the architectural framework and technical requirements for the Company's proprietary thermal management systems implemented in its autonomous mobile robots.

2 This Specification incorporates by reference U.S. Patent No. 11,789,XXX ("Cold-Environment Actuator System") and U.S. Patent No. 11,823,XXX ("Method for Thermal Regulation in Autonomous Systems").

### **2. DEFINITIONS**

1 "TMS" means the Thermal Management System as implemented in Company's autonomous mobile robots.

2 "Operating Environment" means industrial environments with ambient temperatures ranging from -40 C to +45 C.

3 "Critical Components" means electronic control units, battery systems, actuators, and sensors that require thermal regulation.

4 "Thermal Envelope" means the specified temperature range within which Critical Components must be maintained for optimal operation.

### **3. SYSTEM ARCHITECTURE**

1 Primary Thermal Control Unit

- Multi-zone temperature monitoring system

- Adaptive thermal regulation algorithms
- Redundant temperature sensors
- Emergency thermal shutdown protocols

## 2 Heat Distribution Network

- Proprietary heat-pipe configuration
- Multi-layer thermal isolation barriers
- Active thermal bridging system
- Condensation prevention subsystem

## 3 Power Management Integration

- Dynamic power allocation for heating elements
- Temperature-dependent power optimization
- Battery thermal protection system
- Emergency power reserve for thermal maintenance

# 4. PERFORMANCE REQUIREMENTS

## 1 Temperature Control Specifications

- Maintain internal operating temperature between +5 C and +35 C
- Maximum temperature differential rate: 2 C per minute
- Temperature stability: 0.5 C in steady state
- Recovery time from thermal shock: <180 seconds

## 2 System Response Parameters

- Thermal regulation response time: <5 seconds
- Maximum power consumption for thermal management: 800W
- Minimum operational time on backup power: 30 minutes
- System status reporting frequency: 10Hz

# 5. SAFETY AND COMPLIANCE

## 1 The TMS shall comply with:

- IEC 60204-1 Safety of Machinery

- ISO 13849-1 Safety of Control Systems
- UL 1995 Heating and Cooling Equipment
- CE Marking requirements for industrial equipment

## 2 Fail-Safe Operations

- Automated thermal shutdown protocols
- Redundant temperature monitoring
- Emergency ventilation system
- Component-level thermal protection

## **6. INTELLECTUAL PROPERTY PROTECTION**

1 This Specification contains trade secrets and confidential information of the Company. All rights, title, and interest in the TMS architecture and associated intellectual property are exclusively owned by the Company.

2 Implementation of any aspect of this Specification requires explicit written authorization from the Company's Chief Technology Officer or authorized designee.

## **7. VALIDATION AND TESTING**

### 1 Required Testing Protocols

- Thermal stress testing (-40 C to +45 C)
- Power consumption validation
- Response time verification
- Long-term stability assessment
- Emergency system validation

### 2 Documentation Requirements

- Test results documentation
- Calibration records
- Performance validation reports
- Safety compliance certificates

## **8. REVISION AND CONTROL**

1 This Specification is subject to version control under document number SPEC-TMS-2023-114.

2 Modifications require approval from:

- Chief Technology Officer
- Chief Robotics Officer
- Director of Engineering
- Quality Assurance Manager

## **9. EXECUTION**

IN WITNESS WHEREOF, this Specification has been approved and adopted by the authorized representatives of the Company as of the Effective Date.

POLAR DYNAMICS ROBOTICS, INC.

**By:**

Name: Marcus Chen

Title: Chief Technology Officer

**By:**

Name: Dr. James Barrett

Title: Chief Robotics Officer

## **10. CONFIDENTIALITY NOTICE**

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