PDR-TEST-118: Thermal Performance Analysis in -40 C Conditions

Test Protocol Documentation and Certification

Polar Dynamics Robotics, Inc.

Protocol Version: 2.3

Document ID: PDR-TEST-118-v2.3

Effective Date: January 11, 2024

1. Purpose and Scope

1. This document establishes the standardized testing protocol for evaluating the thermal performance of Polar Dynamics Robotics' autonomous mobile robots (AMRs) in extreme cold conditions, specifically at -40 C operational temperatures.

2. This protocol applies to all Series X-500 and X-700 AMR units incorporating the ColdCore(TM) thermal management system and IceNav(TM) navigation platform.

2. Testing Environment Requirements

1. Environmental Chamber Specifications:

- Temperature range capability: -45 C to +25 C
- Temperature stability: 0.5 C
- Humidity control: 15% to 85% RH
- Chamber dimensions: minimum 6m x 6m x 3m
- Air circulation: 0.5 m/s to 2.0 m/s

2. Testing Surface Requirements:

- Non-slip industrial grade flooring
- Temperature-rated to -50 C
- Minimum coefficient of friction: 0.4
- Surface irregularity tolerance: 2mm

3. Test Preparation Procedures

1. Equipment Conditioning:

- Minimum 24-hour temperature stabilization period

- Verified battery charge level: 100%
- System diagnostics check completed
- All actuators in neutral position

2. Sensor Calibration:
- Thermal imaging camera calibration
- Internal temperature sensor verification
- External temperature probe placement
- Data logging system initialization

4. Performance Testing Protocol

1. Startup Sequence Testing:
- Cold start capability verification
- Boot sequence timing measurement
- System initialization check
- Sensor array activation confirmation

2. Mobility Testing:
- Linear movement (10m x 5 repetitions)
- Rotational movement (360 x 3 repetitions)
- Obstacle avoidance course completion
- Emergency stop functionality

3. Load Testing:
- No-load baseline measurements
- 50% rated load testing
- 100% rated load testing
- Maximum load testing (120% rated capacity)

5. Data Collection Requirements

1. Required Measurements:
- Core system temperature

- Motor temperature (all drive units)
- Battery temperature
- Actuator response times
- Power consumption rates
- Navigation accuracy metrics

2. Recording Intervals:

- Continuous data logging at 1Hz
- Critical event marking capability
- Minimum test duration: 4 hours
- Cool-down period monitoring: 2 hours

6. Performance Acceptance Criteria

1. System Operation:

- Maintain core temperature within 5 C of setpoint
- No thermal shutdown events
- Battery capacity retention >85%
- Navigation accuracy within 25mm

2. Mechanical Performance:

- Actuator response time <200ms
- Drive system efficiency >80%
- Zero mechanical binding events
- Successful completion of all mobility tests

7. Safety and Compliance

1. Safety Requirements:

- Emergency stop system verification
- Thermal runaway prevention
- Operator safety zone monitoring
- Environmental protection systems

2. Regulatory Compliance:

- ISO 10218-1:2011 conformity
- EN 61000-6-2 EMC immunity
- UL 1740 safety standards
- CSA-C22.2 No. 73 certification

8. Documentation and Reporting

1. Required Documentation:

- Test execution logs
- Environmental condition records
- Performance data analysis
- System response charts
- Deviation reports (if applicable)

2. Certification Requirements:

- Test engineer signature
- Quality assurance verification
- Technical review approval
- Executive certification

9. Legal Disclaimer

This document contains proprietary and confidential information belonging to Polar Dynamics Robotics, Inc. The testing protocols and acceptance criteria detailed herein are protected under U.S. and international intellectual property laws. Any unauthorized use, reproduction, or distribution is strictly prohibited and may result in civil and criminal penalties.

10. Certification

The undersigned hereby certify that this testing protocol has been reviewed and approved for implementation:

Quality Assurance Director:

Date:

Technical Operations Manager:

Date:

Chief Technology Officer:

Date:

Document Control Number: PDR-TEST-118-v2.3

Last Revision Date: January 11, 2024

Next Review Date: July 11, 2024