

PDR-OPS-2023-441: Extreme Temperature Testing Protocol for Arctic-Grade Actuators

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DOCUMENT VERSION: 1.0

CLASSIFICATION: Confidential - Internal Use Only

ISSUING AUTHORITY: Quality Assurance Department

APPROVED BY: Dr. James Barrett, Chief Robotics Officer

1. PURPOSE AND SCOPE

1. This protocol establishes the mandatory testing procedures and acceptance criteria for Arctic-Grade Actuators ("AGA") manufactured by Polar Dynamics Robotics, Inc. ("Company") for use in extreme temperature environments ranging from -40 C to +50 C.
2. This protocol applies to all Series X-500 and X-700 actuators designated for use in the IceNav(TM) Autonomous Mobile Robot platform and related derivative products.

2. DEFINITIONS

1. "Arctic-Grade Actuator" or "AGA" means any electromechanical actuator designed and manufactured by the Company specifically for operation in extreme cold environments, incorporating proprietary CryoTech(TM) thermal management systems.
2. "Test Cycle" means a complete sequence of operational testing conducted under specified temperature conditions as detailed in Section 4.
3. "Critical Failure" means any malfunction that results in:
 - a) Loss of positional accuracy exceeding 0.02mm
 - b) Response latency exceeding 15ms
 - c) Thermal protection system shutdown
 - d) Mechanical binding or seizure
 - e) Control signal interruption exceeding 50ms

3. TESTING FACILITIES AND EQUIPMENT

1. All testing shall be conducted in Company's ISO/IEC 17025:2017 certified Environmental Testing Laboratory using:

- a) Thermotron SE-2000 Environmental Chamber or equivalent
- b) Fluke Ti480 PRO Thermal Imaging System
- c) Renishaw XL-80 Laser Interferometer
- d) National Instruments PXIe-6363 DAQ System
- e) Proprietary IceNav(TM) Diagnostic Suite v4.2 or later

2. All measurement equipment must be calibrated within the previous 90 days and maintain NIST traceability.

4. TESTING PROCEDURE

1. Pre-Test Conditioning

- a) Subject AGA to minimum 24-hour stabilization at 20 C ± 2 C
- b) Perform baseline performance measurements
- c) Install test specimen in environmental chamber with monitoring sensors

2. Cold Temperature Testing Sequence

- a) Ramp temperature to -40 C at 2 C/minute
- b) Maintain -40 C for 4 hours
- c) Execute full motion profile per Appendix A
- d) Record all parameters specified in Section 5
- e) Perform 1,000 cycles at maximum rated load

3. Heat Cycle Testing

- a) Ramp to +50 C at 2 C/minute
- b) Maintain +50 C for 4 hours
- c) Execute full motion profile per Appendix A
- d) Record all parameters specified in Section 5
- e) Perform 1,000 cycles at maximum rated load

4. Thermal Shock Testing

- a) Perform 10 cycles between -40 C and +50 C

- b) Temperature transition rate: 5 C/minute
- c) 30-minute dwell at temperature extremes
- d) Execute abbreviated motion profile during dwell periods

5. DATA COLLECTION AND REPORTING

1. Required Measurements

- a) Position accuracy (0.001mm)
- b) Velocity stability (0.1%)
- c) Power consumption (0.1W)
- d) Internal temperature at 6 points
- e) Response time (1ms)
- f) Torque output (0.1Nm)
- g) Current draw (0.01A)

2. Data Recording

- a) Minimum sampling rate: 1000Hz
- b) Continuous logging throughout all test phases
- c) Automated anomaly detection and flagging
- d) Backup to secure cloud storage every 15 minutes

6. ACCEPTANCE CRITERIA

1. The AGA shall be deemed to pass qualification testing if:

- a) No Critical Failures occur during testing
- b) Position accuracy maintains 0.01mm throughout
- c) Response time remains below 10ms
- d) Power consumption variation <5% from baseline
- e) All protective systems remain functional
- f) No mechanical degradation observed
- g) All parameters remain within specification limits defined in PDR-SPEC-2023-118

7. DOCUMENTATION AND RECORDS

1. The following records shall be maintained for 7 years:

- a) Raw test data
- b) Calibration certificates
- c) Test reports
- d) Non-conformance reports
- e) Corrective actions
- f) Engineering change orders
- g) Qualification certificates

8. LEGAL NOTICES

1. This document contains proprietary and confidential information of Polar Dynamics Robotics, Inc. and is protected under U.S. and international intellectual property laws.

2. No part of this protocol may be reproduced, modified, or distributed without written authorization from the Company's Legal Department.

9. REVISION HISTORY

Version 1.0 - Initial Release - January 11, 2024

Approved by: Dr. James Barrett, Chief Robotics Officer

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Chief Robotics Officer

Polar Dynamics Robotics, Inc.

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