TEMPERATURE MAPPING QUALIFICATION PROTOCOL

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Department: Quality Assurance

Classification: Confidential

1. PURPOSE

This Temperature Mapping Qualification Protocol ("Protocol") establishes the standardized methodology for conducting temperature mapping studies of Polar Dynamics Robotics, Inc.'s ("Company") cold environment testing facilities used in the validation of IceNav(TM)-enabled autonomous mobile robots and associated thermal management systems.

2. SCOPE

1 This Protocol applies to all temperature-controlled testing environments at Company facilities where autonomous mobile robots undergo cold environment qualification testing, including:

- Primary Cold Chamber Testing Facility (Building A)
- Extreme Temperature Simulation Laboratory (Building C)
- Thermal Stress Testing Units 1-4
- Environmental Validation Chambers

2 This Protocol shall be executed for:

- Initial qualification of new testing facilities
- Annual requalification of existing facilities
- Post-modification validation
- Investigation of temperature-related deviations

3. RESPONSIBILITIES

1 Quality Assurance Department:

- Protocol execution oversight
- Data review and approval
- Final report authorization

- Deviation management

2 Validation Engineers:

- Temperature mapping execution
- Data collection and analysis
- Documentation completion
- Calibration verification

3 Facility Operations:

- HVAC system maintenance
- Environmental controls monitoring
- Support equipment calibration
- Facility preparation

4. EQUIPMENT AND MATERIALS

1 Required Equipment:

- Calibrated temperature data loggers (min. accuracy 0.5 C)
- Validation software system v4.2 or higher
- Mapping grid installation materials
- Secondary reference thermometers

2 Documentation:

- Equipment calibration certificates
- System suitability records
- Raw data collection forms
- Deviation report templates

5. METHODOLOGY

1 Pre-Mapping Requirements:

a) Verify HVAC system qualification status

b) Confirm calibration of all measurement devices

c) Document environmental conditions

d) Install mapping points per grid specifications

2 Data Collection Parameters:

a) Minimum monitoring period: 72 hours

b) Recording frequency: 5-minute intervals

c) Required conditions:

- Empty chamber
- Loaded chamber (50% capacity)
- Loaded chamber (maximum capacity)

3 Mapping Points:

a) Minimum 27 points for spaces <500 ft

b) Additional point per 50 ft above base

c) Vertical levels: floor, middle, ceiling

d) Corner positions mandatory

e) Central axis measurements required

6. ACCEPTANCE CRITERIA

1 Temperature Uniformity:

- Maximum deviation: 2.0 C from setpoint
- Maximum gradient: 1.0 C/meter
- Recovery time: 30 minutes post-door opening

2 Data Quality:

- Minimum 95% data collection efficiency
- No critical point failures
- Complete time series for all positions

7. DATA ANALYSIS AND REPORTING

1 Required Calculations:

- Mean kinetic temperature
- Temperature uniformity indices
- Recovery time analysis
- Statistical significance evaluation

2 Report Contents:

a) Executive summary

b) Raw data tables

c) Statistical analysis

d) Deviation investigations

e) Conclusion and recommendations

8. DEVIATIONS AND CORRECTIVE ACTIONS

1 Temperature Excursions:

- Document all excursions >1.0 C
- Investigate root cause
- Implement corrective actions
- Verify effectiveness

2 Equipment Failures:

- Backup data collection procedures
- Equipment replacement protocol
- Impact assessment requirements

9. DOCUMENTATION AND RETENTION

1 Required Records:

- Executed protocol with raw data
- Calibration certificates
- Deviation reports
- Final qualification report

2 Retention Period:

- Minimum 5 years from execution
- Electronic backup required
- Secure access controls maintained

10. APPROVAL AND AUTHORIZATION

Protocol Prepared By:

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Katherine Wells

Quality Assurance Director

**Date: _**

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Protocol Reviewed By:

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Dr. James Barrett

Chief Robotics Officer

**Date: _**

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Protocol Approved By:

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Dr. Elena Frost

Chief Executive Officer

**Date: _**

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11. REVISION HISTORY

Version 2.0 - January 15, 2024 - Updated acceptance criteria and mapping methodology

Version 1.1 - March 10, 2023 - Added extreme temperature procedures

Version 1.0 - June 15, 2022 - Initial release