PDR-SAFE-087: Emergency Stop System Technical Requirements

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1. PURPOSE AND SCOPE

1. This document establishes the mandatory technical requirements for emergency stop (E-Stop) systems implemented across all Polar Dynamics Robotics, Inc. ("PDR") autonomous mobile robot ("AMR") platforms operating in temperature-controlled environments ranging from ambient to -40 C.

2. These requirements apply to all PDR Series 7000 and 8000 cold-environment AMR models and their subsequent derivatives.

2. DEFINITIONS

1. "Emergency Stop System" or "E-Stop" refers to the complete safety circuit and mechanical components designed to bring AMR operations to an immediate and safe halt.

2. "Response Time" means the total elapsed time between E-Stop activation and complete cessation of all mechanical movements.

3. "Cold Environment Operation" refers to functionality in ambient temperatures between -40 C and +5 C.

3. TECHNICAL SPECIFICATIONS

1. Physical Implementation Requirements

a) Each AMR unit shall be equipped with a minimum of two (2) physical E-Stop buttons:

- Primary: Front-mounted, red mushroom-head button

- Secondary: Rear-mounted, red mushroom-head button

b) Button specifications:

- Minimum diameter: 40mm

- Operating force: 15-20N

- IP67 rated enclosure

- Cold-resistant materials rated to -50 C

2. Circuit Requirements

a) Redundant safety circuits with:

- Dual-channel architecture

- Self-monitoring capability

- Category 4 Performance Level (PL e) per ISO 13849-1

- SIL 3 rating per IEC 61508

b) Fail-safe design ensuring:

- Default to safe state upon component failure

- Automatic system check upon startup

- Continuous monitoring during operation

4. PERFORMANCE REQUIREMENTS

1. Response Time Specifications

a) Maximum allowable response times:

- Ambient temperature (20 C): 100ms

- Cold environment (0 C to -20 C): 150ms

- Extreme cold (-20 C to -40 C): 200ms

2. Braking Requirements

a) Deceleration rates:

- Maximum load: 2.0 m/s

- Unloaded: 3.0 m/s

b) Final position accuracy:

- 50mm from activation point

5. ENVIRONMENTAL REQUIREMENTS

1. Temperature Resistance

a) All E-Stop components must maintain full functionality across:

- Operating temperature range: -40 C to +45 C

- Storage temperature range: -50 C to +60 C

2. Environmental Protection

a) Minimum protection ratings:

- IP67 for external components

- IP65 for internal circuitry

- NEMA 4X equivalent

6. TESTING AND VALIDATION

1. Required Testing Procedures

a) Factory Acceptance Testing (FAT):

- Full functional testing at room temperature

- Cold chamber testing at -40 C

- 1000 activation cycles at temperature extremes

b) Periodic Testing Requirements:

- Monthly activation verification

- Quarterly full system test

- Annual certification renewal

7. MAINTENANCE AND INSPECTION

1. Scheduled Maintenance

a) Visual inspection requirements:

- Daily visual check of button accessibility

- Weekly mechanical function test

- Monthly detailed inspection of all components

2. Documentation Requirements

a) Maintenance records must include:

- Test dates and results

- Inspection findings

- Replacement of components

- Calibration data

8. COMPLIANCE AND CERTIFICATION

1. This specification complies with:

- ISO 13850:2015 Safety of machinery

- IEC 60204-1:2016 Electrical equipment of machines

- ANSI/RIA R15.06-2012 Industrial Robot Safety

- CE Machinery Directive 2006/42/EC

9. REVISION HISTORY

Version	Date	Description	Approved By
2	2024-01-15	Updated cold temp specs	J. Barrett
1	2023-09-20	Added SIL 3 requirements	E. Frost
0	2023-06-15	Major revision	M. Chen

10. APPROVAL

This document has been reviewed and approved by:

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Dr. James Barrett

Chief Robotics Officer

Date: January 15, 2024

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Marcus Chen

Chief Technology Officer

Date: January 15, 2024