

# Robotic Cell Safety Interlock Verification Report

**Polar Dynamics Robotics, Inc.**

Report Date: January 11, 2024

Document Reference: PDR-RSIV-2024-001

## 1. Executive Summary

This report documents the comprehensive safety interlock verification testing conducted on Polar Dynamics Robotics' IceNav-enabled autonomous mobile robot (AMR) cells operating in cold storage environments. Testing was performed in accordance with ISO 10218-2:2011 and ANSI/RIA R15.06-2012 safety standards for industrial robots and robot systems.

## 2. Scope of Verification

### 1. Systems Tested

- IceNav AMR Platform v4.2
- Safety Control System firmware v2.1.3
- Emergency Stop Circuits (All Categories)
- Perimeter Guard Interlocks
- Access Door Safety Switches
- Light Curtain Systems
- Safety Scanner Zones

### 2. Testing Environment

- Primary Test Location: PDR Cold Environment Test Facility
- Temperature Range: -30 C to +25 C
- Humidity Range: 20% to 95% RH
- Testing Period: December 15, 2023 - January 5, 2024

## 3. Testing Methodology

### 1. Safety Circuit Verification

All safety interlocks were tested using the following protocol:

- Functional testing at room temperature (20 C  $\pm$  2 C)

- Cold soak testing at -30 C for 24 hours
- Rapid temperature cycling between -30 C and +25 C
- Verification of response times under load
- Redundancy system validation

## 2. Test Equipment

- Pilz Safety Relay Analyzer Model PST-100
- SICK Safety Controller Diagnostic Tool FX3-MOC000
- National Instruments DAQ-9188 Data Acquisition System
- Fluke 87V Industrial Multimeter
- Environmental Chamber Model TC-3000

## 4. Test Results

### 1. Emergency Stop System

- Response Time: 13ms (within 20ms requirement)
- Redundancy Check: Passed
- Cold Temperature Performance: Maintained Category 4 compliance
- Failure Mode Analysis: Proper fail-safe behavior confirmed

### 2. Perimeter Guard Interlocks

- Contact Reliability: 99.99% over 100,000 cycles
- Temperature Impact: No degradation observed
- Response Time Consistency: 2ms variation
- Integration with IceNav: Verified

### 3. Access Door Safety Switches

- Mechanical Durability: Passed 250,000 cycle test
- Environmental Sealing: IP67 rating maintained
- Position Monitoring Accuracy: 0.5mm
- Tamper Resistance: Verified

### 4. Light Curtain Systems

- Detection Capability: 14mm resolution maintained

- Environmental Immunity: No false triggers
- Response Time: 8ms (within 10ms requirement)
- Cold Weather Operation: Full functionality at -30 C

## **5. Compliance Verification**

### 1. Standard Conformance

- ISO 13849-1:2015 Performance Level 'e'
- IEC 61508 SIL 3 Requirements
- ANSI/RIA R15.06-2012 Risk Assessment
- EN 62061 Safety Requirements

### 2. Documentation Review

- Circuit Diagrams: Verified and archived
- Software Safety Functions: Validated
- Risk Assessment Documentation: Complete
- Training Materials: Updated

## **6. Nonconformities and Resolutions**

### 1. Identified Issues

- Minor timing variation in Door Switch #3 at -25 C
- Light curtain condensation protection upgrade needed
- E-Stop button requiring increased actuation force at low temperatures

### 2. Corrective Actions

- Door Switch #3 replaced with cold-rated version
- Anti-condensation coating applied to light curtains
- E-Stop mechanism modified with low-temperature lubricant

## **7. Recommendations**

### 1. Immediate Actions

- Implement monthly verification of safety circuit response times
- Update maintenance procedures for cold environment operation

- Enhance operator training for winter conditions
- Install temperature monitoring on critical safety components

## 2. Long-term Improvements

- Consider upgrading to next-generation safety controllers
- Implement predictive maintenance for safety systems
- Develop automated testing procedures
- Enhanced documentation of environmental conditions

## 8. Certification

The undersigned hereby certifies that all safety interlocks and associated systems have been tested and verified according to applicable standards and company procedures. The robotic cell safety systems meet or exceed all required safety specifications for operation in cold storage environments.

Certified by:

/s/ Dr. James Barrett

Dr. James Barrett

Chief Robotics Officer

Polar Dynamics Robotics, Inc.

/s/ Marcus Chen

Marcus Chen

Chief Technology Officer

Polar Dynamics Robotics, Inc.

Date: January 11, 2024

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