SUB-ZERO BATTERY PERFORMANCE ANALYSIS

SUB-ZERO BATTERY PERFORMANCE ANAL

Q3 2023 TECHNICAL ASSESSMENT REPORT

POLAR DYNAMICS ROBOTICS, INC.

1. EXECUTIVE SUMMARY

This technical analysis report documents the performance characteris

operational metrics of the BlueCore(TM) lithium-ion battery systems d

Polar Dynamics Robotics' autonomous mobile robot (AMR) fleet durin

assessment focuses on battery performance in sub-zero environment

0 C to -30 C.

2. SCOPE OF ANALYSIS

1. Test Environment Parameters

- Temperature Range: 0 C to -30 C
- Humidity: 15-45%
- Testing Duration: July 1, 2023 - September 30, 2023
- Sample Size: 50 BlueCore(TM) battery units

Testing Locations: PDR Test Facility (Minneapolis, MN)

2. Battery Specifications

- Model: BlueCore(TM) BC-2300
- Nominal Capacity: 2300Wh
- Nominal Voltage: 48V
- Chemistry: Lithium Iron Phosphate (LiFePO4)
- Thermal Management: Proprietary active heating system

3. METHODOLOGY

1. Testing Protocol

Testing conducted pursuant to ISO/IEC 62133-2:2017 standards, mod

extreme cold conditions per PDR Internal Standard PS-231.

2. Performance Metrics

-

Discharge capacity retention

-

Voltage stability under load

-

Internal resistance variations

-

Thermal management efficiency

Cycle life degradation

-

Cold start capability

4. PERFORMANCE RESULTS

1. Capacity Retention

-

92% capacity retention at 0 C

-

87% capacity retention at -15 C

-

81% capacity retention at -30 C

2. Operational Runtime

- Average runtime at -30 C: 8.4 hours
- Standard deviation: 0.6 hours
- Minimum observed runtime: 7.2 hours

3. Thermal Management

- Average warm-up time from -30 C: 12 minutes
- Power consumption for heating: 180W peak
- Temperature differential maintenance: 2.5 C

5. COMPLIANCE VERIFICATION

1. Safety Standards

- UL 2580 certification maintained
- UN 38.3 Transportation testing passed
- IEC 61508 SIL 2 compliance verified

2. Environmental Standards

- IP65 rating confirmed
- Operating temperature specifications validated

EMC compliance per EN 61000-6-2

6. TECHNICAL OBSERVATIONS

1. Performance Improvements

-

15% improvement in cold-start capability vs. Q2 2023

-

8% reduction in internal resistance at -30 C

-

22% faster thermal stabilization

2. Identified Issues

-

Minor voltage fluctuations observed below -25 C

-

Thermal management system optimization required for extended -30

-

Cell balancing variations noted in 3% of test units

7. RECOMMENDATIONS

1. Engineering Modifications

-

Implement enhanced cell balancing algorithm

-

Upgrade thermal management control firmware

-

Optimize power distribution during cold starts

2. Operational Guidelines

- Maintain minimum 20% state of charge during cold storage

- Implement pre-conditioning cycle before deep-cold deployment

- Update maintenance intervals for extreme condition operation

8. LEGAL DISCLAIMERS

This document contains confidential and proprietary information of Po Dynamics Robotics, Inc. ("PDR"). The performance data and technica specifications contained herein are based on controlled testing enviro should not be construed as guarantees of performance under all oper conditions. PDR makes no warranties, express or implied, regarding t

completeness, or reliability of this information.

9. CERTIFICATION

The undersigned hereby certifies that all testing procedures were con
accordance with PDR Quality Management System requirements and
industry standards.

Prepared by:

Dr. Marcus Chen

Chief Technology Officer

Polar Dynamics Robotics, Inc.

Date: October 15, 2023

Reviewed by:

Dr. James Barrett

Chief Robotics Officer

Polar Dynamics Robotics, Inc.

Date: October 17, 2023

10. DOCUMENT CONTROL

Document Number: PDR-TECH-2023-Q3-001

Version: 1.0

Classification: Confidential

Distribution: Authorized Personnel Only

Review Date: October 17, 2023

Next Review: January 15, 2024