June 2018

Final Test Report
for the

Explosive Hydrogen (H_2) Atmosphere Testing on the Piranha BLox Intelligent Self Retracting Lanyard (SRL)-Version Hardwired Personal Protective Equipment (PPE) Interlock System

EPG Publication No. FTR18-05-013

ATEC Project No. 2018-DT-EPG-NOFED-H1883

Reejay Martinez, Test Officer
E4/TEMPEST & Antenna Division
Test Resources & Laboratories Directorate

Report Produced By
The U.S. Army Electronic Proving Ground

Report Produced For
Control Dynamics Inc.

SECURITY STATEMENT

This document was prepared using approved security guidance.

1. Army Tactical Automated Information Systems Security Classification Guide (SCG), April 2008. (FOUO)

OPERATIONS SECURITY

1. Operations security (OPSEC) is a baseline consideration in the production of all technical documentation.
2. The U.S. Army Electronic Proving Ground Operations Security Standard Operating Procedures, 28 January 2016, was considered in conjunction with applicable guidance in the production of this document.

ACKNOWLEDGEMENTS

Supporting Test Personnel

Environmental Test Facility (ETF): Mr. Terry LeMaire, Mr. Clayton Bryan, and Mr. David Hinshaw

20 June 2018

Final Test Report for the
Explosive Hydrogen (H2) Atmosphere Testing on the
Piranha BLox Intelligent Self Retracting Lanyard (SRL)-
Version Hardwired Personal Protective Equipment (PPE)
Interlock System

Submitted by:

Reejay Martinez

FOR THE COMMANDER:

KERRY CARUTHERS
Acting Director, Test Resources & Laboratories Directorate

INTENTIONALLY BLANK

TABLE OF CONTENTS

TABLES

FIGURES

INTENTIONALLY BLANK

SECTION 1. EXECUTIVE DIGEST

1.1 SUMMARY

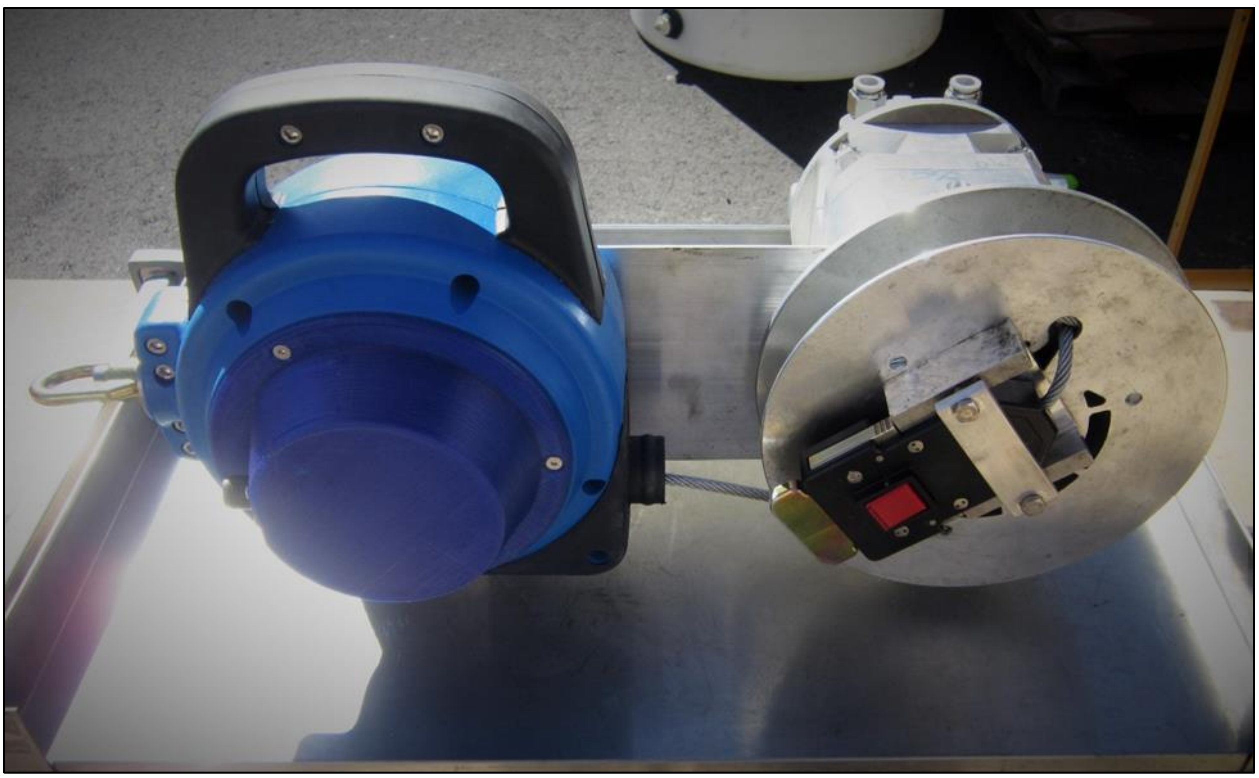
The U.S. Army Electronic Proving Ground (EPG), Fort Huachuca, Arizona, conducted explosive hydrogen (H_2) atmosphere testing on the Piranha BLox Intelligent Self Retracting Lanyard (SRL)-Version Hardwired Personal Protective Equipment (PPE) Interlock System, comprising the Piranha BLox System and a system controller (fig. 1) (hereinafter referred to as Piranha BLox).

1.1.1 Test Objective

The objective was to determine whether the Piranha BLox is safe to operate in an explosive H_2 atmosphere.

1.1.2 Test Authority

The U.S. Army Test and Evaluation Command (ATEC) tasked EPG to conduct testing under ATEC Project No. 2018-DT-EPG-NOFED-H1883. The test sponsor was Control Dynamics, Inc.



UNCLASSIFIED

Figure 1. Piranha BLox Intelligent SRL-Version Hardwired PPE Interlock System

1.1.3 Test Concept

a. Testing was conducted 21 and 22 May 2018 in an explosive H_2 atmosphere test chamber at the EPG Environmental Test Facility (ETF) in accordance with (IAW) Military Standard (MIL-STD)-810G (app D, ref 1), as outlined in the EPG detailed test plan, Publication No. DTP15-08-011 (app D, ref 2).

b. Piranha BLox part number (PN) 650.040.010 was the system under test (SUT). Hydrogen was chosen as a fuel source due to its low minimum ignition energy requirement.

1.1.4 Test Findings

The Piranha BLox demonstrated the capability to operate in a 21-percent H_2/air explosive atmosphere without causing ignition.

1.2 SYSTEM DESCRIPTION

a. The Piranha BLox comprises the BLox Intelligent SRL-Version connector and a wire rope assembly with electrical conductors communicating the contact closure of the Piranha BLox connector via a slip ring assembly and an electrical connector (fig. 1).

b. The Piranha BLox was developed to meet a need based on agreements reached between The Boeing Company ("Boeing") and the Washington State Department of Labor and Industries (Washington L&I), and also to meet existing requirements for the safeguarding of open-sided platforms above 4 feet high.

c. Boeing Legal and Washington L&I agreed that some form of surveillance (e.g., human, electronic) is necessary to ensure that employees continuously wear PPE and properly keep themselves attached to fall protection anchorage points. Since direct human observation is the weakest method of assuring PPE connections, electronic surveillance (wired or wireless) was determined to be the optimal solution. The Boeing Executive Steering Team (EST) agreed and established electronic surveillance as the minimum level of protection for fall PPE on paint protection stackers and gantry lifts, unless demonstrated to be technically infeasible via a High Hazard Deviation justification.

d. The Piranha BLox will monitor connections between various components of PPE and connections to lanyards, anchor points, SRLs, etc., to ensure that all fall PPE connections meet established safety conditions. When thresholds are exceeded, equipment will not be permitted to operate, and warnings and/or alarms will notify personnel in the area of unsafe conditions and actions to take. Direct signals to emergency response organizations may also be activated.

1.3 CONCLUSIONS

The Piranha BLox Intelligent SRL-Version Hardwired PPE Interlock System, as tested (serviceable condition), successfully met the test criteria for safe operation in an explosive hydrogen atmosphere without detonation of the atmosphere.

1.4 RECOMMENDATIONS

None.

SECTION 2. SUBTESTS

2.1 EXPLOSIVE ATMOSPHERE

2.1.1 Test Objective

The objective is to demonstrate whether the Piranha BLox can operate to specifications in an H_2-rich explosive atmosphere, at site altitude, without causing ignition.

2.1.2 Test Criterion [EPG]

The Piranha BLox shall meet the tailored guidelines of MIL-STD-810G (app D, ref 1), Paragraph 5, and Method 511.5, to operate in an explosive H_2 atmosphere without causing an explosion.

2.1.3 Test Procedures

a. ***General.*** Tailored procedures based on those outlined in MIL-STD-810G, Part One, Paragraph 5.2, were followed when testing the SUT. The SUT retained all safety lock mechanisms and was operated via a remote test jig. A pressured air source, external to the SUT, was connected to the SUT via a quick disconnect. An external power supply provided power to the receiver circuitry. An additional power supply and resistive load, connected in series, were wired to the mechanical relay output. The direct current (dc) limit was set at 0.5 amperes to meet factory specifications on the relay (app B, figs. B-1 and B-2). Power supply output display indicators provided visual confirmation that the receiver was responding to the transmitter signal when the reed switches were enabled and engaging the mechanical relay. A pretest baseline was established by verifying and physically inspecting the SUT in a test configuration. A posttest functional check (app C) was performed and all results were recorded in test event logs. Table 1 lists the test support instrumentation used.

Table 1. Test Support Instrumentation (Hydrogen Chamber)

UNCLASSIFIED

Item	Manufacturer	Model	SN/ Asset No.	Calibration	
				Date	Due
Explosion Atmosphere Chamber	Allentown Scientific Associates	NR	GM04933	NR	NR
Chamber Controller	Tidal Engineering	Synergy V	GM04933	23 Jan 18	17 Jan 19
Pressure Sensor	MKS Instruments	626B13TAE	GE58971	20 Feb 18	15 Feb 19
Power Supply/Readout	MKS Instruments	TYP 660B10	016906544	20 Feb 18	15 Feb 19
Mass Flow Controller	Alicat Scientific	MC-100SLPM-D	GE61416	27 Aug 17	22 Aug 18
Mass Flow Controller Software	Flow Vision 1.1.35.0	NR	NR	NR	NR
Power Supply (dc)	Victor-VID	WP-775B	GE 10448	NR	NR
Multimeter	Fluke	79	B689L	22 Jun 17	10 Oct 19
NR – not required; SN – serial number					

b. ***Pretest.*** Prior to the start of testing, EPG test personnel—

(1) Verified that the air within the test chamber had a water vapor dew point lower than 10 degrees Celsius (°C) [50 degrees Fahrenheit (°F)].

(2) Installed the SUT in the explosive atmosphere chamber (figs. 2 through 4).

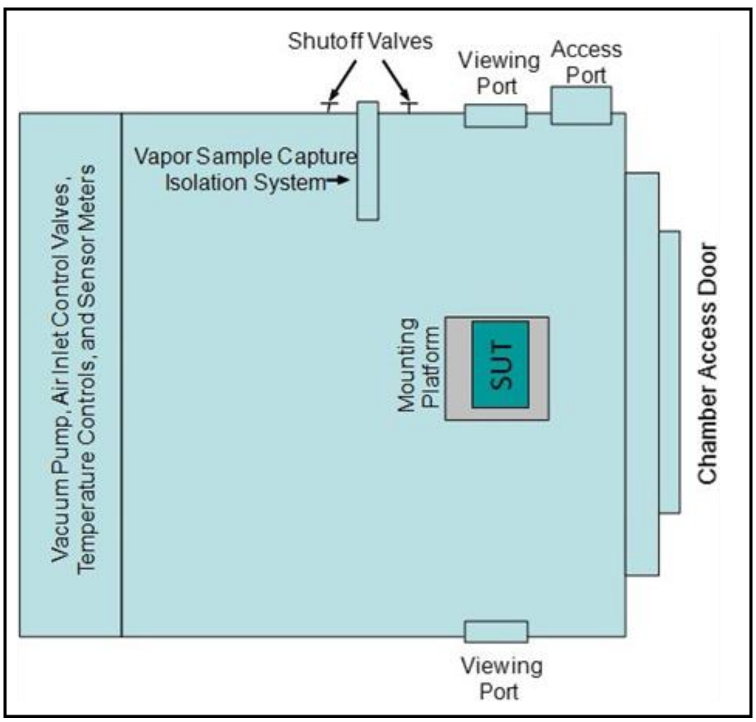
(3) Performed a functional check, then secured the chamber door.

(4) Grounded the chamber and the H_2 delivery system equipment and verified that all test chamber components were firmly grounded.

(5) Performed a functional check.

(6) Brought the SUT and chamber inner walls to within 2 °C (3.6 °F) of the high operating temperature of 40 °C (104 °F).

(7) Initiated data collection and began performing the test procedures.



FOUO

Figure 2. Explosive Atmosphere Test Configuration, Top View

UNCLASSIFIED

Figure 3. SUT Configuration in the Explosive Atmosphere Chamber

UNCLASSIFIED

Figure 4. Close-up of the SUT Configuration in the Test Chamber

c. ***Execution.*** Test personnel—

(1) Applied a vacuum to the chamber until the absolute air pressure reached 9.74 pounds per square inch (psi), then stopped the vacuum pump and engaged the safety check valves.

(2) Secured the equipment and activated remote control operations.

(3) Introduced 296.97 liters of H_2 with a 95-percent or greater purity, per the Hydrogen Worksheet (fig. 6), and activated the internal atmosphere circulation fan.

(4) When the chamber concentration was achieved, remotely engaged the H_2 safety fill valves.

(5) Circulated the test atmosphere for at least 3 minutes, to allow for the complete diffusion of H_2 and the development of a homogeneous (H_2/air) mixture, then powered off the fan.

(6) Verified the potential explosiveness of the H_2/air mixture by remotely igniting a sample of the mixture, taken from the test chamber, using a glow-plug ignition source with sufficient energy to ignite a 21-percent H_2/air mixture.

(7) Remotely powered on the SUT using the Piranha BLox cable controller (fig. 5) and conducted simulated operations for approximately 10 minutes.

(8) Verified potential explosiveness of the air-vapor mixture as described in step (6).

(9) Documented the test conduct and results. The chamber data shown in figures B-1 and B-2 (app B) were captured by the controller and provided to the customer.

UNCLASSIFIED

Figure 5. Piranha BLox Cable Controller

Table 2. Simulated Operations Procedure

UNCLASSIFIED

Step No.	Action
1	Ensure the main air pressure source is set at a minimum amount required to drive the test fixture, approximately 35 psi.
2	Turn the HOA selector switch to HAND position.
3	Press the REVERSE button momentarily to observe reverse rotation of test fixture.
4	Press the FORWARD button momentarily to observe forward rotation of test fixture.
5	Turn the HOA selector to the OFF position. Observe no rotational movement.
6	Turn the HOA selector to the AUTO position, observe automatic reverse and forward rotation of the test fixture alternating in 3-second increments.
7	Maintain the fixture operation in AUTO mode in the explosion chamber for at least 5 minutes of continuous run time to test the slip ring and wire rope electrical connection integrity.
8	At the completion of test, return selector to the OFF position.
HOA – Hand-Off-Auto	

Temperature (°C)	Altitude (ft)	Volume (ft3)	% Hydrogen
40	4777	62.5	21
	25.11		
	637.74		

Pressure	85.025	kPa	
Volume	371.700	liters	
Gas constant	8.310	kPa	
Temperature	313.000	°K	
Number of Moles	12.150	moles	n = PV/RT

Add	296.97	Liters of H2

Vliters@21% H2 concentration = nRT(@25°C cal)/P(@ sea level in kPa) = (12 moles) • 8.31 kPa• L• mol–1• °K–1 • 298 °K)/ (101.32 kPa)

Ideal Gas Law Equation -- PV= nRT

altitude (ft)	inHg	mmHg	psia	kPa
4777	25.11	637.74	12.33	85.025

H2 + Air Worksheet

Basic composition of air:	
O2	20.947%
N2, Ar, CO2, etc.	79.053%

Tank vol.	62.5	ft^3
Temp	40	C
Pressure	12.33	PSIA
Standars(25C)	49.35	SCFT

	Component				PSIA	SCFT	BTU	SCL
	H2	Air	O2	H2/O2	Air fill Pressure	Add H2	Heat (HHV)	Add H2
4	4.00%	96.00%	20.11%	0.199	11.84	2.00	626.4	56.57
	5.00%	95.00%	19.90%	0.251	11.72	2.50	783.0	70.71
	6.00%	94.00%	19.69%	0.305	11.59	3.00	939.6	84.85
	7.00%	93.00%	19.48%	0.359	11.47	3.50	1096.2	98.99
	8.00%	92.00%	19.27%	0.415	11.35	3.99	1252.8	113.13
	9.00%	91.00%	19.06%	0.472	11.22	4.49	1409.4	127.27
	10.00%	90.00%	18.85%	0.530	11.10	4.99	1565.9	141.41
	11.00%	89.00%	18.64%	0.590	10.98	5.49	1722.5	155.56
	12.00%	88.00%	18.43%	0.651	10.85	5.99	1879.1	169.70
	13.00%	87.00%	18.22%	0.713	10.73	6.49	2035.7	183.84
	14.00%	86.00%	18.01%	0.777	10.61	6.99	2192.3	197.98
	15.00%	85.00%	17.80%	0.842	10.48	7.49	2348.9	212.12
	16.00%	84.00%	17.60%	0.909	10.36	7.99	2505.5	226.26
	17.00%	83.00%	17.39%	0.978	10.24	8.49	2662.1	240.41
	18.00%	82.00%	17.18%	1.048	10.11	8.99	2818.7	254.55
	19.00%	81.00%	16.97%	1.120	9.99	9.49	2975.3	268.69
	20.00%	80.00%	16.76%	1.193	9.87	9.99	3131.9	282.83
	21.00%	79.00%	16.55%	1.269	9.74	10.49	3288.5	296.97
	22.00%	78.00%	16.34%	1.346	9.62	10.99	3445.1	311.11
	23.00%	77.00%	16.13%	1.426	9.50	11.48	3601.7	325.25
	24.00%	76.00%	15.92%	1.508	9.37	11.98	3758.3	339.40
	25.00%	75.00%	15.71%	1.591	9.25	12.48	3914.9	353.54
	26.00%	74.00%	15.50%	1.677	9.13	12.98	4071.5	367.68
	27.00%	73.00%	15.29%	1.766	9.00	13.48	4228.1	381.82
	28.00%	72.00%	15.08%	1.857	8.88	13.98	4384.7	395.96
	29.00%	71.00%	14.87%	1.950	8.76	14.48	4541.3	410.10
	30.00%	70.00%	14.66%	2.046	8.63	14.98	4697.8	424.24

UNCLASSIFIED

Figure 6. Example Hydrogen Worksheet

2.1.4 Test Findings

The SUT components demonstrated no susceptibilities to the explosive H_2 atmospheric conditions.

2.1.5 Technical Analysis

The criterion was met.

a. No explosion occurred during operations of the Piranha BLox.

b. During repeated testing the potentially explosive H_2 atmosphere was not ignited while the SUT was operating.

INTENTIONALLY BLANK

SECTION 3. APPENDICES

INTENTIONALLY BLANK

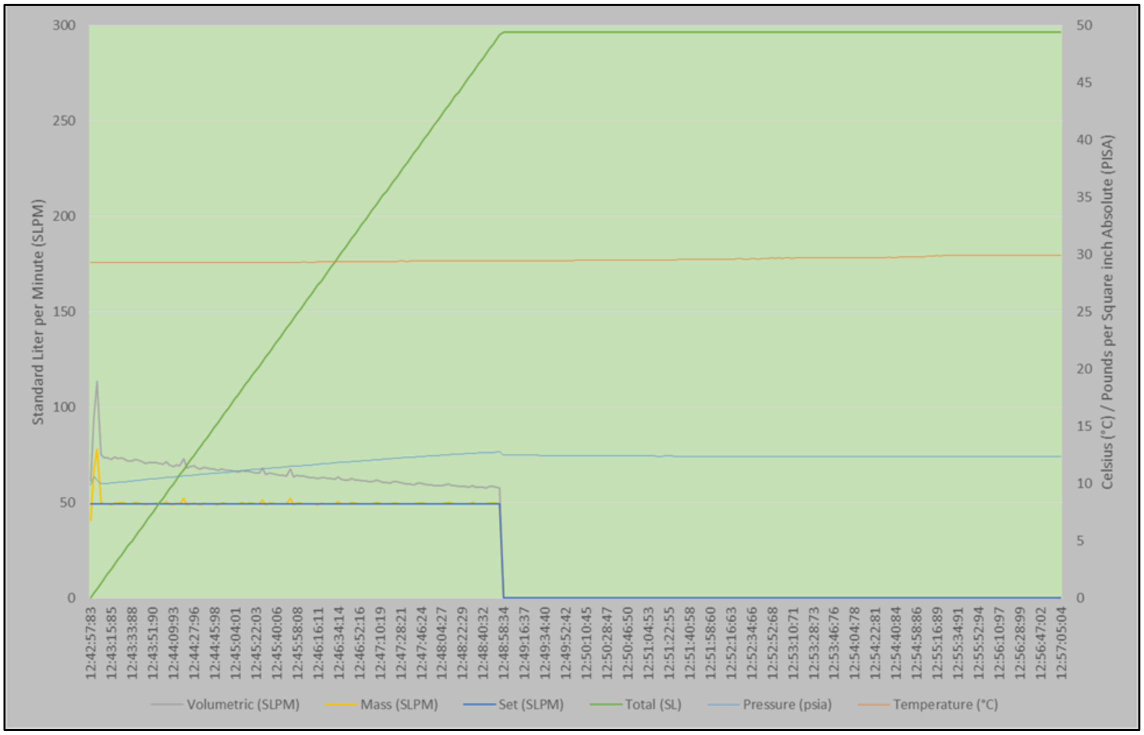
APPENDIX A. TEST CRITERIA

FOUO

Item	Source	Criteria	Subtest	Remarks
1	EPG	The Piranha BLox shall meet the tailored guidelines of MIL-STD-810G (app D, ref 1), Paragraph 5, and Method 511.5, to operate in an explosive H_2 atmosphere without causing an explosion.	2.1	The criterion was met
EPG – U.S. Army Electronic Proving Ground; H_2 – hydrogen; MIL-STD – military standard;				

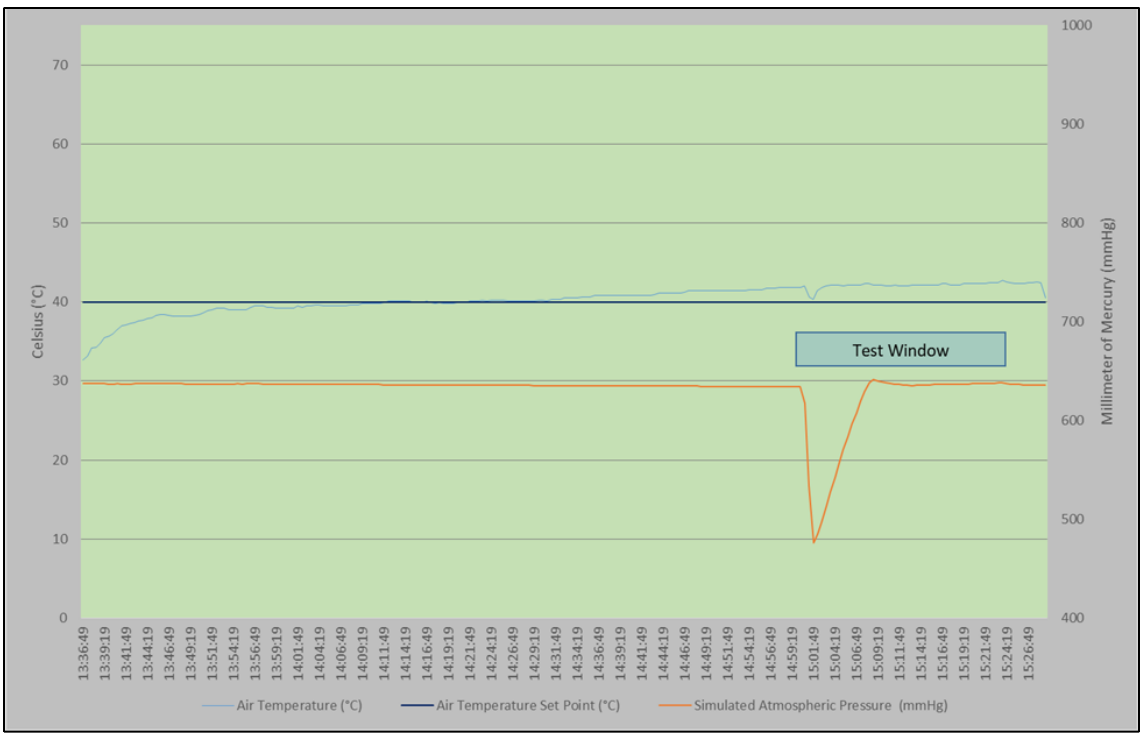
INTENTIONALLY BLANK

APPENDIX B. TEST DATA



FOUO

Figure B-1. Mass Flow Control Response Data



FOUO

Figure B-2. H_2 Climatic Test Environment Response Data

FOR OFFICIAL USE ONLY

INTENTIONALLY BLANK

APPENDIX C. FUNCTIONAL CHECKS

a. ***Operational Concept***

(1) Communication is made when all three reed switches make contact on the harness board and no reed switches are connected on the lift board. In this state, the harness board will send data to the lift board every 500 milliseconds (ms). The lift unit will receive data and confirm receipt of data back to harness board. In this operating state, the relay is actuated and the lift would be operational.

(2) Communication ends when any of the harness-side reed switches do not have contact, or if the lift side does not receive any data from the harness side for 2+ seconds. In this state, the lift controls are inactive.

b. ***Functional Check Procedures.*** A pneumatic apparatus was employed to allow remote manipulation of the lever release mechanism and the two side levers, and to allow removal/insertion of the actuator key. With power applied to both the harness board and lift board, test personnel—

(1) Determined whether the circuits were communicating by visually confirming that 2 amperes was displayed on the power supply (app B, fig. B-2).

(2) Fully depressed the lever release mechanism, then depressed the two side levers and removed the actuator key from the aluminum housing.

(3) Confirmed that communications stopped by verifying that the power supply was displaying 0 amperes across the resistive load (app B, fig. B-1).

(4) Reinserted the actuator key and released all mechanical levers and latches.

(5) Determined whether the circuits were again communicating by visually confirming that the power supply displayed 2 amperes.

INTENTIONALLY BLANK

APPENDIX D. REFERENCES

1. Military Standard (MIL-STD)-810G, Department of Defense Test Method Standard: Environmental Engineering Considerations and Laboratory Tests, 31 October 2008. (UNCLASSIFIED)

2. Detailed Test Plan for the Explosive Hydrogen (H_2) Atmosphere Testing of the Piranha Lox Fall Personal Protective Equipment (PPE) Interlock System, U.S. Army Electronic Proving Ground (EPG), Publication No. DTP15-08-011, 28 September 2015. (FOUO)

INTENTIONALLY BLANK

APPENDIX E. ACRONYMS AND ABBREVIATIONS

°C	degree Celsius
°F	degree Fahrenheit
ATEC	U.S. Army Test and Evaluation Command
dc	direct current
EPG	U.S. Army Electronic Proving Ground
EST	Executive Steering Team
ETF	Environmental Test Facility
H_2	hydrogen
HOA	Hand-Off-Auto
MIL-STD	Military Standard
ms	millisecond
NR	not required
PN	part number
PPE	personal protective equipment
psi	pounds per square inch
SN	serial number
SRL	self-retracting lanyard
SUT	system under test
Washington L&I	Washington State Department of Labor and Industries

INTENTIONALLY BLANK

APPENDIX F. DISTRIBUTION LIST

Addressee	Copies
U.S. Army Evaluation Center ATTN: CSTE-TM (Mr. Thomas R. Masino) 2202 Aberdeen Boulevard Aberdeen Proving Ground, MD 21005-5001 (443) 861-9370 thomas.r.masino2.civ@mail.mil	1
Control Dynamics, Inc. ATTN: Mr. Eric Moran 21 East Marine View Drive, Suite G Everett, WA 98201 (206) 510-3413 eric@cdinw.com	1

INTENTIONALLY BLANK