gh Package & Product Testing and Consulting, Inc.
ISO17025 accredited
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Test Report

Current (Gen 2) Pendant Armor™ and Gen 3 Pendant Armor™
Polymer A Hanger and Polymer B Hanger
March 16, 2016
(Q022516U1R2)

Client

Roboworld, LLC
5749 Chadwick Court
West Chester, OH 45069
Test Per: Chris Tur

Testing Location

gh Package & Product Testing and Consulting, Inc.
Fairfield, Ohio 45014

Testing Date (s) - March 14 - 16, 2016

Test Conditions: 73 degrees Fahrenheit, at 50% Humidity

Test Purpose

The purpose of the testing is to determine if, and how much protection one or both generations of the molded Pendant Armor™ sleeves offered the robot control pendant as well as testing was performed to determine which material might be more appropriate for use as a hanger.

Personnel Present During Testing

H. Perry Hock, President and Technical Director, gh Package & Product Testing and Consulting, Inc .
Curt Orr, Sales Manager, gh Package & Product Testing and Consulting, Inc.
Ernie Lindlar, President, E-L Consultants
Pendant Armor™ design team

Test Equipment

Equipment Used

Lansmont 300 Shock Table

Shock Recorder:	Lansmont m/n: TPUSB 103570-2-B	s/n: 0806-008,	Cal. Date: 8-9-15
Control accelerometer:	Dytran m/n 3010A5	s/n: 599	Cal Date: 12-31-15
Response accelerometer:	PCB m/n 356B21	s/n: 101889	Cal Date: 12-31-15
Swing Arm-Drop Tester 160lb	Accudrop m/n: 160	s/n: 10640126	Cal. Date:12-8-14
Scale:	Empire 72" *Ex-Due 2017	ID 55	Cal. Date: 4-4-12
Tensile/Compression Machine:	Chatillon		
Digital Controller:	m/n: CS1100 with Tablet	S/N: 606	Cal. Date: 3-23-15
Load Cell:	m/n: CLC-1000-DED	S/N: 100LB0060	Cal. Date: 4-7-15

Test Procedure

Shock Machine Testing

Shock testing was performed on a shock machine that is in compliance with the following standard:

ASTM D3332 – 99 (Reapproved 2010) Standard Test Methods for Mechanical-Shock Fragility of Products, Using Shock Machines

The procedure below used was in lieu of, but based on the shock principles of ASTM D3332.

The control accelerometer was mounted on the underside of the shock table and the response (triaxial) accelerometer was mounted on the dummy unit – on what would be the LCD screen. The dummy unit was weighted and balanced (center of gravity) virtually identical to the Motoman pendant.

The shock machine was set for a 12 inch drop (which simulates a 20 to 24" free fall drop, depending on the coefficient of restitution) with the weighted dummy unit mounted in the following orientations:

1. On emergency stop button
2. Top shortest edge

The shock machine was then set for a 30 inch drop (which simulates a 40 to 50" free fall drop, depending on the coefficient of restitution) with the weighted dummy unit mounted in the following orientations:

1. On emergency stop button
2. Top shortest edge

The rationale was to determine the shock transmissibility, otherwise called shock mitigation or dampening, by comparing the input acceleration data to the output data.

Free Fall Drop Testing

The data capture unit and dummy unit was moved over to the free fall drop test machine. The accelerometer remained mounted on the dummy unit – on what would be the LCD screen.

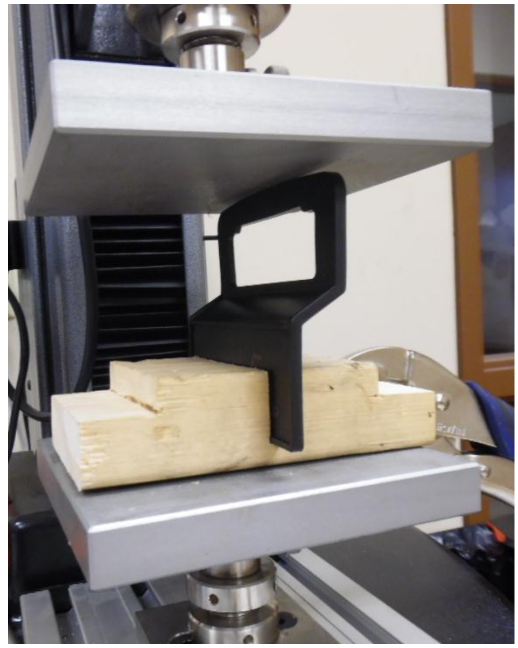
Data was gathered based on free fall drop testing from 48" onto a steel plate.

The drop machine was set for a 48 inch drop with the weighted dummy unit mounted in the following orientations (see photos):

1. On emergency stop button
2. Top shortest edge

Actual pendant was used for drops onto the emergency stop button.

Shock on small face



Hanger in the jig on the compression platen

Hanger Testing

The hangers were positioned vertically in a jig (see photo)

The machine was set for compression and at a speed of 0.5 inches per minute.

A force was applied until either the hanger fractured or the hanger could no longer maintain a peak load and the force started to fall away.

5 of each type were tested

Unit Under Test

Robot Pendant
Dummy Pendant

Gen 2 armor
Gen 3 armor

Polymer A Hanger
Polymer B Hanger

Testing Results, Inspection, and Analysis

Results: The data below was generated from testing the two types of hangers.

Inspection: No hangers broke during the testing

Analysis: Since no hangers broke, it can be assumed that a much more substantial impact, or quick, abrupt force would be required to fracture the hanger.

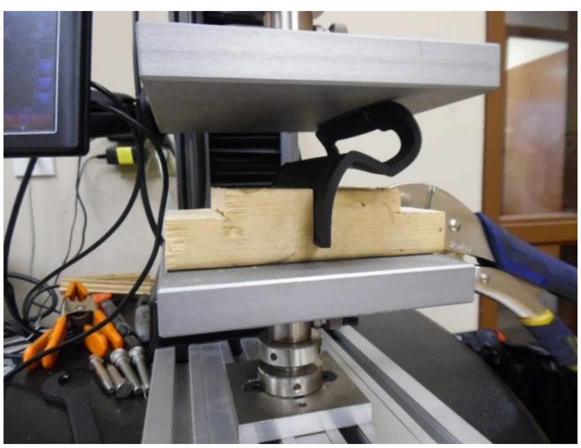
Sample	Polymer A		Polymer B	
	Peak Load*	Break Load*	Peak Load*	Break Load*
1	1019	-	607[1]	-
2	1008	-	700[1]	-
3	1006	-	1005	-
4	1025	-	1000	-
5	999	-	999	-

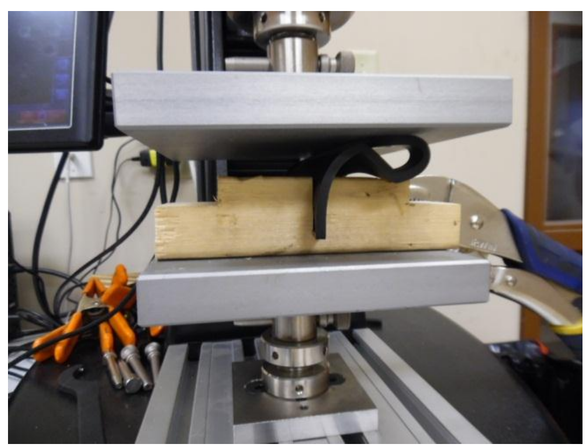
* All forces are Pound-Force
[1] Testing was stopped early by the technician due to non breakage and the deformation characteristics of the polymer.

Sample	Polymer A		Polymer B	
	Peak Load*	Break Load*	Peak Load*	Break Load*
Average	1011	-	862	-

* All forces are Pound-Force

From the data and the fact none of the hangers broke, it would appear the two are virtually identical.





Results: The graphs below represent the general consensus of the performance of Pendant Armor™

Inspection: Inspection of the units revealed no damage using the Pendant Armor™

Analysis: On the emergency stop button: The sleeve mitigates the shock between 50 and 70 percent, depending on how the unit hits on or near the button. If the unit doesn't hit square on the button, thus the shock us distributed in various axis, and the armor is closer to 60%. When it hits square on the button, which is worst case, the armor is most effective.

The corner drop shows approximately the same results.

After a discussion with the design team, it is to be noted that there will be a hanger mounted on the face and therefore a drop cannot occur on that edge because the hanger will be extending well beyond the short edge.

:KDW LV (TXLYDOHQW)UHH)DOO'URS +HLJKW [FK IRUPXOD DUH GHILQLWLRQ WR KHOSH[SODLQ

EFFECTIVE FREEFALL DROP HEIGHT (EFFDH) is an estimate of the drop height associated with a known velocity change. If the coefficient of restitution can be closely estimated, then the equivalent freefall drop height can be determined from a given velocity change input.

$$h = \Delta V^2 / (1 + e)^2 2g$$

KIUHHIDOOGURSKHLJKWLQLQFKHV
HFRHIILFLHQWRIUHVWLWXWLRQRIWKHLPSDFWVXUIDFHVUDQJHVIURPWR
UDYLWDWLRQDOFRQVWDQWLQVHF

VELOCITY (V) is the rate at which displacement changes. It is a vector quantity having both magnitude and direction. It is measured in meters per second, inches per second and similar units. (It is the integral of acceleration and the differential of displacement with respect to time.)

VELOCITY CHANGE (ΔV) refers to the difference between an initial and final velocity and can be thought of as a measure of energy dissipated during a dynamic event. It is equal to the area under the acceleration vs. time pulse (the integral of the pulse). Velocity change can be estimated by multiplying the peak acceleration of a pulse times its effective duration.

The following equations apply:

$$\Delta V = A_p T_e = (A)(g)(Dur)(\text{wave shape factor})$$

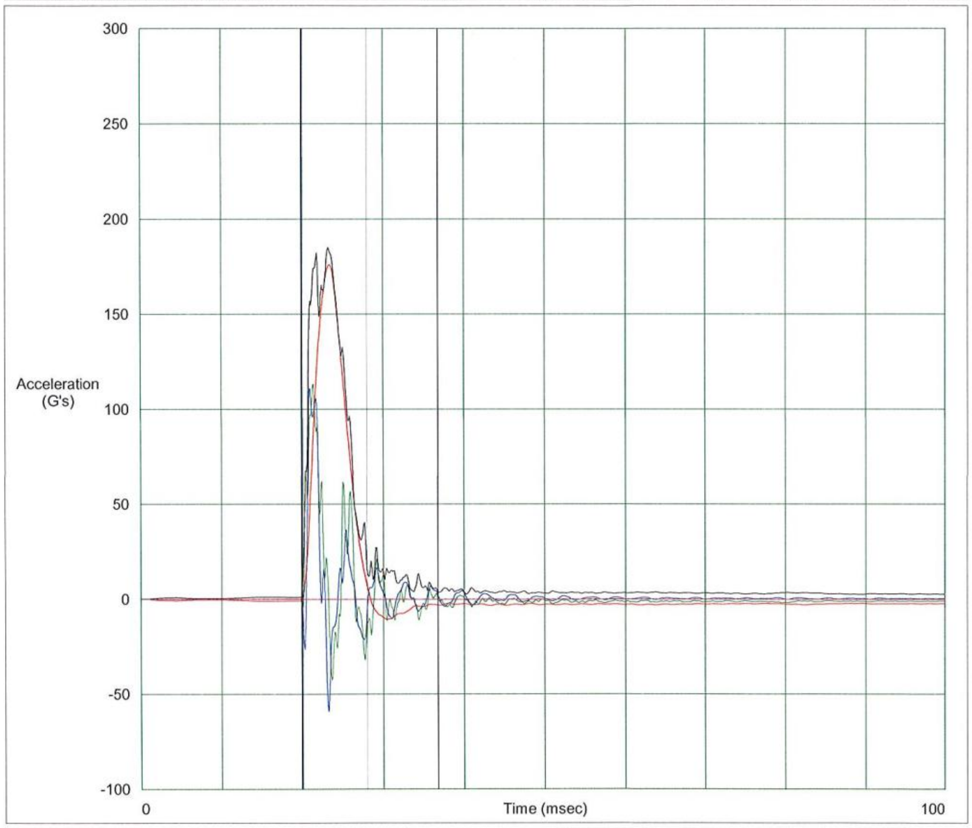
$$\Delta V = V_i - (-V_r) = V_i + V_r = (1 + e)\, ã2\overline{gh}$$

COEFFICIENT OF RESTITUTION (e) is the ratio of the rebound velocity to the impact velocity expressed as a percentage (V_r / V_i). It is a measure of the energy dissipated or stored during a dynamic event such as an impact.

Acceleration vs. Time   C:\TP3\TP3 RapidFire - 2016-03-14 12-05-22.PL3   12:05:22 PM Mar-14-2016

Lansmont Corporation   TEST PARTNER

	Channel Description:	G's	msec	In/S	Filter Hz	Max G's	Min G's
Ch 1	X - Axis	176.11	7.00	286.96	100.00	176.11	-10.72
Ch 2	Y - Axis	99.63	2.50	71.70	330.00	113.03	-42.75
Ch 3	Z - Axis	102.97	1.70	54.78	330.00	110.79	-59.22
Ch 4	Table	0.05	1.30	0.02	1000.00	0.11	-0.11
Triaxial	Vector Resultant Magnitude	185.05	7.90	392.78	None	185.05	0.02



Pendant Armour

Q022516U1R2

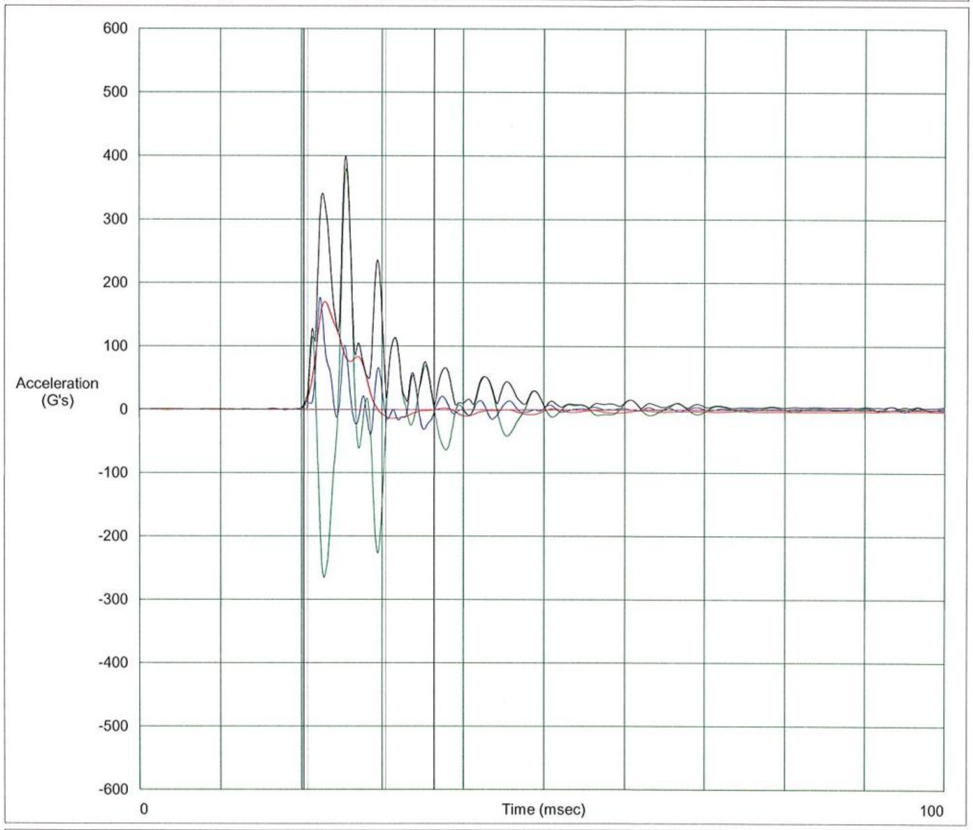
Free Fall Drop Test

Dummy unit, gen 2, free fall drop test, 48 inches

Acceleration vs. Time C:\TP3\TP3 RapidFire - 2016-03-14 12-08-17.PL3 12:08:17 PM Mar-14-2016

Lansmont Corporation TEST PARTNER

	Channel Description:	G's	msec	In/S	Filter Hz	Max G's	Min G's
Ch 1	X - Axis	170.29	8.10	298.16	100.00	170.29	-13.93
Ch 2	Y - Axis	380.12	2.00	184.84	330.00	380.12	-265.17
Ch 3	Z - Axis	176.70	2.60	96.73	330.00	176.70	-39.46
Ch 4	Table	0.12	0.50	0.01	1000.00	0.12	-0.10
Triaxial	Vector Resultant Magnitude	400.11	9.60	797.51	None	400.11	0.03



Pendant Armour

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Free Fall Drop Test

Dummy unit, unprotected, free fall drop test, 48 inches

Revisions

None

Testing Compliance and Accreditation

Unless otherwise noted, the testing stated above complies with the above stated procedure.

The completed testing above was in compliance with ISO/IEC 17025 and was in compliance with the customer requested test(s) and requirements. All reference and data logging materials used in the above testing are traceable to NIST. The testing performed above was performed at gh Package & Product Testing and Consulting, Inc., in Cincinnati. This test report cannot be reproduced, except in full, without written permission from gh Package & Product Testing and Consulting, Inc. If customer requested measurement uncertainty, the calculations are listed in the report. The measurement uncertainties represent an expanded uncertainties expressed at approximately 95% confidence level using a coverage factor of K=2.

Test Criteria, Understanding and Product Disposition

Test Criteria and Understanding

All reasonable efforts have been exercised to provide accurate data from resultant tests or consultation. Test methods utilized and followed in conducting various tests involve standards established by A.S.T.M., T.A.P.P.I., D.O.T., Federal Spec. and Mil-Spec., I.S.T.A. as well as private company test standards and procedures. gh Testing assumes no responsibility or guarantees/warranties regarding (specifically stated or implied) performance and only assumes responsibility for the test data presented by it. Responsibilities involving alterations and/or changes to the packages and/or product beyond item(s) originally tested are those of the user/supplier/client, of which, gh testing assumes no responsibility.

Please contact me should you have questions regarding this testing.

This report respectfully submitted by:

Mr. H. Perry Hock
President and Technical Director
gh Package & Product Testing and Consulting, Inc.

HPH/hph