Bendix Commercial Vehicle Systems LLC **Elyria, Ohio**		
GUIDELINE TITLE: Electronics Test Guideline Mechanical Validation Tests	**DEPARTMENT**:	*Platform 8439*
	PLM Team:	*EEE1*
	Guideline Number:	Y203399
	REVISION:	
	ISSUE DATE:	10-Nov-21
Guideline Owner: *Thomas Legeza*	**PAGE:**	1 of 26
KE CVS Next Level Process: Product and Process Validation	**KE CVS next level #**	TPD-30-40

Cover Sheet

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Revision Summary Table

Revised By	Approved By	Rev	Section	Description	Reason	Date
EEB	TSL	00		Initial Release		30-Sep-2016
JAM	TSL	001	All	Removed number of units tested for each test	Clarification	28-Sept-2021
JAM	TSL	001	3.1	Update Industry Specification date	Update	28-Sept-2021
JAM	TSL	001	6.1	Update Operating Temperature	Update	2-Nov-2021
JAM	TSL	001	7.1	Added Three Temperature Parametric Test	New	18-Oct-2021
JAM	TSL	001	7.3	Update grms value for all profiles	Grms value incorrect	28-Sept-2021
JAM	TSL	001	7.4	Added clarification about test being performed on component	Clarification	18-Oct-21
JAM	TSL	001	7.5,7.6	Remove voltage from test parameters	Update	28-Sept.-2021
JAM	TSL	001	7.7	Added Polarity and note about polarity	Update	28-Sept-2021
JAM	TSL	001	Various	Update J1455 to latest revision and section references	Update	28-Sept-2021
JAM	TSL	001	7.13	Update test sequence	Update	28-Sept-2021

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Table of Contents

1. Introduction

The purpose of this guideline is to provide a framework for standard product testing during the product development process. This document is to serve as a guide to how each test should be performed; engineers may customize individual tests to meet their product requirements.

This document shall be treated as confidential and for internal use only. Where external reporting is needed, refer to industry specifications such as those by SAE or ISO.

2. Scope

This guideline is applicable to all North American facilities and all functional areas of Bendix Commercial Vehicle Systems.

3. Related Documents

3.1. Industry Standards

Document Number	Publication Date	Title
SAE J1455	*MAR 2017*	Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

3.2. Bendix Documents

Document Number	Publication Date	Title

4. Definitions

A = Amperes
DC = direct current
DTC = Diagnostic Trouble Code
DUT = Device Under Test
Multivolt = operation across 12V and 24V system voltages
V = Volts

5. Tolerances

Unless otherwise specified, the tolerances within this document are:

- Pressure: ± 0.25 psi (± 0.02 bar)
- Voltage: ± 0.2 VDC
- Current: ± 10 milliamp
- Time: ± 0.5 milliseconds
- Force: ± 0.1 lbs (± 0.4 N)
- Temperature: ± 1ºC)

6. Operating Environment

6.1. Operating Temperature

Mounting Location	Minimum Temperature	Maximum Temperature
In Cab	-40^{0}C	85^{0}C
In Cab (Direct Sunlight)	-40^{0}C	115^{0}C
Chassis *(Forward/Rear)*	-40^{0}C	*120^{0}C* / 85^{0}C
Chassis (near heat source)	-40^{0}C	150^{0}C
Chassis (Wheel End)	-40^{0}C	*165^{0}C*
Engine Bay	-40^{0}C	125^{0}C
Engine Bay (near heat source)	-40^{0}C	150^{0}C

Table 6.1

6.2. Operating Voltage

System Voltage	Minimum Voltage	Nominal Voltage	Maximum Voltage
12 Volts	9.0 ± 0.1 Volts	14.2 ± 0.1 Volts	18.0 ± 0.1 Volts
24 Volts	18.0 ± 0.1 Volts	28.4 ± 0.1 Volts	36.0 ± 0.1 Volts

Table 6.2

7. Design Validation Test Standards - Mechanical

Prior to performing any of the prescribed validation tests in this document, the responsible Engineer shall define:

- All test harness lengths, connection points, and measurement points.
- All DUT operating modes to be exercised during the test.
- The pre-test, in-test, post-test functional test, data collecting, and inspection requirements to be used as part of the test acceptance criteria (pass/fail).
    - Include any additional function tests pertaining to harnesses and enclosures (i.e. High Pot Tests, Pressurization Tests, etc.)
    - Follow best practice of performing functional tests “as a system” which includes: any electrical harnesses that would be used (standard or specialty), any air hoses that would be connected (even if testing without air pressure), and anything else that is called out to be connected to the DUT (covers, brackets, connectors, etc.)

All critical test parameters (e.g. DTC’s, temperature, pressures, sensor outputs, solenoid activations, etc.) shall be monitored and analyzed for anomalies continuously during the duration of the test.

Except where noted otherwise, multivolt DUTs shall be tested with the test parameters listed for both 12V and the 24V system voltages.

Except where noted otherwise, the DUT shall be connected to a voltage supply source capable of providing at least 15A of current more than the DUT’s maximum rated current.

Except where noted otherwise, an in-line fuse or circuit breaker shall not be used between the voltage source and the DUT. When using a fuse, the fuse rating shall be according to the product specification communicated to the customer.

Units must adhere to all expected outputs during the Test Acceptance Criteria steps to be considered passing the test.

Record all relevant DUT information which will include but not limited to: part number, serial number, software revision, and configuration of the DUTs.

All DUTs will be labeled per each test request that it is tested. It will be labeled with the minimum of the test request number and index number (example: TR009999-01).

7.1. Three Temperature Parametric Test (Pre and Post Test)

Test Overview

The DUT will be subjected to minimum and maximum operating voltages (Table 6.2) at room temperature, minimum, and maximum temperatures (Table 6.1). Place the DUT in an environmental chamber at ambient temperature and at nominal voltage. Ramp temperature to minimum test temperature and allow DUT to soak at this temperature for one hour. Change test voltage to minimum operating voltage and dwell for one hour then change test voltage to maximum test voltage and dwell for one hour. Change operating voltage to nominal and ramp temperature of chamber maximum test temperature and allow unit to soak at this temperature for 1 hour. Change test voltage to minimum operating voltage and dwell for one hour then change test voltage to maximum test voltage and dwell for one hour. Change test voltage to nominal and ramp test temperature to ambient.

Test Summary

Test Summary	
SAE Specification	*N/A*
Typical State of Sample	*Powered*
Test Frequency	*Before/After Test*

Test Parameters

Test Parameters	
Parameter	***Value***
Test Temperature	*Table 6.1*
Test Voltage	*Table 6.2*
Temperature Change Rate	*Max of 5 °C/minute*
Dwell Time @ each temperature and voltage	*1 Hour*

Test Acceptance Criteria

- *All critical test parameters (e.g. DTC's, temperature, pressures, sensor outputs, solenoid activations, etc.) shall be monitored and analyzed for anomalies continuously during the duration of the test.*
- *The DUTs shall pass a functional test during this test (at each temperature and voltage). This functional test may differ from the one performed at the end of the test.*
- *There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.*
- *At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.*
- *The DUT will not have any physical damage at the completion of this test.*

7.2. Swept Sine Vibration Test

Test Overview

The DUT will be subjected to Swept Sine Vibration test with values outlined below in the test parameters. Then dwell at the major resonances (if in the operational spectrum) to determine failure modes due to vibration. Each sample is to be tested on each of the three mutually perpendicular planes.

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.10.4.1
Typical Number Tested	3
Typical State of Sample	Powered
Functional Test	Before/During/After Test

Test Parameters

In Cab/Chassis/Engine Compartment	
Parameter	**Value**
Voltage	Table 6.2
g-Force (Freq Sweep)	1g
Sweep Frequency	5 Hz to 2 KHz *
g-Force (Dwell)	5g (49 m/s^2)
Rate	½ Octave per Minute
Cycles	3 (once each plane)
Dwell	30 Minutes @ each resonance frequencies

Test Acceptance Criteria

- All critical test parameters (e.g. DTC's, temperature, pressures, sensor outputs, solenoid activations, etc.) shall be monitored and analyzed for anomalies continuously during the duration of the test.
- The DUTs shall pass a functional test during this test. This functional test may differ from the one performed at the end of the test.

- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.
- The DUT will not have any physical damage at the completion of this test.

7.3. Random Vibration Test

Test Overview

The DUT will be subjected to Random Vibration test with values outlined below in the test parameters. Each sample is to be tested on each of the three mutually perpendicular planes.

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.10.4.2
Typical State of Sample	Powered
Functional Test	Before/During/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Voltage	Table 6.2 (nominal)
g-Force	Figures 7.2.1 thru 7.2.3
Test Time	Figures 7.2.1 thru 7.2.3
Cycles	3 (once each plane)

Break Point	Frequency	Value (g^2/Hz)
1	8	0.1485
2	10	0.1336
3	14	0.0742
4	20	0.0446
5	25	0.0037
6	30	0.0015
7	40	0.0223
8	50	0.0030
9	100	0.0045
10	300	0.0007
11	500	0.0007
Vibration Level		*1.40 grms*
Tested for 30 hours each axis		

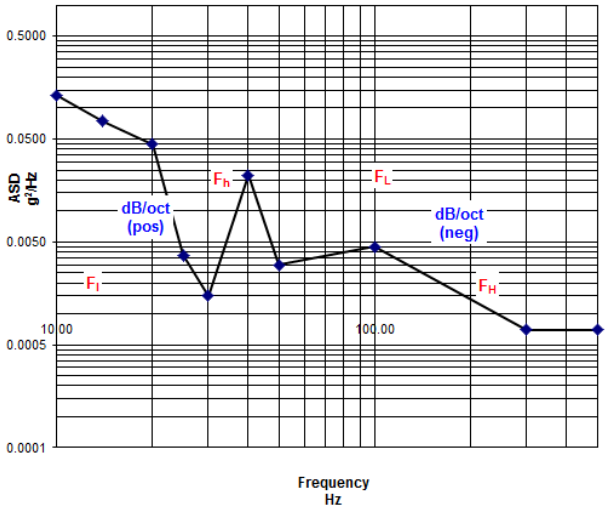


Figure 7.2.1 – Random Vibration Profile (Cab-Mounted)

Break Point	Frequency	Value (g^2/Hz)
1	10	0.0001
2	20	0.4
3	30	0.1
4	45	0.09
5	100	0.05
6	150	0.03
7	500	0.0025
8	505	0.001
9	1000	0.015
10	2000	0.002
Vibration Level		*4.62grms*
Tested for 71 hours each axis		

Ref. Similar to IEC 68-2-34

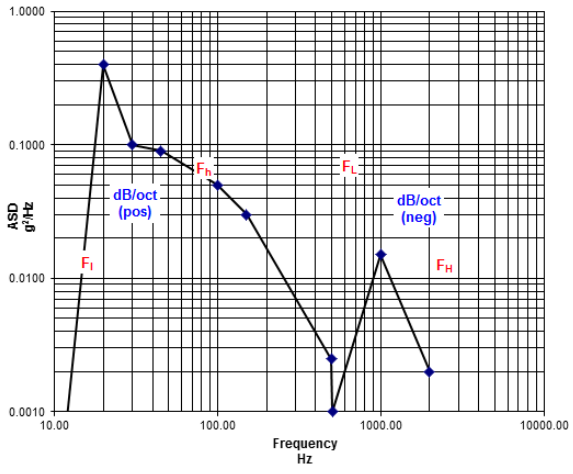
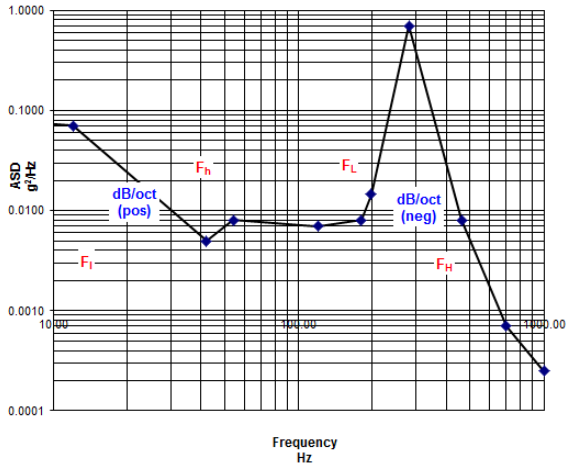


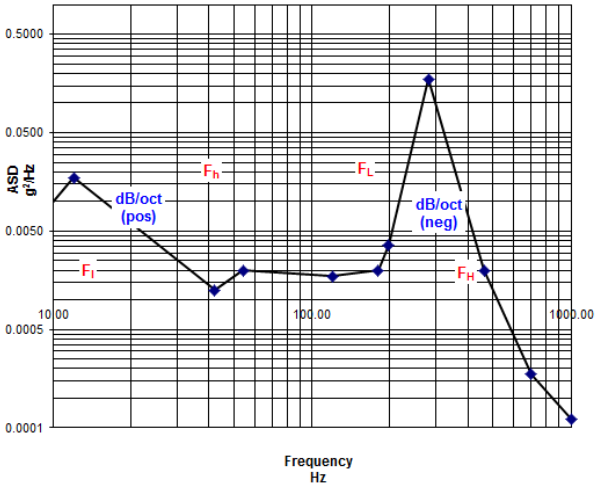
Figure 7.2.2 – Random Vibration Profile - Chassis-Mounted – Electronic Components

Frequency (Hz)	Major Axis*	Minor Axis
	PSD (g^2/Hz)	PSD(g^2/Hz)
6	0.08	0.002
12	0.07	0.0175
42	0.005	0.00125
54	0.008	0.002
120	0.007	0.00175
180	0.008	0.002
198	0.0145	0.003625
282	0.7	0.175
462	0.008	0.002
702	0.0007	0.000175
1000	0.00025	0.000062
Vibration Level	*6.58* grms	*3.28 grms*
Tested for 10 hours each axis		

** Vertical axis through the modulator as it is mounted in vehicle is defined as major axis*



Major Axis



Minor Axis

Figure 7.2.3 – Random Vibration Profile - Chassis-Mounted – Mechanical Components

Break Point	Frequency	Value (g^2/Hz)
1	10	0.001
2	100	0.001
3	150	0.150
4	250	0.001
5	500	0.001
Vibration Level		*2.13 grms*
Tested for 20 hours vertical axis only		

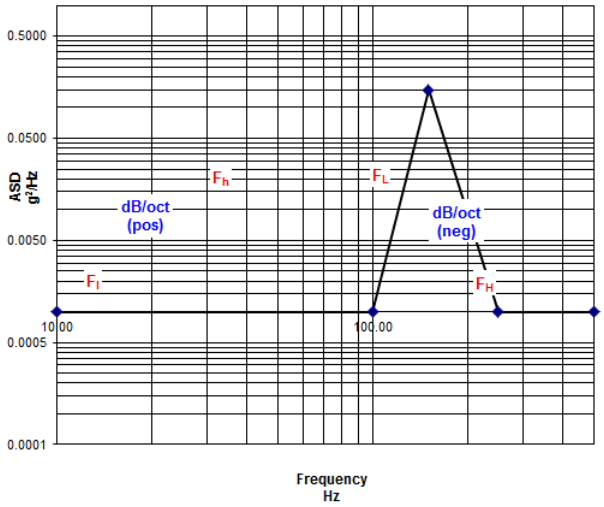


Figure 7.2.1 – Random Vibration Profile (Trailer Tank-Mounted)

Test Acceptance Criteria

- All critical test parameters (e.g. DTC's, temperature, pressures, sensor outputs, solenoid activations, etc.) shall be monitored and analyzed for anomalies continuously during the duration of the test.
- The DUTs shall pass a functional test during this test. This functional test may differ from the one performed at the end of the test.
- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.
- The DUT will not have any physical damage at the completion of this test.

7.4. Handling Drop Test

Test Overview

The DUT shall be subjected to a handling drop test from a height of 1 meter onto a flat concrete surface two times in each of the three mutually perpendicular planes. Drop the DUT on both the positive and negative planes under test. *Intent of test is the handling of the components such as in production line or prior to install on vehicle.*

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.11.3.1
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Voltage	Table 6.2
Height	1 Meter
Cycles	6 (two each plane per sample)

Test Acceptance Criteria

- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- If there is physical damage and DUT is not functional, that does not constitute a test failure. A failure would be if there is not obvious physical damage and the DUT does not function after this test (obvious damage would result in part rejection).
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.

7.5. Transit Drop Test

Test Overview

The DUT will be placed in its normal shipping container. The shipping container will be fully loaded as it would be shipped to the customer location. The shipping container will be subjected to a drop test from a height determined by total package weight as outlined below. The shipping container will be dropped in the order called out below.

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.11.3.2
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Shipping Package Weight	Drop Height
0.45 kg to 9.52 kg	76 cm
9.53 kg to 18.59 kg	61 cm
18.60 kg to 27.66 kg	46 cm
27.67 kg to 53.31 kg	31 cm

Step	Procedure
1	The 2-3-5 corner; corner formed by the right side, bottom, and near end
2	The shortest edge radiating from that corner
3	The next longest edge radiating from that corner
4	The longest edge radiating from that corner
5	Flat on one of the smallest faces
6	Flat on the opposite small face
7	Flat on one of the medium faces
8	Flat on the opposite medium face
9	Flat on one of the largest faces
10	Flat on the opposite large face

Test Acceptance Criteria

- Inspect both the shipping container and the DUTs. The container shall be considered to have passed the test if it is still able to provide reasonable protection of the contents contained inside.
- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.
- The DUT will not have any physical damage at the completion of this test.

7.6. Installation Harness Shock Test

Test Overview

Attach the DUT to a 1 meter long harness at a height so that the DUT will not impact the ground once it is released. A single test cycle is defined as releasing the DUT and having it swing in a pendulum motion until motion stops.

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.11.3.3
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Height	1 Meter
Cycles	20

Test Acceptance Criteria

- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.
- The DUT will not have any physical damage at the completion of this test.

7.7. Operational Shock Test

Test Overview

The DUT will be subjected to shock as described as outlined below. Mount each DUT on a different plane and run test (typically test is only run on one plane, i.e. no need to run each DUT on each plane).

Test Summary

Test Summary	
SAE Specification	SAE J1455 *MAR 2017*, section 4.11.3.4
Typical State of Sample	Powered
Functional Test	Before/During/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Voltage	Table 6.2
Pulse	Sawtooth
*Polarity**	*Positive*
Peak	30 g
Duration	11 mS *
Number of Pulses	18

*Note:
Polarity: Intention is positive, additionally negative depending on the mounting of the DTU
Duration: Test Chamber may only be able to perform test with max duration of 7 mS

Test Acceptance Criteria

- All critical test parameters (e.g. DTC's, temperature, pressures, sensor outputs, solenoid activations, etc.) shall be monitored and analyzed for anomalies continuously during the duration of the test.
- The DUTs shall pass a functional test during this test. This functional test may differ from the one performed at the end of the test.
- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.

- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.
- The DUT will not have any physical damage at the completion of this test.

7.8. Over-Pressurization Test

Test Overview

The DUT will be tested for over-pressurization by applying hydrostatic pressure to the main supply port and the rest of the ports (delivery and exhaust) blocked.

Test Summary

Test Summary	
SAE Specification	N/A
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Hydrostatic Pressure Applied	4x MDP *
Duration	10 Seconds *

* Verify with responsible engineer the Maximum Design Pressure (MDP) before running test (e.g. 600 psi hydrostatic pressure applied for product design for maximum 150 psi)

Test Acceptance Criteria

- The DUT will not have any physical damage at the completion of this test (fractures, cracks or leaks).
- If the DUT is not functional at the completion of this test, that does not constitute a test failure. A failure would be if there any physical damage to the DUT.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.

7.9. Strength of Screw Connection Test

Test Overview

The DUT will be tested for strength of screw connection of any covers that are connected to the body of the DUT. The screws shall be torqued to failure in order to document the results.

The first part of the test is to torque all the screws to the specified torque five times for each screw. The second part of the test is to document the torque required for failure (the point where the screw is "stripped"). Note if and when (what torque) any plastic covers crack before the screw reaches the point of being "stripped".

Test Summary

Test Summary	
SAE Specification	N/A
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Tested Torque(s)	Provided by responsible engineer

Test Acceptance Criteria

- The DUT will not have any physical damage at the completion of this test beyond the failure of the tested screws (fractures, cracks or leaks).
- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer.
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.

7.10. NPT Over-Torque Test

Test Overview

The DUT will be tested for NPT Over-Torque of the pneumatic ports. The ports shall be torqued to failure in order to document the results.

The first part of the test is to torque the pneumatic ports to the specified torque. The second part of the test is to document the torque required for failure (the point where the port is "stripped").

Test Summary

Test Summary	
SAE Specification	N/A
Typical State of Sample	Not Powered
Functional Test	Before/After Test

Test Parameters

Test Parameters	
Parameter	**Value**
Tested Torque(s)	Provided by responsible engineer

Test Acceptance Criteria

- The DUT will not have any physical damage at the completion of this test beyond the failure of the pneumatic ports (fractures, cracks or leaks).
- There should be no degradation of performance or function after the completion of this test. It will meet the requirements at room temperature as defined by the responsible engineer (prior to the failure point).
- At the completion of the functional tests when testing is complete, the DUTs shall be disassembled then inspected for internal contamination and material degradation as defined by the responsible engineer.

7.11. Wire pull-force testing

Test Overview

Take 30 production test samples and perform the pull test on each sample. If there is any stress relief in place, this should be removed from the samples prior to performing the test (the strain relieve can mask the crimped connection performance).

Apply the load to pull the conductor out of the barrel or rupture the conductor. Record the maximum pull applied and the failure mode (pull out, wire break, etc.). For connections that have multiple wires, perform the test on the smallest diameter conductor.

Test Summary

Test Summary	
ASTM Specification	B913-05
Typical Number Tested	34 (30 tested, 4 for reference)
Typical State of Sample	Not Powered
Functional Test	N/A

Test Parameters

Test Parameters	
Parameter	**Value**
Travel Speed – Testing Head	25 mm/min ± 5 mm

Test Acceptance Criteria

- Determine the minimum value observed during the testing of all 30 samples. If the minimum observed value is greater than the corresponding value in 7.10.1, the test is considered to have passed.

Wire Gauge or Size, AWG	Minimum Strength, N	Minimum Strength, lbf
28	18	4
26	22	5
24	31	7
22	44	10
20	71	16
18	89	20
16	133	30

Table 7.10.1 – Required Minimum Pull Strength

7.12. List of Various Additional Tests of Interest

Test	Reference	Notes
Cyclic Bending	ISO 14572	
Wire Abrasion Testing	ISO 14572	

7.13. Recommended Test Sequences

Final sequence and test sample quantity to be determined by the product group.