Reliability Testing and Validation Specification

Proprietary and Confidential

Validation Test Plan for High Voltage Battery Coolant Hoses

TESLA MOTORS CONTACT

Alexander Yee, Richard Baker

Document History

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1.0		Initial Release	Richard Baker Alexander Yee

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1 Scope

This document defines the reliability validation test requirements of coolant hoses used in the High Voltage Battery Coolant Loop. Reliability Engineers shall use this document to identify the test requirements necessary to validate the reliability of the DUT. Where applicable, validation testing shall be performed at the assembly level in order to test the interactive effects between connectors in which they are mounted.

This document defines test plans specific to the success-run approach, where all units must pass the test in order to validate the reliability requirement. This document can be seen as a repository, from which tests may be selected for a specific component or system. Sample sizes and test durations may be adjusted with the approval of the Reliability Engineer. DUTs that have passed similar reliability validation test plans or have in-field reliability performance data may be exempted from this requirement with the approval of the Reliability Engineer.

Acceptance of the test reports does not automatically result in a release.

This document does not describe the methods required to produce a reliable component design. Development tests such as Finite Element Analysis, etc., and development activities such as DFMEA and Fault Tree Analysis shall be performed in house or by the supplier early in the design process so that reliability risks can be addressed in advance of validation testing.

Note: The tests described in the document do not replace component qualification tests or the qualification of the manufacturing process.

2 Test Requirements

The test engineering team is responsible for providing all of the testing resources, including test equipment, measurement gauges, hardware, software, and the required technical and management personnel to complete the testing and analysis within the agreed upon timeframe. Upon request, the test team shall provide proof of calibration certification of all test equipment and measurement gauges.

The Laboratory needs to be certified by the DIN EN ISO/ IEC 17025 and or by QS 9000 Tesla Motors reserves the right to visit the test facilities and check the test procedures.

2.1 Documentation

Documentation of all tests is an important part of the validation. By documenting the test results and test conditions, all test data and assumptions for the testing are acknowledged in detail and can be understood by other engineers.

2.1.1 Documentation of Changes

Any changes made by the supplier have to be documented and reported to the Design Release and Reliability Engineers. Changes are, for example, changes in the design, function, production process, location of the production, testing procedure, or test cycle.

2.1.2 Documentation of Testing

The supplier shall provide a written report on the completed qualification test including the following items:

- The testing procedures and equipment
    - test date and duration
    - type of test
    - purpose of test
    - test standard edition
    - test parameters like chamber conditions and operation mode
    - test methods
    - test environment
    - calibration data and uncertainties of measuring system
    - test sequence
- Detailed test results

- parametric measurements
- photographs of the DUT and test equipment
- pass and fail criteria of the DUT
- performance of test specimens
- summary of the test and test results
- results of the visual inspection

as described in each IEC standard of the test. Results measured as numerical values must not be reduced to pass/fail information, but should be documented as numerical values and shall be included in the test report. The format of the test documentation shall be agreed upon between the supplier and the Reliability and Design Release Engineers.

2.2 Test Setup

A test fixture shall be required to mechanically simulate the intended system and exercise all functions of the DUT. The test fixture shall simulate the mounting position, including the appropriate hose routing and connectors. Unless otherwise specificed, production-representative connectors shall be used for testing. Test equipment must be able to withstand vibration and shock intensities specified in this document. **If not explicitly specified, the DUT shall be mounted in vehicle orientation during the test**. **If vehicle orientation is not specified, verify with a Reliability or Design Engineer before conducting the test.**

2.2.1 Default Values & Tolerances

In the absence of any value specification and tolerances, the following values shall apply to all validation tests:

Definition	Value
Frequency	f = Spec ±1%
Relative Humidity	rH = 45% - 75 % ±5%
Room Temperature	T_{RT} = 23 ±5 °C
Shock	Spec ±20%
Test Temperature	T_{Test} = T_{max} ±3 °C
Time	t_{Test}+2%, -0%

Definition	Value
Vibration	Spec ±20%

2.2.2 Temperature conditions during the test

At steady state conditions during active operation of the DUT, the temperature shall not change more than ±3 °C at the component location at any time. **The temperature shall be tracked through active operation for the duration of the test**. The time constant for the steady state conditions must be evaluated before starting the active testing. The documentation of any temperature changes larger than ±3 °C is required and must be reported to the Reliability Engineer.

2.2.3 Coolant Composition

For tests specifiying the use of coolant, a mixture of 50% ethylene glycol and 50% water should be used.

2.3 Reporting Test Status

A weekly report of the test status has to be sent to the Reliability Engineer, including

- Test profiles (temperature, resistance measurements, current profiles, …) as defined in each test
- Status of functional checks
- Pass/ Fail
- Percent complete

2.4 Pass Criteria

In order to validate the reliability of the DUT, the supplier must demonstrate 100% success for all tests specified in the Validation Test Plan. A test is successful if the test is completed and the DUT passes all functional requirements, passes the visual inspection, and meets all specifications in the DUT's specification document following the final test in the test leg.

The results of the functional tests and visual inspections must be reported to the Reliability and Design Release Engineers.

To better understand how the functional test and the visual inspection have to be done, please review the following descriptions. Functional and visual inspections may be modified by the Reliability and Design Release Engineers to properly assess the functionality of a specific component.

2.4.1 Visual Inspection of the DUT

Purpose:
Visually identify and document any defects or failures of the DUT caused by testing.

Procedure:

To inspect the DUT visually, the enclosure of the DUT has to be disassembled. The visual inspection of the DUT involves the analysis of all possible failure modes and mechanisms the test was designed for.

1. **Documentation**

Following the completion of each test, each DUT shall be digitally photographed in its final state. Following the completion of all tests in a test leg, the DUT shall be torn down and photographed to show:

- Exterior surfaces of the coolant hose
- Coolant hose-to-connector fittings
- Evidence of cracks, discoloration, hose degradation, or leaking

2. Inspection of the DUT

The DUT has to be inspected externally by a microscope after the test. During the inspection, the focus should be on the following anomalies:

- cracks in the hose
- sealing failures (leaking seal)
- change in the color and look of the DUT
- change in hardness, elasticity, or other mechanical properties

A summary of the inspection results must be documented and reported to Tesla Motors. **Any failure in the test and any anomalies must be photographed and documented in the final report.** If additional failure analysis (X-ray, cross sectioning, SEM, etc.) is required, the further failure analysis must be coordinated by the supplier and the Reliability and Design Release Engineers.

All possible failure modes that are known for the product should be taken into account during the inspection, including any not listed above.

2.4.2 Room Temperature Burst Resistance

Purpose:
Validate the coolant hose ability to maintain a burst resistance greater than 150 psi throughout its operational lifetime.

Procedure:

Fill the DUT with room temperature water and apply pressure to 100 psi using a pressure ramp rate of 1000 psi/min. Hold 100 psi pressure for 1 min and then apply pressure at 1000 psi/min until failure.

2.4.3 Elevated Temperature Burst Resistance

Purpose:
Validate the coolant hose ability to maintain a burst resistance greater than 150 psi throughout its operational lifetime when subjected to the highest expected operational temperature.

Procedure:

Fill the DUT with water or coolant at 70°C and soak for 1 hour. After 1 hour, apply pressure to 100 psi using a pressure ramp rate of 1000 psi/min. Hold 100 psi pressure for 1 min and then apply pressure at 1000 psi/min until failure.

2.4.4 Failures During the Validation

If a DUT fails during any of these tests, the supplier shall conduct a root cause analysis to determine the cause(s) of failure(s). **Notify Tesla of any test incidents (anomalies, defects, failures, etc.) within 48 business hours of findings (root cause analysis not required at time of notification).**

Following the analysis, an 8-D written report must be provided to the Design Release Engineer and Reliability Engineer containing the following sections:

1. Team members
2. Problem description
3. Interim (short term) containment/actions
4. Root cause analysis/identification
5. Permanent corrective action
6. Verification (to determine effectiveness of permanent actions)
7. Prevention of problem recurrence and
8. Review

The effectiveness of the corrective actions must be shown by repeating the entire test sequence with new samples, and not by continuing the sequence from the test in which the DUT failed. A truncated test may only be performed with the approval of the Design Release Engineer and Reliability Engineer.

2.4.5 Incomplete Testing

If for any reason the test cannot be completed before start of production, or if failures have been detected shortly before the start of production, a risk assessment must be made. The goal of the risk assessment is to identify the cumulative failure rate at end-of-life. The risk assessment must be structured as follows and must contain the itemized topics:

I. Introduction
   1. Overview (project, part number, serial number, testing time, and period)
   2. Sample description
   3. Lifetime requirements
   4. Test plan (critical test leg or finished and unfinished test leg)
   5. Normative references and standards
II. Issues
   1. List of critical components and failure mechanisms in the critical/ unfinished test leg
   2. Mission profile
      i. Lifetime requirements
      ii. Operation modes
      iii. Usage
      iv. Critical load types for the failed/ incomplete test leg(s)
      v. Critical components
      vi. Mission profile
      vii. Acceleration factor and durability testing
      viii. Success run and reliability testing
   3. Comparison of the required and achieved testing time
III. Risk assessment
   1. References to previous projects with the same testing and components (for calculation of the reliability)
   2. Calculation of the reliability/failure rate based on end of life tests and previous testing
   3. Forecast for the field reliability
IV. Conclusion
   1. Effects of the system defects (likelihood, impact, risk score)
   2. Release for xxx years and reason for the release
V. Follow-up
   1. Further testing
   2. Design changes
   3. Service topics

The results of the risk assessment must be discussed with Tesla Motors.

3 Validation

3.1 Test Plan

The supplier shall follow the validation test process below, starting at the top of each test leg and working through each subsequent test. The supplier is responsible for obtaining any additional test procedures referenced in the Validation Testing section. Tests may be omitted if they do not apply based upon the physical location or functional requirement of the DUT in the vehicle. A test may be omitted only with the approval of the Design Release Engineer and Reliability Engineer. In order to validate performance and continue with subsequent tests, a functional test and visual inspection must be completed after every test in the sequence, and a full tear down inspection must be performed after the whole test leg. Any deviation from the test setups described in this document must be approved by the Design Release Engineer and Reliability Engineer. Validation of the DUT is complete when 100% success (in functional test and visual inspection) is achieved for all tests.

~~The test plan summary~~ is shown in Figure 1 below and will be provided in a different document and contains an overview of all tests and test sequences. The longest test duration for a given leg is approximately 9 weeks.

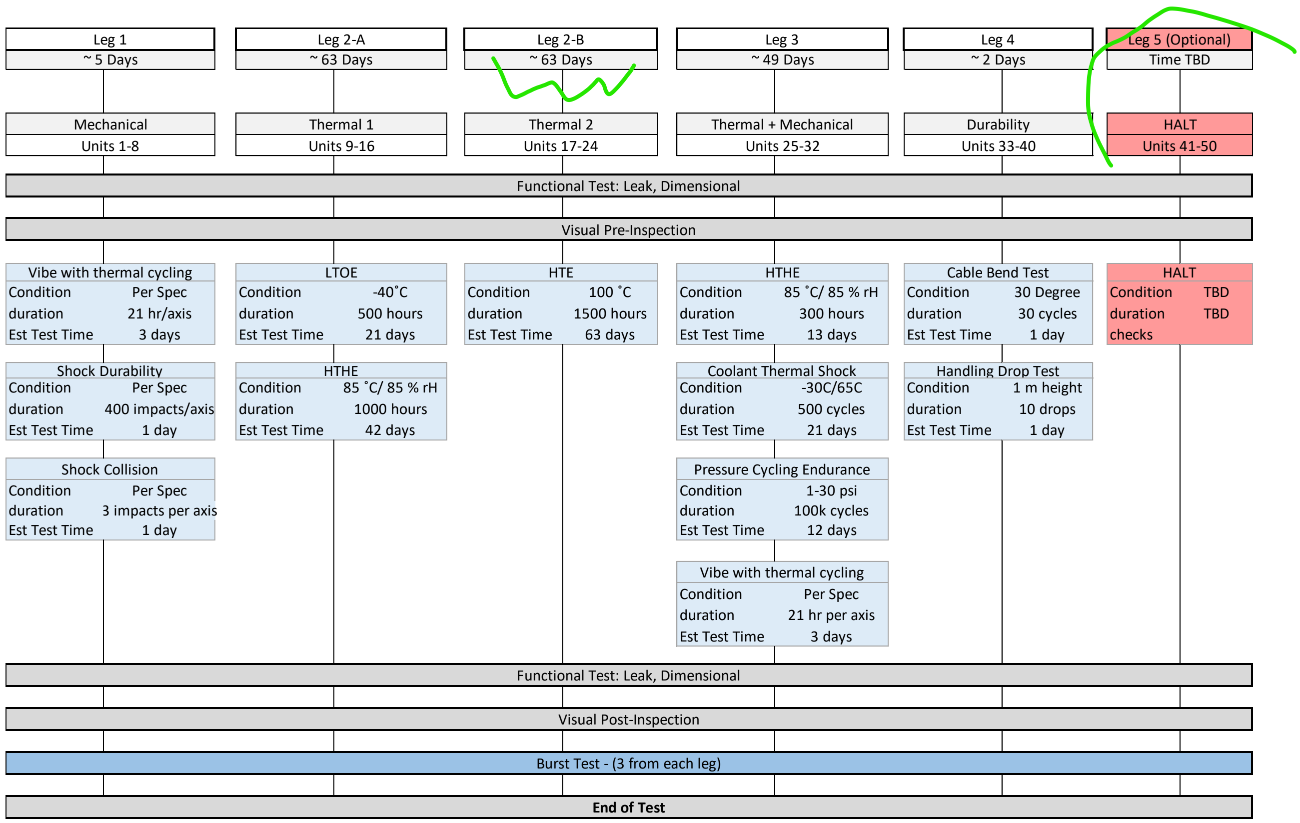

Figure 1. Validation test plan summary indicating test sequence and approximate test time.

3.2 Leg 1 - Mechanical Durability

3.2.1 Vibration with Thermal Cycle

3.2.1.1 Purpose

Validate the component's ability to operate within its functional specification when subjected to a simulated operational life.

3.2.1.2 Test Procedure

Test	Description
Sample Size	8
Operation Mode	With coolant undergoing thermal cycling
Tmin	-20°C
Tmax	55°C
Ramp Rate	5°C/min
Isothermal Hold at Tmin and Tmax	1 hour
Vibrational Load	Profile defined in 3.2.1.3
Vibration Excitation	Wide-band random vibration
Duration	21 hours per axis
Monitoring	• Visual Inspection before and after the test • Dimensional inspection before and after test

Test Procedure:

1. Start the vibrational profile specified in Section 3.2.1.3 .
2. Cycle the coolant temperature between Tmin and Tmax at a ramp rate of 5°C/min, with isothermal holds at Tmin and Tmax of 1 hour.
3. Run the vibrational profile while temperature cycling for 21 hours per axis.
4. Repeat the test for each of the three axes.

3.2.1.3 Vibrational Load Profile

X-Axis		Y-Axis		Z-Axis	
RMS = 0.37		RMS = 0.53		RMS = 0.62	
f [Hz]	PSD [g^2/Hz]	f [Hz]	PSD [g^2/Hz]	f [Hz]	PSD [g^2/Hz]
5	0.00150	5	0.01100	5	0.02200
15	0.00700	15	0.01100	13	0.02200
20	0.00700	20	0.00300	20	0.00300
33	0.00080	50	0.00300	50	0.00300
88	0.00020				
200	0.00002	200	0.00002	200	0.00002

3.2.1.4 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.2.2 Shock Durability

3.2.2.1 Purpose

Validate the component's ability to operate within its functional specification when subjected to mechanical shock events produced by potholes or other small road events.

3.2.2.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Containing coolant

Environmental Conditions	Ambient temperature/humidity
Shock Load	Profile defined in 3.2.2.3
Nominal Shock Shape	Half sine
Number of impacts per orientation	400 (200 in positive and 200 in negative direction)
Monitoring	• Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	
1. Fill the DUT assembly with coolant 2. Perform 400 impacts per axis according to the profiles outlined in Section 3.2.2.3	

3.2.2.3 Shock Durability Load Profile

Axis	Load (G)	Duration (ms)
X	4.4	10
Y	14	9
Z	7.3	11

3.2.2.4 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.2.3 Shock Collision

3.2.3.1 Purpose

Validate the component's ability to operate within its functional specification when subjected to mechanical shock events produced by minor collisions.

3.2.3.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Containing coolant
Environmental Conditions	Ambient temperature/humidity
Shock Load	Profile defined in 3.2.3.3
Nominal Shock Shape	Half sine
Number of impacts per orientation	3
Monitoring	• Visual Inspection before and after the test • Dimensional inspection before and after test

Test Procedure:

1. Fill the DUT assembly with coolant
2. Perform 3 impacts per axis according to the profiles outlined in Section 3.2.3.3

3.2.3.3 Shock Collision Load Profile

Axis	Load (G)	Duration (ms)
X	28	60
Y	35	30
Z	12	10

3.2.3.4 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.2.4 Burst Test

Following testing of all components through the mechanical durability leg, three samples must be subjected to a functional burst test as outlined in section 2.4.2 to evaluate performance degradation of the hose.

3.3 Leg 2 – Environmental Durability

3.3.1 Low Temperature Endurance (LTE)

3.3.1.1 Purpose

Validate the ability of the DUT to withstand low operating temperatures in the field.

3.3.1.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Containing Coolant
Temperature	-40°C
Duration	500 hours
Monitoring	• Leak Check every 150 hours • Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	

1. Fill the DUT assembly with coolant
2. Place the DUT assembly in a chamber at -40°C for 500 hours

3.3.1.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.3.2 High Temperature Endurance (HTE)

3.3.2.1 Purpose

Validate the ability of the DUT to withstand extended time at elevated operating temperatures in the field.

3.3.2.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Containing Coolant
Temperature	100°C
Duration	1500 hours
Monitoring	• Leak Check every 150 hours • Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	

1. Fill the DUT assembly with coolant
2. Place the DUT assembly in a chamber at 100°C for 1500 hours

3.3.2.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.3.3 High Temperature and Humidity Endurance (HTHE)

3.3.3.1 Purpose

Validate the ability of the DUT to operate within its functional specification when subjected to extended time at high temperature and high humidity.

3.3.3.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Containing Coolant
Temperature	85°C
Relative Humidity	85%
Duration	1000 hours
Monitoring	• Leak check every 150 hours • Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	
1. Fill the DUT assembly with coolant 2. Place the DUT assembly in a chamber at 85°C and 85% RH for 1000 hours	

3.3.3.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.3.4 Burst Test

Following testing of all components through the environmental durability leg, three samples must be subjected to a functional burst test as outlined in section 2.4.2 to evaluate performance degradation of the hose.

3.4 Leg 3 – Thermal + Mechanical Durability

3.4.1 High Temperature and Humidity Endurance (HTHE)

HTHE testing should first be performed on 8 DUT assemblies as outlined in Section 3.3.3. Testing should be conducted for 300 hours for leg 3, not the 1000 hours outlined in leg 2.

3.4.2 Coolant Thermal Shock (CTS)

3.4.2.1 Purpose

Validate the ability of the DUT to withstand thermal cycling stress due to the heating and cooling of the coolant within the coolant system.

3.4.2.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	Flowing Coolant
Tmin	-30°C
Tmax	65°C

Ramp Rate	Instantaneous
Isothermal Hold at Tmin and Tmax	30 minutes
Pressure	20-30 psi
Duration	500 cycles
Monitoring	• Leak check ever 100 cycles • Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	
1. Place DUT into the coolant loop of the tester 2. Flow coolant at -30°C for 30 minutes, at a pressure of 20-30 psi. 3. Switch coolant flow to a coolant at 65°C for 30 minutes, maintaining a pressure of 20-30 psi. 4. Repeat the test for 500 cycles.	

3.4.2.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.4.3 Pressure Cycling Endurance

3.4.3.1 Purpose

Validate the ability of the DUT to withstand pressure cycles experienced within the battery cooling system during normal operation

3.4.3.2 Test Procedure

Test	Description

Sample Size	8
Operation mode of DUT	Flowing Coolant
Tmin	-30°C
Tmax	65°C
Ramp Rate	4°C/min
Isothermal Hold at Tmin and Tmax	1 hour
Min Pressure, Pmin	1 psi
Max Pressure, Pmax	30 psi
Pressure Ramp Rate	Instantaneous
Soak time at Pmin and Pmax	5 seconds
Duration	100k cycles
Monitoring	• Continuous leak check monitoring • Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	

1. Place DUT into the coolant loop of the tester
2. Decrease the coolant temperature to -30°C at 4°C/min
3. Begin intaneously cycling pressure of the system between 1 and 30 psi, soaking at 5 seconds for each pressure
4. While pressure cycling, cycle the coolant temperature between -30°C and 65°C at 4°C/min, holding isothermal at Tmin and Tmax for 1 hour
5. Continue pressure and coolant temerpature cycling until 100k pressure cycles have been achieved.

3.4.3.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Damage on the hoses or connectors
- Coolant Leaking

3.4.4 Vibration with Thermal Cycling

Following the completion of Pressure Cycling Endurance testing, the 8 DUTs should be subjected to vibration testing as outlined in Section 3.2.1.

3.4.5 Burst Test

Following testing of all components through the thermal + mechanical durability leg, three samples must be subjected to a functional burst test as outlined in section 2.4.2 to evaluate performance degradation of the hose.

3.5 Leg 4 – Handling and Abuse

3.5.1 Cable Bend Test

3.5.1.1 Purpose

Validate the ability of the DUT to withstand multiple bends that may be experienced during installation on the assembly line.

3.5.1.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	No Coolant
Environmental Condition	Ambient
Angle of Bend	30 Degrees

Duration	30 reverse bends
Monitoring	• Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	
1. Rigidly fix the coolant hose at one end 2. Apply a load to bend the hose 30 degrees 3. Reverse the load to bend the hose 30 degrees in the opposite 4. Repeat for 30 cycles	

3.5.1.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Cracking of the hose body
- Discoloration near the fixed portion of the hose

3.5.2 Handling Drop Test

3.5.2.1 Purpose

Validate the ability of the DUT to withstand drops that may occur during assembly.

3.5.2.2 Test Procedure

Test	Description
Sample Size	8
Operation mode of DUT	No Coolant
Environmental Condition	Ambient
Height of Drop	1 meter
Duration	10 drops

Monitoring	• Visual Inspection before and after the test • Dimensional inspection before and after test
Test Procedure:	
1. Drop the DUT from a height of 1 meter onto a concrete surface 2. Repeat 10 times	

3.5.2.3 Pass Criteria

The test has to be passed before further testing of the DUT is performed. All DUTs must be completely functional before and after this test as defined in the component specification document.

During the visual inspection, ensure that none of the following failure modes are visible:

- Cracking of the hose body or connectors

3.5.3 Burst Test

Following testing of all components through the handling and abuse leg, three samples must be subjected to a functional burst test as outlined in section 2.4.2 to evaluate performance degradation of the hose.

4 References and Glossary

4.1 Normative References

No	Standard	Description
1	**DIN 40050**	Road vehicles; degrees of protection (IP-code); protection against foreign objects; water and contact; electrical equipment
2	**DIN 50018**	Testing in a saturated atmosphere in the presence of sulfur dioxide
3	**DIN EN 60512 (3,6,9,10,12)**	Electromechanical components for electronic equipment; basic testing procedures and measuring methods
4	**DIN EN ISO 6270-2: 2005-09**	Paints and varnishes; Determination of resistance to humidity; Part 2: Procedure for exposing test specimens in condensation-water atmospheres
5	**DIN EN ISO 9227**	Corrosion tests in artificial atmospheres; Salt spray tests

No	Standard	Description
6	**GMW14872**	General Motors Cyclic Corrosion Laboratory Test Procedure
7	**GMW3172**	General Motors Electrical/Electronic Component Reliability Validation Standard
8	**GMW8287**	General Motors HALT process
9	**IEC 60068-1**	Environmental testing - General and Guidance
10	**IEC 60068-2-1**	Cold
11	**IEC 60068-2-10**	Mold growth
12	**IEC 60068-2-11**	Salt mist
13	**IEC 60068-2-13**	Low air pressure
14	**IEC 60068-2-14**	Change of temperature
15	**IEC 60068-2-2**	Dry heat
16	**IEC 60068-2-27**	Shock
17	**IEC 60068-2-30**	Damp heat, cyclic
18	**IEC 60068-2-31**	Rough handling shock, primarily for equipment-type specimens
19	**IEC 60068-2-38**	Composite temperature/humidity cyclic test
20	**IEC 60068-2-39**	Combined sequential cold, low air pressure, and damp heat test
21	**IEC 60068-2-40**	Combined cold/low air pressure tests
22	**IEC 60068-2-41**	Combined dry heat/low air pressure tests
23	**IEC 60068-2-42**	Sulphur dioxide test for contacts and connections
24	**IEC 60068-2-43**	Hydrogen sulphide test for contacts and connections
25	**IEC 60068-2-45**	Immersion in cleaning solvents
26	**IEC 60068-2-46**	Hydrogen sulphide test for contacts and connections
27	**IEC 60068-2-47**	Mounting of specimens for vibration, impact, and similar dynamic tests
28	**IEC 60068-2-5**	Simulated solar radiation

No	Standard	Description
29	**IEC 60068-2-53**	Combined climatic (temperature/humidity) and dynamic (vibration/shock) tests
30	**IEC 60068-2-57**	Time history and sine beat method
31	**IEC 60068-2-59**	Vibration - Sine-beat method
32	**IEC 60068-2-6**	Sinusoidal vibration test
33	**IEC 60068-2-60**	Flowing mixed gas corrosion test
34	**IEC 60068-2-61**	Climatic sequence
35	**IEC 60068-2-64**	Broadband (random) vibration test
36	**IEC 60068-2-65**	Acoustically induced method
37	**IEC 60068-2-66**	Damp heat, steady state (unsaturated pressurized vapor)
38	**IEC 60068-2-67**	Damp heat, steady state, accelerated test primarily intended for components
39	**IEC 60068-2-68**	Dust and sand
40	**IEC 60068-2-7**	Acceleration, steady state
41	**IEC 60068-2-70**	Abrasion of marking and lettering due to rubbing of fingers/ hands
42	**IEC 60068-2-74**	Fluid contamination
43	**IEC 60068-2-75**	Hammer test
44	**IEC 60068-2-77**	Body strength and impact shock
45	**IEC 60068-2-78**	Damp heat, steady state
46	**IEC 60068-2-80**	Vibration - Mixed mode
47	**IEC 60068-2-81**	Shock response spectrum synthesis
48	**IEC 60068-2-82**	Whisker test methods for electronic and electric components
49	**IEC 60068-3-1**	Cold and dry heat tests
50	**IEC 60529**	Degrees of protection provided by enclosures (IP Code)

No	Standard	Description
51	**IEC 60749 (1,3,4,5,6,10, 12,13,14,25,36,37,40)**	Semiconductor devices - Mechanical and climatic test methods
52	**ISO 12103-1**	Road vehicles - Test dust for filter evaluation; Part 1: Arizona test dust
53	**ISO 16750-1**	Environmental conditions and testing for electrical and electronic equipment - General
54	**ISO 16750-2**	Electrical loads
55	**ISO 16750-3**	Mechanical loads
56	**ISO 16750-4**	Climatic loads
57	**ISO 16750-5**	Chemical loads
58	**ISO/IEC 17025**	General requirements for the competence of testing and calibration laboratories
59	**LV124**	Electric and electronic components in motor vehicles up to 3.5 t General requirements, test conditions, and tests
60	**MBN 10 305-1**	Daimler E/E Environmental Testing; Part 1: Test Specifications
61	**MBN 10 305-1**	Daimler E/E Environmental Testing; Part 2: Test Selection Process
62	**ISO 26262**	Road vehicles - Functional safety

4.2 Acronyms

Acr.	Definition	Acr.	Definition
AOI	Automatic Optical Inspection	**PTCE**	Power Temperature Cycling Endurance
AVL	Approved Vendor List	**PTH**	Plated Through Hole
BGA	Ball Grid Array	**R**	Reliability
CAD	Computer Aided Design	**RA**	Risk Assessment
CM	Coffin-Manson Parameter	**rH**	Relative Humidity
CTE	Coefficient of Thermal Expansion	**RV**	Robustness Validation
DfM	Design for Manufacturing	**SAC**	SnAgCu Lead Free Solder
DFMEA	Design Failure Mode Effects & Analysis	**SILC**	Stress Induced Leakage Current
DfR	Design for Reliability	**SMD**	Surface Mounted Device
DfT	Design for Test	**SS**	Steady State
DUT	Device Under Test	T_{amb}	Ambient Temperature of the DUT
ECU	Electronic Control Unit	T_{atm}	Temperature of the Atmosphere
EEM	Electric and Electronic Module	T_C	Temperature Cycling
f	Frequency	T_{comp}	Temperature of the Component (resistor, capacitor, etc.)
FCT	Functional Test	t_f	Fall time
FEM	Finite Element Method	T_{in}	Internal Air Temperature on the Board
HALT	High Accelerated Life Testing	T_{max}	Maximum Ambient Temperature
HASS	High Accelerated Stress Screening	T_{min}	Minimum Ambient Temperature
HAST	Highly Accelerated Stress Test	T_{Omin}	Minimum Operating Temperature
HTHE	High Temperature Humidity Endurance	T_{Omax}	Maximum Operating Temperature

Acr.	Definition	Acr.	Definition
HTOE	High Temperature Operating Endurance	t_R	Rise Time
HTOL	High Temperature Operating Life Test	T_{RT}	Room Temperature ((23 ± 5) °C.
HTS	High Temperature Storage	**TS**	Thermal Shock
ICT	In Circuit Test	T_{Test}	Test Temperature
I_N	Nominal current	t_{Test}	Testing time
LTOE	Low Temperature Operating Endurance	**TTF**	Test To Failure
MP	Mission Profile	**UHAST**	Unbiased HAST
MTBF	Mean-Time-Between-Failure	U_{max}	Maximum Voltage
MTTF	Mean-Time-To-Failure	U_{min}	Minimum Voltage
OEM	Original Equipment Manufacturer	U_N	Nominal Voltage
OM	Operation Mode	U_O	Operating Voltage
PA	Confidence	U_{Omax}	Maximum Operating Voltage Limit
PC	Power cycling	U_{Omin}	Minimum Operating Voltage Limit
PCB	Printed Circuit Board	U_{PP}	Peak-to-Peak Voltage
PoF	Physics of Failure	U_{Test}	Test Voltage
PSD	Power Spectral Density[1]	U_{const}	Constant Voltage Stress
PTC	Power Temperature Cycling	U_{th}	Threshold Voltage

[1]PSD describes the power of random vibration intensity in g2/Hz or [(m/s2)2/Hz] where, 1 g equals 9.80665 m/s^2. Over a frequency bandwidth, random vibration is expressed in units of root mean squared acceleration, GRMS.