GM WORLDWIDE ENGINEERING STANDARDS	Test Procedure	For Approval GMW18165

Plastic Plumbing for Water/Coolant Application - Low Temperature Coolant Circuits Assemblies Validation

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This specification defines the Design Validation (DV) and Product Validation requirements for Plastic Coolant Plumbing Assemblies on Low Temperature Coolant Circuits external to Rechargable Energy Storage System (RESS)

1.2 Applicability. This test is applicable to all thermoplastic glycol/water cooling lines for low temperature circuits such as external battery cooling lines, drive unit cooling lines, etc.

1.3 Remarks. The thermoplastic low-temperature lines shall pass GMW18152 to support the diverse packaging and processing requirements.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ISO17025

2.2 GM Standards/Specifications.

GMW3059	GMW15760	GMW18152	GMW18130
GMW15758	GMW15920	GMW3420	GMW3116
GMW14573	GMW14797	GMW15468	GMW14638
GMW15760	GMW3221	GMW16295	GMW15272
GMW14872			

2.3 Additional References.

- 9986100 dexcool® Premix
- GM1829 Analysis/Development/Validation Plan and Report (ADVP&R)
- Subsystem Technical Specification (SSTS)
- Vehicle Technical Specification (VTS)
- Verband der Automobileindustrie (VDA) (German Association of the Automotive Industry) information can be found at www.vda.de/en.html

3 Requirements

3.1 System/Subsystem/Component/Part Definition. Not applicable

3.2 Facilities. As required to perform the test as described on this document.

3.2.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label. Test facilities certification per ISO17025.

3.2.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.3 Requirements on Test Specimens. Reference GMW3221. Unless otherwise specified, the shape and size of test pieces shall be in accordance with the relevant test method. The minimum number of samples (hose assemblies) per test is defined in Table 1. Samples are finished parts or to be taken from finished parts. Where the dimensions on the finished parts do not allow preparing of test pieces, tests are to be performed on material from the same production batch. For testing of a hose construction to the following performance properties of Table 1 of this specification, each type of quick connector, inline, T connector or Y connector used in a design released to this specification must be incorporated into the samples tested.

3.4 Reliability

3.4.1 Reliability Evaluation Point. This specification provides a test exposure representing a Reliability Evaluation Point (REP) required by GM

3.4.2 Reliability Requirements. This specification supports the demonstration of the required reliability of 99% or greater at a 50% confidence (R99C50), at the REP for the coolant pipe joints. The supplier shall utilize "vehicle equivalent" laboratory test setups to simulate "in-vehicle" orientations. If the orientation may be different from one vehicle to another, use the orientation which will provide the worst caseloads for all physical level reliability demonstration testing.

The reliability demonstration is provided by the Design Validation (DV) Endurance Tests specified in Table 2.

Note: Failure is defined as, but not limited to, the loss of function, unacceptable performance degradation and nonconformance of the component as stated in this specification.

3.4.3 Accelerated Test Methods. GM encourages the use of appropriate accelerated test methods, wherever possible; for example, the use of accelerated stress testing to reduce test time.

Note: The required number of test samples may be negotiable if it is not practical to run, for example, 23 samples. Negotiation of sample size shall consider test equipment limitations, physical size of test samples, test duration, etc. However, reduction of the sample size may require inclusion/use of longer test durations or other test methods such as Highly Accelerated Stress Screening (HASS), Highly Accelerated Stress Testing (HAST), Calibrated Accelerated Life Testing (CALT), Highly Accelerated Life Testing (HALT), etc. Weibull slope values available from previous failure testing may be considered as a way to reduce the sample size and/or test duration.

Note: GM Validation Engineering shall review and accept reliability demonstration test plans prior to the supplier submitting the Analysis Development Validation (ADV) Test Plan for approval.

3.5 Serviceability. Not applicable

3.6 Identification and Marking. All assemblies must be labeled with the GM part number, date code and tool/cavity number in a visible location. All labels shall conform to GMW14573.

3.7 Recycling. Materials shall be recyclable per GMW3116. Attempts shall be made to minimize the variety of materials used, to make recycling more viable.

3.8 User System/Subsystem/Component/Part Interface. Not applicable.

3.9 Equipment.

3.9.1 Instrumentation. As required to make sure the test is performed following the parameters as described on this document.

3.9.2 Test Equipment.

3.9.2.1 Fixturing. The fixtures shall not impact the performance of the part on the test.

3.9.2.2 Test Piece. Test material include all Tube and attachments as required to simulate in-vehicle installation.

3.10 Test Vehicle/Test Piece. Test material include all hose assembly and attachments as required to simulate in-vehicle installation.

3.11 Test Time. Time depends on the number of samples tested. The following are estimates.

Calendar time:	30 d
Test time Long Lead Test:	20 d

3.12 Test Required Information. The performance measurements and durability test results shall be summarized and reported to GM on the supplier form GM1829 for the component or components being tested.

Full test reports shall be available for viewing by GM personnel per GMW15920. If there is a breakage, leak or condition out of the acceptance criteria on test, GM must be informed within 24 h.

As a preparation for all testing, supplier shall bend the hose 180° on the convoluted portion and fix it on that position for 1 hour at standard ambient temperature, then take the part back to it is original position to start the test. If the hose assembly has more than one portion of convolutes, the bend should be made only on one portion, select the bend with the biggest angle; figure 1 shows an example.

Figure 1 Bend Hose 180°

3.12.1 Burst Test

3.12.1.1 Procedure.

a. Mount the mating interfaces (e.g., Verband der Automobileindustrie (VDA) spigot, hose barb, etc.) in a test chamber.

b. Install the assembly being tested. All ends of the pipe shall be attached to the test chamber and sealed.

c. As a testing fluid, either coolant or air can be used. The test equipment shall be capable of supplying sufficient pressure until burst.

d. Completely fill the pipe test sample with testing fluid.

e. Maintain test chamber ambient temperature at Max Excursion Temperature ± 2 °C for 4 h. Use 60°C for hose construction type A per GMW18152. For Hose construction Type B and Type C per GMW18152 use VTS Max Excursion Temperature.

f. Increase pressure at a rate of 20 kPa/s ± 5 kPa/s until either burst or leakage occurs. A diagram of pressure vs. time must be recorded on the chart of the software of the equipment.

3.12.1.2 Requirements: The minimum burst pressure shall be at least 2 times ± 5 kPa the maximum continuous system working pressure per SSTS/VTS (SOR Appendix B). Burst pressure and failure mode shall be documented in supplier document (supplier-owned form/format).

3.12.2 Dimensional Analysis.

3.12.2.1 Before the following test, 3.12.3 to 3.12.6, a dimensional analysis is required on each sample being tested as well as the spigots used for the testing.

3.12.2.2 For the case of Pressure Vibration Temperature (PVT) per 3.12.6, additional dimensional analysis is required for the position of the pipe on the chamber.

3.12.2.3 The dimension analysis must be delivered as part of the test report and shall include at least the following characteristics:

3.12.2.3.1 Spigots of the Interfaces in the Chamber. Dimensions shown on the respective drawing. Report required for parts to be used on Design Validation (DV) and Production Validation (PV).

3.12.2.3.2 Intermediate Connections. Dimensions shown on the respective drawing. Dimensions to be taken before the subcomponents are assembled. Report required for DV parts only.

3.12.2.4 Assemblies. Report at least the following dimensions on samples to be tested for DV and PV:

- Hose Inner and Outside Diameter
- Minimum and Maximum diameter on convoluted portions on external surface only (peaks and valleys)
- Routing profile

3.12.3 Vacuum Collapse Test.

3.12.3.1 Procedure. All the hoses shall be exposed to a vacuum pressure of 2kPa (Absolute Pressure) for 30 s.

3.12.3.2 Requirement. The test can be considered as passed under any of the following circumstances:

a. The minimum outside diameter shall decrease by no more than 20% during application of vacuum pressure.
b. There is no indication of delamination between plastic layers.
c. No permanent deformation of the hose ID after application of vacuum pressure.
d. No bulge or crack effects of hose outer surface.
   - After completion of vacuum pressure, conduct leak test per 3.12.4.

3.12.4 Leak Test.

3.12.4.1 Procedure.

a. Mount the complete assembly on a bench using interfaces/spigots made of either aluminum or thermoplastic with a geometry that meets VDA standards. Use aluminum if the interface on the vehicle is metal, use thermoplastic if the interface in the vehicle is plastic.
b. Connect the assembly to a pressure decay system and apply an internal pressure equal to 1.20 times ± 5 kPa maximum continuous system working pressure per SSTS/VTS, hold this pressure for 5 minutes. If no pressure value is specified, consider 200 kPa.
c. Make sure the temperature is stabilized at 23 °C.

3.12.4.2 Requirement. No reduction of internal pressure which could indicate leaks.

3.12.5 Cold Leak Test.

3.12.5.1 Procedure.

a. Place the assembly on a bench using interfaces/spigots made of either aluminum or thermoplastic with a geometry that meets VDA standards. Use aluminum if the interface on the vehicle is metal, use thermoplastic if the interface in the vehicle is plastic.
b. If the assembly includes mid connections or plumbing branches, make sure the branch is included and tested with its corresponding spigot as shown in Figure 2.
c. Follow the procedure as indicated on GMW18152.

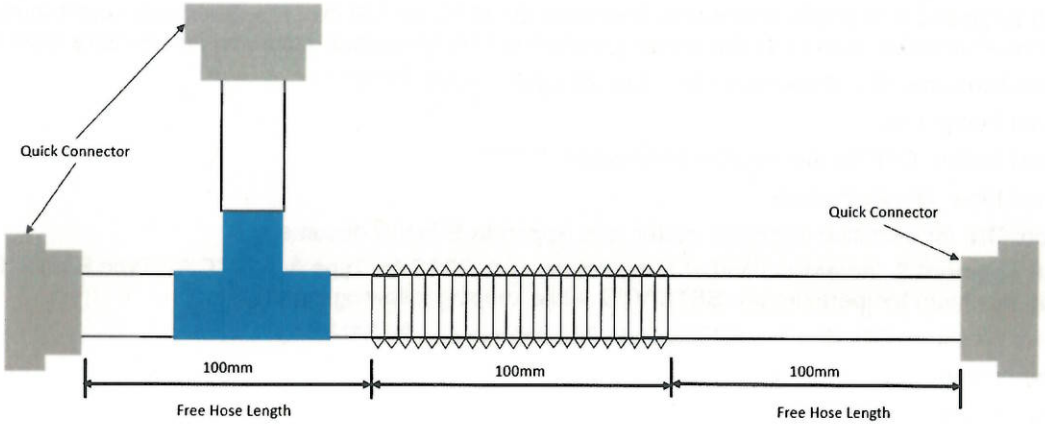

Figure 2: Setup for Cold Leak Test

3.12.5.2 Requirements. No stains that could indicate leaks. Inspection using Ultraviolet (UV) light equipment is recommended.

3.12.6 Pressure Vibration Temperature (PVT).

3.12.6.1 Procedure. This test applies only for the parts subjected to relative movement between the interfacing components.

3.12.6.1.1 Procedure. Prior to testing, visually inspect all hoses for evidence of bloom, cuts/damage or residual oils or other residue from the manufacturing process and capture findings.

- Samples for this test shall be the same samples used for tests on sections 3.12.2 to 3.12.5 (Appendix A, Figure A1,A2,A3,A4 includes a graphical representation of the profile, pressure signal and coolant flow).

3.12.6.1.2 Segment 1. Raise chamber temperature linearly at a range of 1.5 °C/minute up to 90 °C for Type A, 120 °C for Type B and 130°C for Type C or maximum temperature per SSTS/VTS and stabilize for 540 minutes while keeping the following conditions:

- Coolant heater: ON. See Note 1
- System Pressure: ON (Maximum Flow Rate 26 Liter/minute). See Note 2
- Coolant pump: ON
- Motion: ON, for definition of motion vector, see Appendix B in this document.
- Coolant Flow: 26 Liter/minute

3.12.6.1.3 Segment 2. Increase coolant temperature at a rate of ≈1 °C/minute until the fluid reaches the extreme temperature set by SSTS/VTS, or 75 °C for Type A, 125 °C for Type B and 135 °C for Type C. Keep chamber at 90 °C for Type A, 120 °C for Type B and 130°C for Type C or maximum temperature per SSTS/VTS and finish segment under the following conditions:

- System Pressure: ON (Maximum Flow Rate 26 Liter/minute). See Note 2
- Coolant pump: ON
- Motion: ON, for definition of motion vector, see Appendix B in this document.
- Coolant Flow: 26 L/m

3.12.6.1.4 Segment 3. Reduce chamber temperature until it reaches -40 °C keeping the next conditions:

- System Pressure: OFF
- Coolant pump: OFF
- Coolant heater: OFF
- Motion: OFF

3.12.6.1.5 Segment 4. Maintain chamber temperature at -40 °C for 120 minutes. Stabilize coolant temperature at -40 °C for 90 minutes, then raise coolant temperature until fluid reaches excursion temperature in 30 minutes

- System Pressure: ON, (Maximum Flow Rate 26 Liter/minute). See Note 2
- Coolant Pump: ON.
- Coolant heater: OFF 90 minutes/ON 30 minutes See Note 1
- Coolant Flow: 26 Liter/minute
- Motion: ON, for definition of motion vector, see Appendix B in this document.

3.12.6.1.6 Segment 5. Increase chamber temperature up to 90 °C for Type A, 120 °C for Type B and 130°C for Type C or maximum temperature per SSTS/VTS while keeping following conditions:

- System pressure: ON, (Maximum Flow Rate 26 Liter/minute). See Note 2
- Coolant pump: ON
- Coolant heater: ON See Note 1
- Coolant Flow: 26 Liter/minute
- Motion: ON, for definition of motion vector, see Appendix B in this document.

Note 1: Coolant temperature must reach maximum excursion temperature per SSTS/VTS, if no value is specified consider 55 °C for Type A, 110 °C for Type B and 125 °C for Type C.

Note 2: The pressure signal is shown in Appendix A, Figure A4.

Note: One (1) life of customer usage is defined as ten (10) cycles of endurance testing. 1 cycle is from Segment 1 to Segment 5 of the test as shown on Appendix A, Figure A2.

3.12.6.2 Requirements. After the assembly has been subjected to Reliability performance of 99% at 50% Confidence level (R99C50) of test, subject the assemblies to Leak test per 3.12.4, no leaks shall be observed after this test or during the PVT testing.

3.12.7 Serviceability. Special scheduled maintenance or repair procedures are not permitted. All connections shall be reusable and withstand a minimum of five (5) remove and install procedures and pass Air leak Test requirements per 3.12.4 afterwards. However, if the same sample has gone through tests from sections 3.12.3 to 3.12.6 and passed those requirements, no test is required for serviceability.

3.13 Personnel/Skills. Test technician shall be qualified on the basis of appropriate education, training, experience, and/or demonstrated skills.

4 Procedure

4.1 Preparation. Not applicable.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.3 Test Setup and equipment shall be capable of maintaining test parameters (example. Load, angles, temperature, etc.) Within the limits outlined by the design specification.

4.2.4 Sample Size. Validation test samples per Table 1 or per GM Validation Engineer request.

4.2.5 Performance Objective. Provided by test plan. Consult GM DRE or GM Validation Engineer.

4.2.6 Acceptable Leak Rate. No leak permissible.

4.2.7. Sample selection. Per GMW15760.

4.3 Instructions. The tests in this GM Engineering Standard are development tests, production tests and in-process tests. Development tests shall be performed and passed in order to obtain the approval from the responsible GM Release Engineer prior to start of production. Production tests shall be performed and passed with each manufactured part.

4.3.1 Design Validation (DV). Assemblies shall be tested with the procedures described in Table 1.

Table 1. Test Table

Paragraph	Test	Minimum Number of Samples
3.12.1	Burst Test	12
3.12.2	Dimensional Analysis	12
3.12.3	Vacuum Collapse Test	All samples from 3.12.2
3.12.4	Leak Test	All samples from 3.12.3
3.12.5	Cold Leak Test	All samples from 3.12.4
3.12.6	Pressure Vibration Temperature (PVT)	Per Table 2
3.12.7	Serviceability	3.12.3, 3.12.5, 3.12.8

4.3.1.1 Test Samples. Per GMW15760.

4.3.1.2 Test to Failure (TTF). If the decision is made to define tests that are run to failure, the number of samples shall be defined as required to achieve R99C50 and use Weibull analysis to determine slope. This shall be decided in agreement with GM DRE and GM Validation Engineer by exposing the samples to procedure 3.5.8.

Note:

- If any failure occurs in the first life of customer usage, stop the entire test. Do a Design Review Based upon Test Results (DRBTR). Perform root cause analysis. If and as determined, redesign the part/product and start testing all over again.
- First life/customer usage shall be normal stress, 2nd and 3rd life can be accelerated and/or Step Stress.
- Upon failure, plot Weibull slope and calculate reliability demonstrated.
- If no failures by the end of the 3rd life, remove ½ of the samples from test stand and do the functional tests followed by a DRBTR.
- Continue test to failure with the other remaining samples using steps of stress method to induce failure and do the functional tests followed by a DRBTR to analyze failed samples.

4.3.1.3 Success Testing. If the decision is made to define tests that are run for a finite number of cycles by exposing the samples to procedure 3.5.8, the number of samples shall be defined as required to achieve R99C50 with a minimum of eight (8) samples and maximum of sixteen (16), using a Weibull slope of two (2), see Table 2.

Table 2. Example of Number of Samples Required for Endurance Testing Tests (Based on Weibull Slope of Two)

Reliability Requirement	Success Test (per 4.3.1.4)	Minimum sample size required	
		Test to Failure (TTF)	Success Testing
		Sample size	Sample size
R99C50	2.1 Customer Usage lives		16 samples (no failures)
R99C50	2.4 Customer Usage lives		12 samples (no failures)
R99C50	2.9 Customer Usage lives		8 samples (no failures)

4.3.1.4 Design Level Requirements. All assemblies manufactured for Engineering Source Approval per this specification shall be completely representative of production level materials, components, processes and tooling. The exceptions are those assemblies needing to be specially manufactured under extremes of dimensions and/or tolerances to meet the test requirements of the specification. Any exceptions to this requirement shall be reviewed beforehand and approved by the GM DRE and GM Validation Engineer.

4.3.1.5 Design Validation (DV) Approval Requirements.

4.3.1.5.1 Approval Requirements. Approval shall be provided by the GM DRE and the GM Validation Engineer.

4.3.1.5.2 Documentation All test samples shall be qualified dimensionally. All data points shall be reported. For samples destructively tested, failure mode shall be reported. All test specimens shall be retained by the supplier for 1 year and be available for review by the GM DRE and GM Validation Engineer, if requested. Test Procedures referencing specific minimum test values, shall be met by the -3 sigma limit of the sample population tested.

4.3.2 Product Validation (PV).

4.3.2.1 Plastic Tube Required Tests. Plastic Tubes shall be tested for conformance as described in Table 1.

4.3.2.2 Test Samples. Production test samples shall be produced on production representative equipment including the effects of manufacturing-induced variation. Sample selection of components to be utilized for PV Reliability requirements demonstration purposes shall be in concurrence with the guidelines set forth in GMW15760.

4.3.2.3 Test Requirements. PV tests are intended to verify that production parts meet the same requirements as the previously tested DV samples. PV testing shall be performed with the same rigor as DV, especially with respect to Endurance Tests.

4.3.2.4 Product Validation (PV) Approval. PV approval shall be provided by either the appropriate GM Supplier Quality Engineer or GM Validation Engineer.

4.3.2.5 Documentation. Documentation shall be per normal Production Part Approval Process (PPAP).

4.3.3 In-Process Verification (IPV) (GMW15758). These tests shall be successfully completed with parts from normal production runs.

Note: As an option, the leak test can be performed at room temperature. In that case a correlation between a leak test per 3.12.4 and a leaktest at room temperature shall be defined, during development, to adjust leak test requirements for IPV. This shall be approved by GM Validation Engineer and GM Supplier Quality Engineer.

4.3.3.1 Test Samples. One (1) test sample shall be selected from a normal production run, at each shift or tool change or when the process will be interrupted, for example due to maintenance. The first production Sample shall be selected. The tests in Table 1 shall be performed on these samples.

4.3.3.2 Approval. IPV tests are self-approved by the supplier and are subject to audit by GM Supplier Quality Engineering.

4.3.3.3 Lot Retention. In case of IPV test nonconformance, the affected production lot shall be retained by the supplier until root cause analysis is complete. The supplier shall then scrap the suspect lot and contact the GM Supplier Quality Engineer to document root cause and countermeasures applied to the process.

4.3.3.4 Documentation. Records shall be maintained for 1 year from date of test.

4.3.3.5 Alternative IPV Compliance. The supplier may request an exemption from IPV testing provided that it can be demonstrated that sufficient process controls are in place so as to make IPV testing unnecessary. Approval shall be provided by GM Supplier Quality Engineering and the GM Release Engineer.

4.4 Validation Cross Reference Index (VCRI). Approval for final VCRI or GM1829 shall be provided by GM System Validation Engineer (SVE).

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results. Not applicable.

5.3 Test Documentation. Test results will be presented in Supplier-defined form/format rather than a specific template.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

R99C50: Reliability performance of 99% at 50% Confidence level.

7.2 Acronyms, Abbreviations, and Symbols.

1D	One Dimension(al)
ADVP&R	Analysis/Development/Validation Plan and Report
CAE	Computer Aided Engineering
DE	Design Engineer
DRBTR	Design Review Based upon Test Result
DRE	Design Responsible Engineer
DV	Design Validation
IPV	In-Process Verification
OD	Outside Diameter
PPAP	Production Part Approval Process
PV	Production Validation
PVT	Pressure Vibration Temperature
R	Radius
SVE	System Validation Engineer
TTF	Test to Failure
UV	Ultraviolet
VCRI	Validation Cross Reference Index
VDA	Verband der Automobileindustrie

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:
Test to GMW18165

9 Release and Revisions

This standard was originated in May 2019. It was first approved by HVAC – Chassis Propulsion Integration and Thermal Systems in Month 2019. It was first published in Month 2019.

Issue	Publication Date	Description (Organization)
1	MMM 2019	Initial publication.

Appendix A

Figure A1: Endurance Testing Profile for Hose Construction Type A (GMW18152)

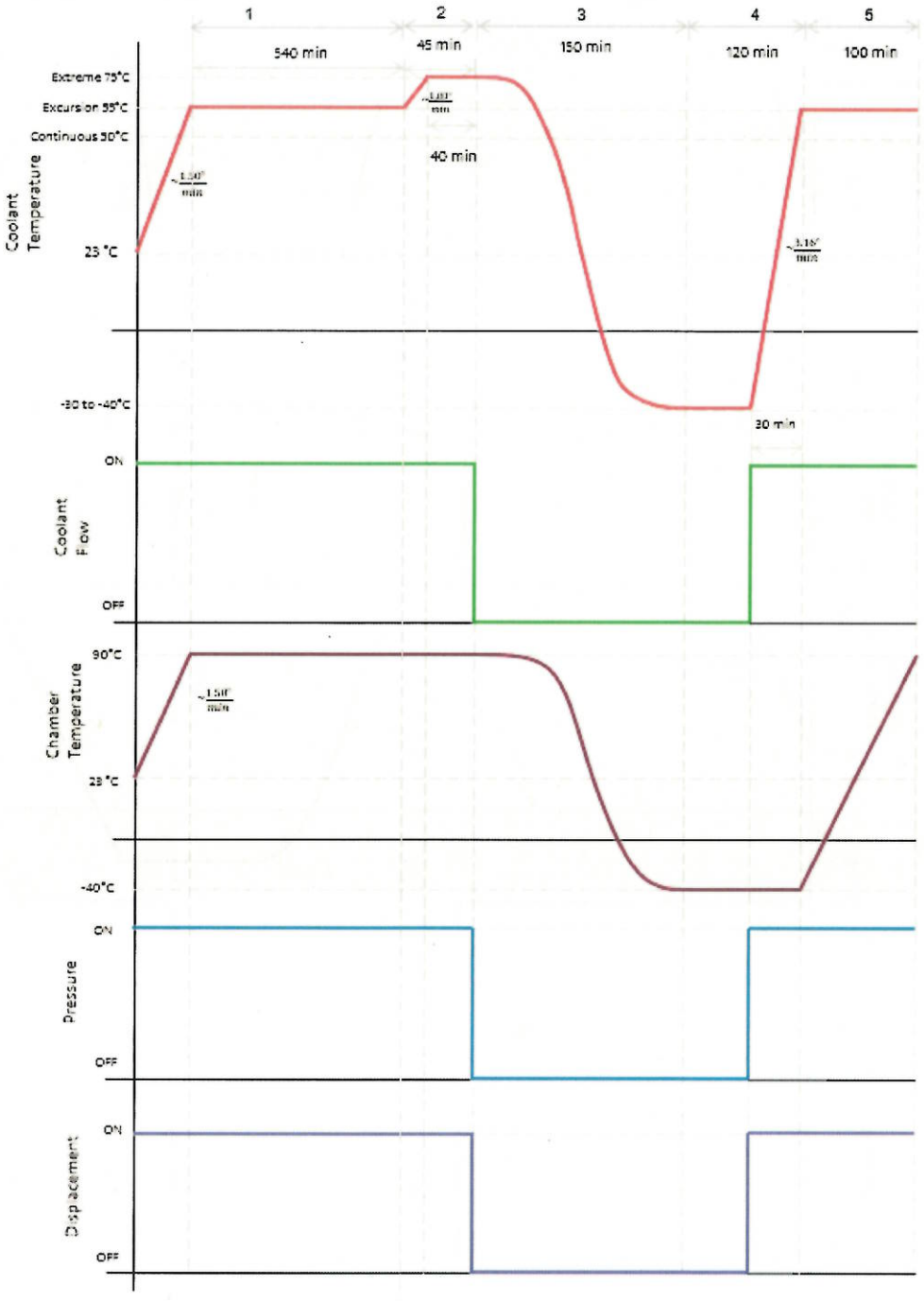

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Figure A2: Endurance Testing Profile for Hose Construction Type B (GMW18152)

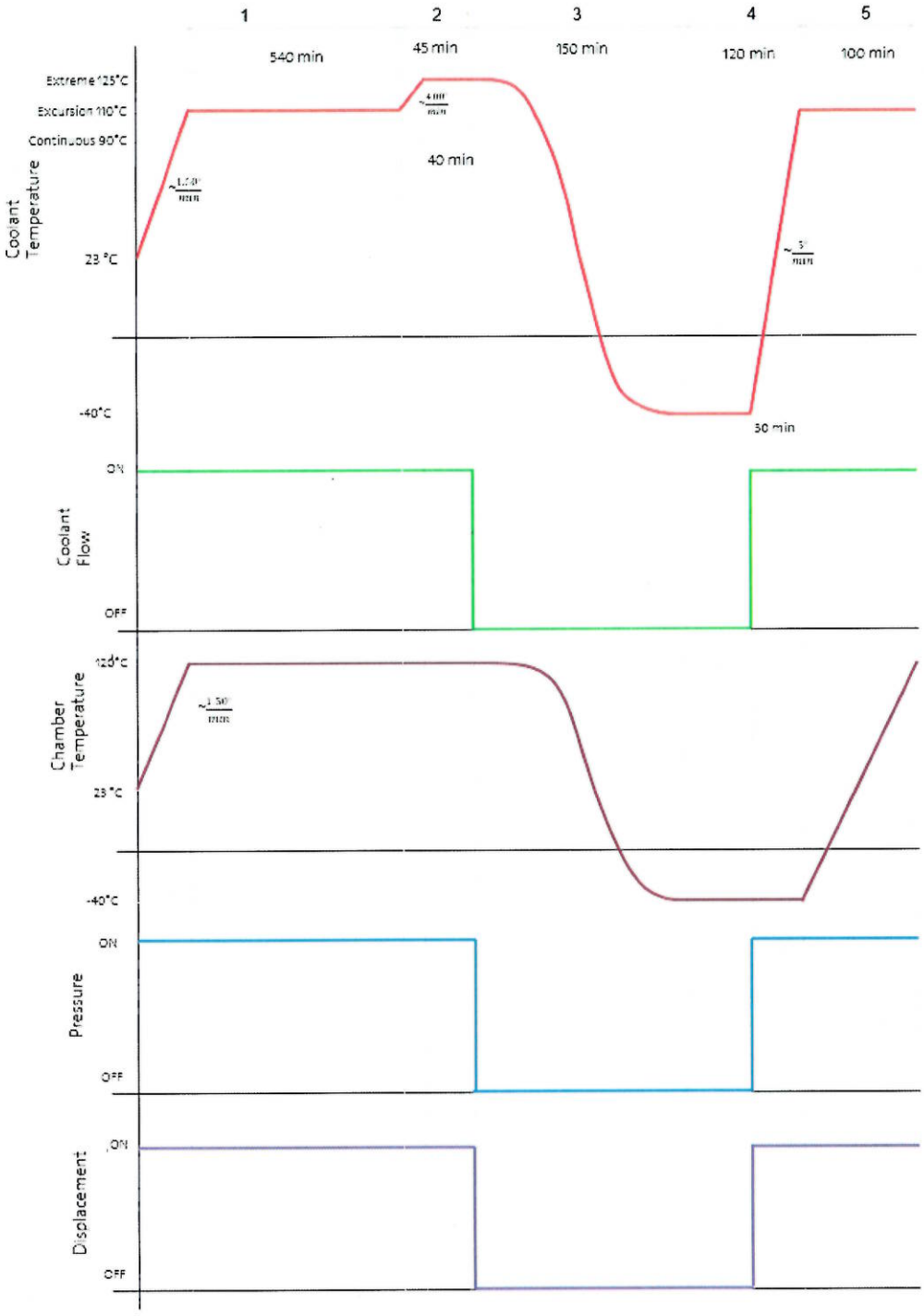

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Figure A3: Endurance Testing Profile for Hose Construction Type C (GMW18152)

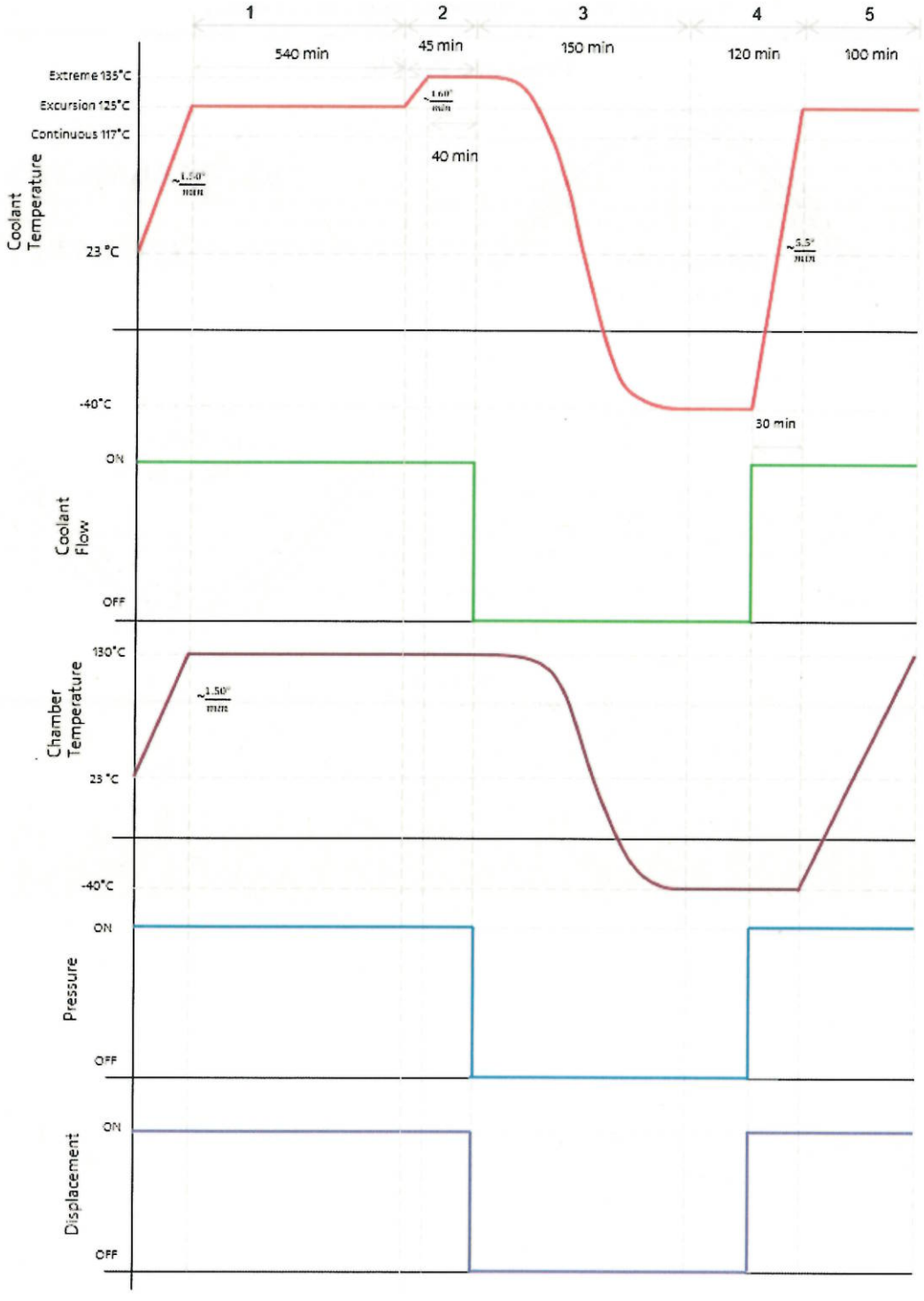

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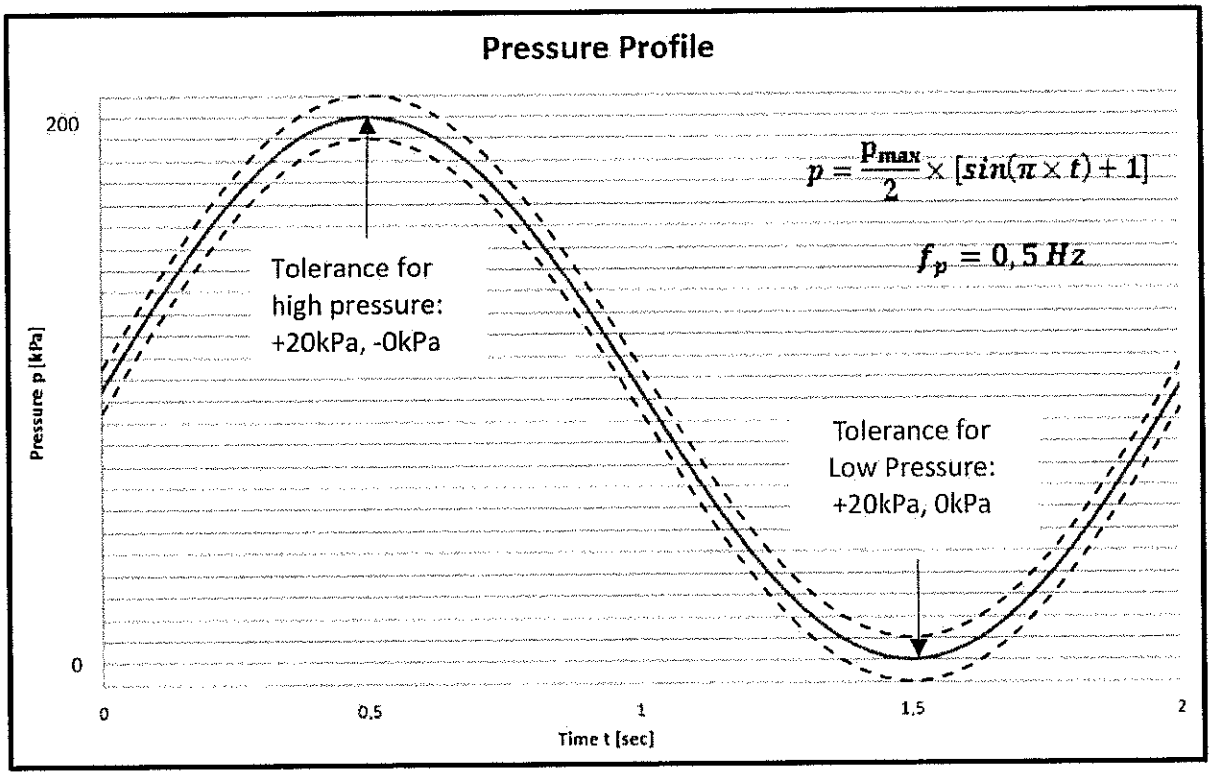
Figure A4: Pressure Profile on Endurance Testing



Appendix B

B1 Calculation of Vector and Amplitude of Movement

B1.1 Use Engine roll file.

B1.2 Run Engine roll analysis to the centerpoint of the spigot on the interfacing component which has movement relative to the vehicle structure.

B1.3 Use script (contact GM DRE for details) to get an Excel chart with the displacements for each load.

B1.4 Disregard the displacements from loads 10,11, 12, 13, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, 29, 30, 31 and 32. Those are considered Extreme loads, not representative of the number of movement cycles from the PVT test.

B1.5 Take the minimum and maximum value of each axis coordinate.

B1.6 Movement would be applied on such vector as three dimensional (3D) movement during the full number of cycles. Movement frequency for each axis is shown below:

Axis	Maximum Deflection	Frequency
X	± per SSTS, CTS or GM approved drawing	0.9 Hz
Y	± per SSTS, CTS or GM approved drawing	1.0 Hz
Z	± per SSTS, CTS or GM approved drawing	1.1 Hz

Appendix B Figure B2 shows an example of the resultant 3D motion in standard coordinate system. A linear (one-dimensional (1D)) motion is not acceptable.

Figure B1: Setup and Dimensions

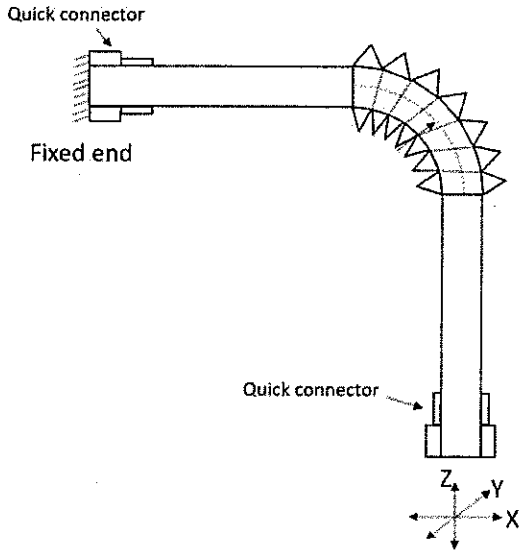


Figure B2 3D Motion