CITADIS SPIRIT
Type Test Report

ADD0000939180

TS10 - Climate Comfort

TS24 - Climatic Conditions

25/02/2019	H.Deligne	N.Bousquet	S. Rouer	L.Goudge
DATE	ESTABLISHED	CHECKED	CHECKED	APPROVED

ALSTOM

Alstom Transportation, Inc.

1 Transit Drive,
Hornell, NY 14843 USA

DISTRIBUTION	Confidentiality Category		Control Category	
	Restricted ☐	Normal ☒	Controlled ☒	Not Controlled ☐

ADD0000939180	Rel.	Lang.	N.Shts
	D	en	41

REVISIONS

Version/ Release	Auteur/ Author	Date *(fr: jj/mm/aaaa) (en: dd/mm/yyyy)*	Page / Paragraph	Commentaires/ Comments
A	N.BOUSQUET	31/07/2017	All	Initial release
B	N.BOUSQUET	5/7/2018	§5.1.7.3 §5.1.9.3 §5.1.13.3 §5.1.14.3 §5.1.15.3 §5.1.31.3	Updated per City comments in CRE ALS-58-0-14F6-CRE-0230_B Items No. 20-21
C	H.DELIGNE	16/01/2019	Appendix B	Procedure for windshield and gradient test added as Appendix B, updated per City comments in OLR-ALS-1758
D	H.DELIGNE	25/02/2019	AppendixC	Report for windshield and gradient test added as Appendix C

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 PURPOSE

This document reports on Alstom Transportation, Inc. climate comfort and climatic conditions testing of the Citadis Spirit 404 Light Rail Vehicle (LRV).

2 DOCUMENTS

Table 1 **List of Reference Documents**

Id	Title	Reference	Revision	§
[R1]	Citadis Spirit Climatic Room Climate Comfort	ADD0000939184	C	All
[R2]	Citadis Spirit Climatic Room Climatic Conditions	ADD0000939178	B	All
[R3]	Citadis Spirit Auxiliary Power Systems Tests,	ADD0000939034	0	All
[R4]	Citadis Spirit Windshield Wipers	ADD0000939216	A	All
[R5]	Citadis Spirit Sanding	ADD0000939056	A	All
[R6]	Citadis Spirit Vehicle Battery Discharge Test	ADD0000939031	B	All
[R7]	Citadis Spirit 404 Climatic Test Procedures	ST-R-TP-100	F	All

Table 2 **List of Applicable Documents**

Id	Title	Reference	Revision	§
[A1]	Citadis Spirit Carbody Climatic Test Report	ST-R-TR-0080	B	All

Document [A1] is included in Appendix A of this report.

3 TEST SUMMARY

Climate room testing was done to evaluate the performance of the Citadis Spirit in the following categories:

- Climatic conditions testing was intended to assess basic functionality of the light rail vehicle when exposed to environmental conditions including wind, rain, ice and snow at temperatures ranging from -38°C to 38°C.
- Climatic comfort testing was intended to assess the Heating, Ventilation and Air Condition (HVAC) performance during both heating and cooling (with simulated passenger and solar loads) at temperatures ranging from -22°C to 35°C with varying humidity conditions.
- Auxiliary Power System (APS) test was intended to evaluate the power capacity of the APS and ensure that the light rail vehicle maintained all required auxiliary functions after the loss of high voltage power.
- Windshield wipers testing was intended to ensure the functionality of specified hardware when exposed to severe environmental conditions.
- Sanding nozzles testing was intended to ensure the functionality of specified hardware when exposed to severe environmental conditions.
- Vehicle battery testing was intended to ensure the functionality of specified hardware when exposed to severe environmental conditions.

4 TEST SETUP

4.1 General Test Conditions

Alstom Transportation contracted Automotive and Surface Transportation, a division of the National Research Council Canada, to conduct testing in their climate chamber. Tests were performed on a partial trainset comprising a LMC2 and LCC car. Climatic Test Report [A1] outlines the general test conditions in detail.

4.2 Ambient Conditions

Climatic testing was done over a wide range of ambient conditions as specified in the Climate Comfort [R1] and Climatic Conditions [R2] test specifications. Refer to Climatic Test Report [A1], Table 1, Climatic Test Sequence, for a list of all tests and their corresponding conditions (temperature, humidity, wind, solar and precipitation).

4.3 Configuration of Vehicle under Test

The test configuration is described in the Climatic Test Report [A1], Section 2, Test Setup and Section 3, Test Instrumentation.

4.4 Data to be Recorded / Identification of Measurement Tools

The NRC laboratory provided all equipment and instrumentation necessary to conduct the tests, as described in Climatic Test Report [A1], Section 3, Test Instrumentation. Refer to Climatic Test Report [A1], Table 3, Equipment and Instrumentation, for a list of all equipment and instruments and their corresponding serial number, range, accuracy and calibration date.

4.5 Tooling and Personnel

All tools and personnel to simulate test conditions and document results were provided by NRC with support from Alstom Transportation as needed.

4.6 Pre-Requisite Tests

Routine tests on the partial trainset provided to NRC for climate testing has demonstrated that all required hardware and subsystems including doors, lighting, air conditioning units and heating floors are fully functional.

4.7 Test Date(s) and Test Location(s)

Climatic testing was performed in from January 10 to February 27, 2017, in Ottawa, Ontario, Canada.

4.8 Test Participants

Table 3 **Test Participants**

Name	Company	Function	Dates of Presence
Tom Jeulin	Alstom	Test & Commissioning	Jan 10 – Feb 27
Greg Barstow	STV Inc.	Consultant for City of Ottawa	Jan 10-12, 16-19, 24-27, 30-31, Feb 1-2
Eric Dube	City of Ottawa	Program Manager	Jan 31
Matt Pieters	City of Ottawa	Program Lead	Feb 9
Raymond Dumoulin	Alstom	Train Design Engineer	Jan 10, 12
Loic Monteyne	Alstom	Project Engineering Manager	Jan 10, 12
Yang Liu	Alstom	Test & Commissioning	Jan 11
Thomas Demachy	Alstom	Project Operation Manager	Jan 12, 14
Jean-Cyril Gauthier	Alstom	Train Validation Engineer	Jan 14, 17
Simon Belet	Alstom	Train Validation Engineer	Jan 14, 17
Lowell Goudge	Alstom	Train System Engineer	Jan 16-19, 24-26, Feb 05-06, 19-23, 27
Guillaume Carree	Alstom	Test Engineer	Jan 30-31, Feb1-2, Feb 6-8, Feb 12-14
Todd Garrett	NRC	Test Engineer	Jan 10 – Feb 27
Medhat Hanna	NRC	Project Manager	Jan 10 – Feb 27
Donald LeBlanc	NRC	Manager Climatic Engineering	Jan 10 – Feb 27

5 TEST CONDUCTED

All climatic tests were performed as described in the NRC Climatic Test Procedure [R7]. Section 5.1 summarizes the overall test results and sections 5.1.1 to 5.1.39 give a brief description of each test, any deviation necessary from the test procedure to complete the test, the acceptance criteria specified by Alstom and the test conclusion. The supporting climatic chamber data and results for each test are included in the NRC Climatic Test Report [A1] as referenced in Table 4 and attached in Appendix A of this report.

5.1 Test Results

The following table summarizes the results of all climatic tests with their respective references to the applicable Alstom Test Specification [R1]→[R6], NRC Climatic Test Procedure [R7] and NRC Climatic Test Report [A1]. For presentation purposes, the tests are listed in the order in which they are presented in the report. The actual test sequence during testing may have differed, as stated in the Climatic Test Report [A1] introduction.

Table 4 **Climatic Test Results Summary**

Test	Alstom Test Specification Reference	NRC Climatic Test Procedure Reference	NRC Climatic Test Report Reference	Result (Pass/Fail)
Climatic Conditions Test 1	ADD0000939178 §4	3.1.1	5.1.1	Pass
Climatic Conditions Test 2	ADD0000939178 §4	3.1.2	5.1.1	Pass
Climatic Conditions Test 3	ADD0000939178 §4	3.1.3	5.1.1	Pass
Climatic Conditions Test 4	ADD0000939178 §4	3.1.4	5.1.1	Pass
Climatic Conditions Test 5	ADD0000939178 §4	3.1.5	5.1.1	Pass
Climatic Conditions Test 6	ADD0000939178 §4	3.1.6	5.1.1	Pass
Climatic Conditions Test 7	ADD0000939178 §4	3.1.7	5.1.1	Fail
Climatic Conditions Test 8	ADD0000939178 §4	3.1.8	5.1.1	Pass
Climatic Conditions Test 9	ADD0000939178 §4	3.1.9	5.1.1	Fail
Climatic Conditions Test 13	ADD0000939178 §7	3.1.10	5.1.2	Fail
Climatic Conditions Test 14	ADD0000939178 §7	3.1.11	5.1.2	Fail
Climatic Conditions Test 15	ADD0000939178 §6	3.1.12	5.1.3	Pass
Climatic Conditions Test 16	ADD0000939178 §6	3.1.13	5.1.4	Pass

Climatic Conditions Test 17	ADD0000939178 §6	3.1.14	5.1.4	Pass
Climatic Conditions Test 18	ADD0000939178 §6	3.1.15	5.1.4	Pass
Pre Heating Test	ADD0000939184 §5.3	3.2.1	5.2.1	Pass
Climate Investigation Tests	ADD0000939184 §5.4	3.2.2	5.2.2	Done [1]
Pre Cooling Tests	ADD0000939184 §5.5	3.2.3	5.2.3	Done [1]
Condensation Test	Not applicable	Not applicable	5.2.4	Done [1]
Performance and Regulation Tests Procedure A in Cooling Mode	ADD0000939184 §5.6.1a	3.2.4.2	5.2.5.1	Pass
Performance and Regulation Tests Procedure B in Cooling Mode	ADD0000939184 §5.6.1b	3.2.4.4	5.2.5.2	Pass
Performance and Regulation Tests Procedure C in Cooling Mode	ADD0000939184 §5.6.1c	3.2.4.6	5.2.5.3	Done [1]
Performance and Regulation Tests Procedure D in Cooling Mode	ADD0000939184 §5.6.1d	3.2.4.8	5.2.5.4	Pass
Performance and Regulation Tests Procedure E in Cooling Mode	ADD0000939184 §5.6.1e	3.2.4.10	5.2.5.5	Done [1]
Performance and Regulation Tests Procedure F in Heating Mode	ADD0000939184 §5.6.1f	3.2.4.12	5.2.5.6	Pass
Performance and Regulation Tests Procedure G in Heating Mode	ADD0000939184 §5.6.1g	3.2.4.14	5.2.5.7	Done [1]
Performance and Regulation Tests Procedure H in Heating Mode	ADD0000939184 §5.6.1h	3.2.4.16	5.2.5.8	Pass
Performance and Regulation Tests Procedure I in Heating Mode	ADD0000939184 §5.6.1i	3.2.4.18	5.2.5.9	Pass
Performance and Regulation Tests Procedure J Layover Heating	ADD0000939184 §5.6.1j	3.2.4.20	5.2.5.10	Done [1]
Doors Opening/Closing Cooling Mode	ADD0000939184 §5.7	3.2.5	5.2.6	Pass
Doors Opening/Closing Heating Mode	ADD0000939184 §5.7	3.2.5	5.2.6	Pass
Doors Opening/Closing Heating Mode	ADD0000939184 §5.7	3.2.5	5.2.6	Pass
Insulation Validation	ADD0000939184 §5.8	3.2.6	5.2.7	Pass
APS Test in Winter Conditions	ADD0000939034 §4.1	3.3.1	5.3.1	Pass

APS Test in Summer Conditions	ADD0000939034 §4.2	3.3.2	5.3.2	Pass
Windshield Wiper & Demisting Testing	ADD0000939216 §6	3.4	5.4	Pass
Sanding Test at Low Temperature	ADD0000939056 §5	3.5	5.5	Pass
Discharge Test, Aged Battery	ADD0000939031 §6	3.6.1	5.6.1	Pass
Train Start Test	ADD0000939031 §7	3.6.2	5.6.2	Pass

[1] Test was done for characterization purpose as there are no applicable test criteria.

5.1.1 Climatic Conditions Test 1 - 10% RH, 0 kph Wind, 38°C, Solar Load Applied

Climatic conditions test 1 was performed as specified in [R2] and [R7].

5.1.1.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.1.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok (not applicable at low humidity)	N/A

5.1.1.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.2 Climatic Conditions Test 2 - 10% RH, 100 kph Wind, 38°C, Solar Load Applied

Climatic conditions test 2 was performed as specified in [R2] and [R7].

5.1.2.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.2.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok (not applicable at low humidity)	N/A

5.1.2.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.3 Climatic Conditions Test 3 - 10% RH, 180 kph Wind, 38°C, Solar Load Applied

Climatic conditions test 3 was performed as specified in [R2] and [R7].

5.1.3.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.3.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok (not applicable at low humidity)	N/A

5.1.3.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.4 Climatic Conditions Test 4 - 30-50% RH, 0 kph Wind, -38°C

Climatic conditions test 4 was performed as specified in [R2] and [R7].

5.1.4.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.4.2 Acceptance Criteria

Description	Criteria	Results
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK

5.1.4.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.5 Climatic Conditions Test 5 - 30-50% RH, 100 kph Wind, -38°C

Climatic conditions test 5 was performed as specified in [R2] and [R7].

5.1.5.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.5.2 Acceptance Criteria

Description	Criteria	Results
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK

5.1.5.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.6 Climatic Conditions Test 6 - 30-50% RH, 180 kph Wind, -38°C

Climatic conditions test 6 was performed as specified in [R2] and [R7].

5.1.6.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.6.2 Acceptance Criteria

Description	Criteria	Results
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK

5.1.6.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.7 Climatic Conditions Test 7 - 98% RH, 0 kph Wind, 38°C

Climatic conditions test 7 was performed as specified in [R2] and [R7].

5.1.7.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.7.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	NOK [1]

5.1.7.3 Test Conclusion

The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Alstom has been able to replicate the specific leakages in the production water test and will demonstrate the solution to this leakage separately.

5.1.8 Climatic Conditions Test 8 - 98% RH, 100 kph Wind, 38°C

Climatic conditions test 8 was performed as specified in [R2] and [R7].

5.1.8.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.8.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK

5.1.8.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.9 Climatic Conditions Test 9 - 98% RH, 180 kph Wind, 38°C

Climatic conditions test 9 was performed as specified in [R2] and [R7].

5.1.9.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.9.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	NOK [1]

5.1.9.3 Test Conclusion

The climatic chamber results are detailed in §5.1.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Alstom has been able to replicate the specific leakages in the production water test and will demonstrate the solution to this leakage separately.

5.1.10 Climatic Conditions Test 13 - 30-50% RH, 100 kph Wind, 20°C, Rain 60mm/hr

Climatic conditions test 13 was performed as specified in [R2] and [R7].

5.1.10.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.10.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	NOK [1]

5.1.10.3 Test Conclusion

The climatic chamber results are detailed in §5.1.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Alstom has been able to replicate the specific leakages in the production water test and will demonstrate the solution to this leakage separately.

5.1.11 Climatic Conditions Test 14 - 30-50% RH, 180 kph Wind, 20°C, Rain 60mm/hr

Climatic conditions test 14 was performed as specified in [R2] and [R7].

5.1.11.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.11.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	NOK [1]

5.1.11.3 Test Conclusion

The climatic chamber results are detailed in §5.1.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Alstom has been able to replicate the specific leakages in the production water test and will demonstrate the solution to this leakage separately.

5.1.12 Climatic Conditions Test 15 - 30-50% RH, 0 kph Wind, -20°C, Freezing Rain 5mm/hr

Climatic conditions test 15 was performed as specified in [R2] and [R7].

5.1.12.1 Variations Compared with Test Procedure

The test was repeated with 3mm ice buildup at -10°C.

5.1.12.2 Acceptance Criteria

Description	Criteria	Results
Freezing rain accretion in nominal mode	Windscreen defrosted < 2min and 30sec.	NOK [1]
	Doors can operate with 3mm ice buildup.	OK

5.1.12.3 Test Conclusion

The climatic chamber results are detailed in §5.1.3 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The test is considered as passed on the basis that the only readily available procedure (MIL-STD-810G) calls for the ice to be formed at -20°C and to be set and hardened for 4 hours, which is not representative of service conditions where the ice will be accumulating at most for 30 minutes before end to end change overs and even less time for the operational cycling of the doors. Therefore the test in some aspects is excessive, and the result at best shows the need to manage freezing rain conditions to prevent mal operation. It is important to note that vehicle storage is covered; therefore the need to “de-ice” a vehicle prior to service is not as severe as the conditions tested here.

5.1.13 Climatic Conditions Test 16 - 30-50% RH, 0 kph Wind, -10°C to -25°C, Snow 55mm/hr

Climatic conditions test 16 was performed as specified in [R2] and [R7].

5.1.13.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.13.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK
HVAC fresh air proportion	Fresh air proportion = fresh air proportion in normal condition ± 20%	OK
Horn function	Horn must sound audibly	OK
HVAC condenser fan	No snow accumulation	NOK [1]

5.1.13.3 Test Conclusion

The climatic chamber results are detailed in §5.1.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The test is considered as passed on the basis that while there was snow accumulation on the condenser fan area, this does not impact operation in any way, as the HVAC compressor and condenser fans are not operational below 8°C therefore snow accumulation in a nonoperational state is not an issue. There is minor snow near the fresh air inlet but the amount of accumulation is not considered problematic.

5.1.14 Climatic Conditions Test 17 - 30-50% RH, 100 kph Wind, -10°C to -25°C, Snow 55mm/hr

Climatic conditions test 17 was performed as specified in [R2] and [R7].

5.1.14.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.14.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK
HVAC fresh air proportion	Fresh air proportion = fresh air proportion in normal condition ± 20%	OK
Horn function	Horn must sound audibly	OK
HVAC condenser fan	No snow accumulation	NOK [1]

5.1.14.3 Test Conclusion

The climatic chamber results are detailed in §5.1.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The test is considered as passed on the basis that while there was snow accumulation on the condenser fan area, this does not impact operation in any way, as the HVAC compressor and condenser fans are not operational below 8°C therefore snow accumulation in a nonoperational state is not an issue. There is minor snow near the fresh air inlet but the amount of accumulation is not considered problematic.

5.1.15 Climatic Conditions Test 18 - 30-50% RH, 180 kph Wind, -10°C to -25°C, Snow 55mm/hr

Climatic conditions test 18 was performed as specified in [R2] and [R7].

5.1.15.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.15.2 Acceptance Criteria

Description	Criteria	Results
Train starting	Train fully functional	OK
Visual inspection	No damage identified	OK
Water tightness	Water tightness controls ok	OK
HVAC fresh air proportion	Fresh air proportion = fresh air proportion in normal condition ± 20%	OK
Horn function	Horn must sound audibly	OK
HVAC condenser fan	No snow accumulation	NOK [1]

5.1.15.3 Test Conclusion

The climatic chamber results are detailed in §5.1.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The test is considered as passed on the basis that while there was snow accumulation on the condenser fan area, this does not impact operation in any way, as the HVAC compressor and condenser fans are not operational below 8°C therefore snow accumulation in a nonoperational state is not an issue. There is minor snow near the fresh air inlet but the amount of accumulation is not considered problematic.

5.1.16 Pre Heating Test - No passenger load, -21.8°C External Temp

Pre-heating test was performed as specified in [R1] and [R7].

5.1.16.1 Variations Compared with Test Procedure

The pre-heating setpoint was changed to 16°C from 19°C. Therefore, the acceptance criterion for the interior temperature was also reduced to 16°C.

5.1.16.2 Acceptance Criteria

Description	Criteria	Results
Interior temperature	Minimum interior temperature of 16°C	OK

5.1.16.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.2.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.17 Climate Investigation Test - Thermal Gradients

Climate investigation test was performed as specified in [R1] and [R7].

5.1.17.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.17.2 Acceptance Criteria

The data gathered for this test was for characterization purpose.

5.1.17.3 Test Conclusion

The climatic chamber results are detailed in §5.2.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

Although the report shows there was roughly equal gradient with heated floors as opposed to baseboard heaters, the heated floor scenario had not reached thermal stability and was still trending upwards for the floor temperature, where over time it would have shown a reduced gradient compared to baseboard heat, confirming Alstom's design analysis that the use of heated floors would improve the gradient more than the use of base board heaters. To illustrate that point, Figure 1 compares the gradient of each scenario at the same elapsed time *t* since powering on the HVAC (time between the two red vertical lines). With the red vertical line at time *t* representing the heated floors gradient, Figure 1 shows that the heated floors gradient is smaller than that of base board heaters.

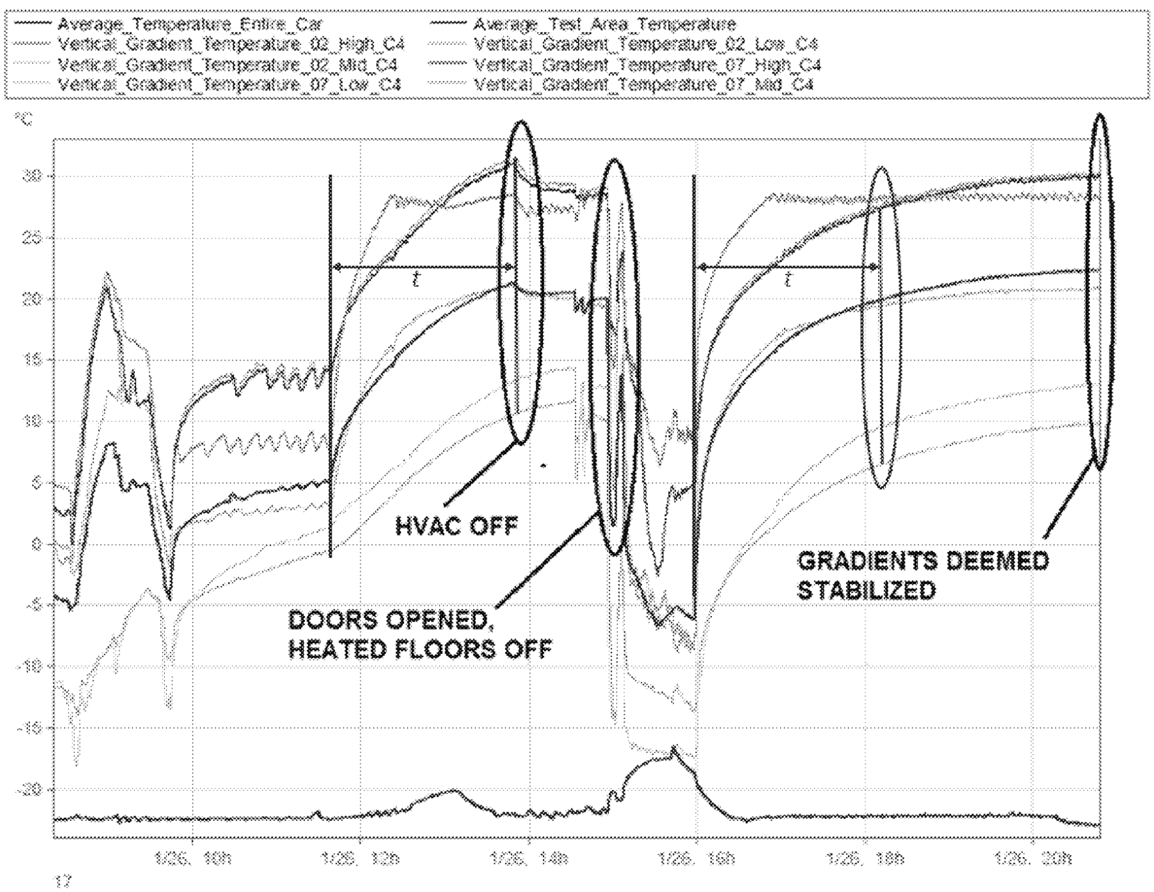


Figure 1 **Climate Investigation Test**

5.1.18 Pre Cooling Test - No passenger load, 28.9°C, 48% RH, 15kW Solar

Pre-cooling test was performed as specified in [R1] and [R7].

5.1.18.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.18.2 Acceptance Criteria

The data gathered for this test was for characterization purpose.

5.1.18.3 Test Conclusion

The climatic chamber results are detailed in §5.2.3 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.19 Condensation Test - 15°C with Passengers

Condensation test was added at the city's request.

5.1.19.1 Variations Compared with Test Procedure

Condensation test was not in the procedure.

5.1.19.2 Acceptance Criteria

The data gathered for this test was for characterization purpose.

5.1.19.3 Test Conclusion

The climatic chamber results are detailed in §5.2.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.20 Performance and Regulation Test - Procedure A - Regulation in Cooling Mode without Passengers

Performance and regulation test, procedure A, was performed as specified in [R1] and [R7].

5.1.20.1 Variations Compared with Test Procedure

The simulated solar load was reduced by 0.5kW to 14.5kW. It was changed due to the application of too much heat in the cab because the original estimate did not take into account the tapered geometry of the cab face.

5.1.20.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	OK
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	NOK [1]
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	OK
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	OK
Relative humidity	Internal humidity shall be between 30 and 50%	OK
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The supply air temperature must be higher than 12°C	NOK [2]

5.1.20.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Although the cab temperature was above the 2K band for the duration of the test, it is considered as passed on the basis that the cab booster was set to low speed and had it been switched to high speed on the Thermo King control panel, cab temperature would have decreased within tolerances by increasing cooled airflow in the cab.

[2] Although the supply air temperature is below 12°C for part of the test when the HVAC is operating in full cooling, it is considered as passed on the basis that the accepted industry norm, as described in ASHRAE Guideline GPC-23, states that supply air temperature during cooling operation should be no more than 25°F (14°C) below the average vehicle interior temperature. With regards to this guideline, the test demonstrates that the HVAC operates within industry norms even though it fails to meet Alstom's internal test criterion.

5.1.21 **Performance and Regulation Test - Procedure B - Regulation in Cooling Mode with Passengers**

Performance and regulation test, procedure B, was performed as specified in [R1] and [R7].

5.1.21.1 Variations Compared with Test Procedure

The simulated solar load was reduced by 0.5kW to 14.5kW. It was changed due to the application of too much heat in the cab because the original estimate did not take into account the tapered geometry of the cab face.

5.1.21.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	OK
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	OK
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	NOK [1]
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	NOK [1]
Relative humidity	Internal humidity shall be between 30 and 50%	OK
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The supply air temperature must be higher than 12°C	NOK [2]

5.1.21.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Although the global temperature gradient is above tolerance, further analysis and interpretation of the data has identified a number of factors that may have increased the temperature variability in the saloon:

- The simulated passenger load distribution in the climatic chamber was not truly representative of actual passenger load (eg. Higher passenger density in the doorways than in seated areas).
- The split end of the LCC car was sealed by a plywood sheet that may have impeded air circulation where an open gangway is normally found.
- Weaker insulation and probable air leaks in the doors due to watertightness issues may have contributed to hot and cold air pockets in the doorways.
- Greater airflow at the gangway where the HVAC plenum ends and at the cab due to the cab booster may have contributed to colder temperature at the car ends.

The test is considered as passed on the basis that excluding some of the affected locations from the dataset would lower the global gradient within the 6K band.

[2] Although the supply air temperature is below 12°C for part of the test when the HVAC is operating in full cooling, it is considered as passed on the basis that the accepted industry norm, as described in ASHRAE Guideline GPC-23, states that supply air temperature during cooling operation should be no more than 25°F (14°C) below the average vehicle interior temperature. With regards to this guideline, the test demonstrates that the HVAC operates within industry norms even though it fails to meet Alstom's internal test criterion.

5.1.22 Performance and Regulation Test - Procedure C - Performance in Cooling Mode

Performance and regulation test, procedure C, was performed as specified in [R1] and [R7].

5.1.22.1 Variations Compared with Test Procedure

The simulated solar load was reduced by 0.5kW to 14.5kW. It was changed due to the application of too much heat in the cab because the original estimate did not take into account the tapered geometry of the cab face.

5.1.22.2 Acceptance Criteria

The data gathered for this test was for characterization purpose..

5.1.22.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.3 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.23 Performance and Regulation Test - Procedure D - Regulation in Cooling Mode with Passengers

Performance and regulation test, procedure D, was performed as specified in [R1] and [R7].

5.1.23.1 Variations Compared with Test Procedure

The simulated solar load was reduced by 0.5kW to 14.5kW. It was changed due to the application of too much heat in the cab because the original estimate did not take into account the tapered geometry of the cab face.

5.1.23.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	OK
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	NOK [1]
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	NOK [2]
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	NOK [2]
Relative humidity	Internal humidity shall be between 30 and 50%	OK
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The supply air temperature must be higher than 12°C	NOK [3]

5.1.23.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Although the cab temperature was above the 2K band for part of the test, it is considered as passed on the basis that the cab temperature had not stabilized yet; it was steadily decreasing throughout the recording period and settled within tolerance by the end of test.

[2] Although the global temperature gradient is above tolerance, further analysis and interpretation of the data has identified a number of factors that may have increased the temperature variability in the saloon:

- The simulated passenger load distribution in the climatic chamber was not truly representative of actual passenger load (eg. Higher passenger density in the doorways than in seated areas).
- The split end of the LCC car was sealed by a plywood sheet that may have impeded air circulation where an open gangway is normally found.
- Weaker insulation and probable air leaks in the doors due to watertightness issues may have contributed to hot and cold air pockets in the doorways.
- Greater airflow at the gangway where the HVAC plenum ends and at the cab due to the cab booster may have contributed to colder temperature at the car ends.

The test is considered as passed on the basis that excluding some of the affected locations from the dataset would lower the global gradient within the 6K band.

[3] Although the supply air temperature is below 12°C for part of the test when the HVAC is operating in full cooling, it is considered as passed on the basis that the accepted industry norm, as described in ASHRAE Guideline GPC-23, states that supply air temperature during cooling operation should be no more than 25°F (14°C) below the average vehicle interior temperature. With regards to this guideline, the test demonstrates that the HVAC operates within industry norms even though it fails to meet Alstom's internal test criterion.

5.1.24 Performance and Regulation Test - Procedure E - Performance in Cooling Mode

Performance and regulation test, procedure E, was performed as specified in [R1] and [R7].

5.1.24.1 Variations Compared with Test Procedure

The simulated solar load was reduced by 0.5kW to 14.5kW. It was changed due to the application of too much heat in the cab because the original estimate did not take into account the tapered geometry of the cab face.

5.1.24.2 Acceptance Criteria

The data gathered for this test was for characterization purpose..

5.1.24.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.5 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.25 Performance and Regulation Test – Procedure F - Regulation in Heating Mode without Passengers

Performance and regulation test, procedure F, was performed as specified in [R1] and [R7].

5.1.25.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.25.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	OK
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	OK
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	NOK [1]
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	NOK [1]
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The temperature of grill must be under 50°C.	OK
Supply air temperature	The supply air temperature must be under 45°C in heating mode.	OK
Supply air temperature	The temperature at any of the accessible supply air outlets must be under 45°C	OK
Supply air temperature	The air diffused onto the seated driver must be under 35°C	OK
Surface temperature	The difference between Surface Temperature (walls and ceilings) and Internal Temperature must be under 13K.	OK
Surface temperature	The difference between Surface Temperature (windows and doors) and Internal Temperature must be under 15K.	OK
Surface temperature	The Surface Temperature (walls, ceiling, floor) must be higher than 3°C.	OK
Surface temperature	The difference between Surface Temperature (floor and ceiling) and Mean Interior Temperature must be under 12K under stationary conditions.	NOK [2]
Surface temperature	The difference between Surface Temperature (front windows, walls and outer doors) and Mean Interior Temperature must be under 15K under stationary conditions.	OK

5.1.25.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.6 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Although the global temperature gradient is above tolerance, further analysis and interpretation of the data has identified a number of factors that may have increased the temperature variability in the saloon:

- The simulated passenger load distribution in the climatic chamber was not truly representative of actual passenger load (eg. Higher passenger density in the doorways than in seated areas).
- The split end of the LCC car was sealed by a plywood sheet that may have impeded air circulation where an open gangway is normally found.
- Weaker insulation and probable air leaks in the doors due to watertightness issues may have contributed to hot and cold air pockets in the doorways.

- Greater airflow at the gangway where the HVAC plenum ends and at the cab due to the cab booster may have contributed to colder temperature at the car ends.

The test is considered as passed on the basis that excluding some of the affected locations from the dataset would lower the global gradient within the 6K band.

[2] Although two floor surface temperatures were greater than 12K from the mean interior temperature, the test is considered as passed on the basis that floor heaters are designed to cycle between 33°C and 35°C. Thus, it is acceptable to have floor surface temperatures in the 30°C to 35°C range.

5.1.26 Performance and Regulation Test – Procedure G - Performance in Heating Mode

Performance and regulation test, procedure G, was performed as specified in [R1] and [R7].

5.1.26.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.26.2 Acceptance Criteria

The data gathered for this test was for characterization purpose..

5.1.26.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.7 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

Although the test was terminated before thermal stability it demonstrated the installed capacity of the heating system was sufficient to maintain a temperature above the specified temperature range at the ASHREA 1% temperature as required in the project agreement.

5.1.27 Performance and Regulation Test – Procedure H - Regulation in Heating Mode without Passengers

Performance and regulation test, procedure H, was performed as specified in [R1] and [R7].

5.1.27.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.27.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	OK
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	NOK [1]
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	NOK [2]
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	NOK [2]
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The temperature of grill must be under 50°C.	OK
Supply air temperature	The supply air temperature must be under 45°C in heating mode.	OK
Supply air temperature	The temperature at any of the accessible supply air outlets must be under 45°C	OK
Supply air temperature	The air diffused onto the seated driver must be under 35°C	OK
Surface temperature	The difference between Surface Temperature (walls and ceilings) and Internal Temperature must be under 13K.	OK
Surface temperature	The difference between Surface Temperature (windows and doors) and Internal Temperature must be under 15K.	OK
Surface temperature	The Surface Temperature (walls, ceiling, floor) must be higher than 3°C.	OK
Surface temperature	The difference between Surface Temperature (floor and ceiling) and Mean Interior Temperature must be under 12K under stationary conditions.	NOK [3]
Surface temperature	The difference between Surface Temperature (front windows, walls and outer doors) and Mean Interior Temperature must be under 15K under stationary conditions.	OK

5.1.27.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.8 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] Although the cab temperature was above the 2K band for the duration of the test, it is considered as passed on the basis that the cab heater was ON and set to high speed. Had the booster been switched to low speed or OFF on the Thermo King control panel, it would have brought the cab temperature down to within tolerances by decreasing heated airflow in the cab.

[2] Although the global temperature gradient is above tolerance, further analysis and interpretation of the data has identified a number of factors that may have increased the temperature variability in the saloon:

- The simulated passenger load distribution in the climatic chamber was not truly representative of actual passenger load (eg. Higher passenger density in the doorways than in seated areas).

- The split end of the LCC car was sealed by a plywood sheet that may have impeded air circulation where an open gangway is normally found.
- Weaker insulation and probable air leaks in the doors due to watertightness issues may have contributed to hot and cold air pockets in the doorways.
- Greater airflow at the gangway where the HVAC plenum ends and at the cab due to the cab booster may have contributed to colder temperature at the car ends.

The test is considered as passed on the basis that excluding some of the affected locations from the dataset would lower the global gradient within the 6K band.

[3] Although two floor surface temperatures were greater than 12K from the mean interior temperature, the test is considered as passed on the basis that floor heaters are designed to cycle between 33°C and 35°C. Thus, it is acceptable to have floor surface temperatures in the 30°C to 35°C range.

5.1.28 Performance and Regulation Test – Procedure I - Regulation in Heating Mode with Passengers

Performance and regulation test, procedure I, was performed as specified in [R1] and [R7].

5.1.28.1 Variations Compared with Test Procedure

The simulated passenger load was increased from 10.5kWto 13kW as per calculations in Appendix A of the NRC test procedure.

5.1.28.2 Acceptance Criteria

Description	Criteria	Results
Internal temperature	Difference between Mean Interior Temperature and Interior Setting Temperature must be in the range +/-2K in saloon.	NOK [1]
Internal temperature	Difference between Interior Temperature and Interior Setting Temperature must be in the range +/-2K in cab.	OK
Temperature repartition	Horizontal temperature repartition must be under 6K in saloon	NOK [2]
Temperature repartition	Vertical temperature repartition must be under 6K in saloon	NOK [2]
Supply air temperature	Difference between the temperature at diffusers outlets and air inlet of the HVAC unit shall be inferior to 14K.	OK
Supply air temperature	The temperature of grill must be under 50°C.	OK
Supply air temperature	The supply air temperature must be under 45°C in heating mode.	OK
Supply air temperature	The temperature at any of the accessible supply air outlets must be under 45°C	OK
Supply air temperature	The air diffused onto the seated driver must be under 35°C	OK
Surface temperature	The difference between Surface Temperature (walls and ceilings) and Internal Temperature must be under 13K.	OK
Surface temperature	The difference between Surface Temperature (windows and doors) and Internal Temperature must be under 15K.	OK
Surface temperature	The Surface Temperature (walls, ceiling, floor) must be higher than 3°C.	OK
Surface temperature	The difference between Surface Temperature (floor and ceiling) and Mean Interior Temperature must be under 12K under stationary conditions.	NOK [3]
Surface temperature	The difference between Surface Temperature (front windows, walls and outer doors) and Mean Interior Temperature must be under 15K under stationary conditions.	OK

5.1.28.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.9 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] This test scenario shows that at warmer outside temperature in heating mode, the rate of passenger heat dissipation can be higher than carbody heat losses, resulting in interior temperatures greater than the setpoint tolerances. The test is considered as passed on the basis that in revenue service with passengers onboard, the doors cycling at station stops will increase carbody losses to keep interior temperatures within setpoint tolerances.

[2] Although the global temperature gradient is above tolerance, further analysis and interpretation of the data has identified a number of factors that may have increased the temperature variability in the saloon:

- The simulated passenger load distribution in the climatic chamber was not truly representative of actual passenger load (eg. Higher passenger density in the doorways than in seated areas).
- The split end of the LCC car was sealed by a plywood sheet that may have impeded air circulation where an open gangway is normally found.
- Weaker insulation and probable air leaks in the doors due to watertightness issues may have contributed to hot and cold air pockets in the doorways.
- Greater airflow at the gangway where the HVAC plenum ends and at the cab due to the cab booster may have contributed to colder temperature at the car ends.

The test is considered as passed on the basis that excluding some of the affected locations from the dataset would lower the global gradient within the 6K band.

[3] Although two floor surface temperatures were greater than 12K from the mean interior temperature, the test is considered as passed on the basis that floor heaters are designed to cycle between 33°C and 35°C. Thus, it is acceptable to have floor surface temperatures in the 30°C to 35°C range.

5.1.29 Performance and Regulation Test – Procedure J - Layover Heating Mode Test

Performance and regulation test, procedure J, was performed as specified in [R1] and [R7].

5.1.29.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.29.2 Acceptance Criteria

The data gathered for this test was for characterization purpose..

5.1.29.3 Test Conclusion

The climatic chamber results are detailed in §5.2.5.10 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.30 Test with Doors Opening/Closing – Cooling Mode

Test with doors opening/closing was performed as specified in [R1] and [R7].

5.1.30.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.30.2 Acceptance Criteria

Description	Criteria	Results
Time required for T_{im} to achieve T_{ic} ± 1.5°C	Target of 2 minutes	OK

5.1.30.3 Test Conclusion

The test passed without issues. The interior temperature remained within ± 1.5°C of setpoint throughout the duration of the test. The climatic chamber results are detailed in §5.2.6 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.31 Tests with Doors Opening/Closing – Heating Mode, -20°C

Test with doors opening/closing was performed as specified in [R1] and [R7].

5.1.31.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.31.2 Acceptance Criteria

Description	Criteria	Results
Time required for T_{im} to achieve T_{ic} ± 1.5°C	Target of 2 minutes	NOK [1]

5.1.31.3 Test Conclusion

The climatic chamber results are detailed in §5.2.6 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The climatic test report defines setpoint T_{ic} as the average of the stabilized T_{im} prior to opening the doors rather than the HVAC heating setpoint of 16°C, as per procedure. As a result, the NRC calculations used a higher target temperature of 15.7°C instead of the required 14.5°C. The time values revised for the 16°C setpoint are presented in Table 5.

Table 5 **Doors Open/Closed Test Results for 16°C Setpoint, Heating Mode, -20°C**

Test Sequence	Doors Opened	Floor Heater	Temperatures (°C)		Humidity	T(s)	
			Int (T_{ic})	Ext (T_{em})		Time to Tset-1.5	Time to Tav-1.5
2	All doors on one side	ON	16	-20	N/A	122	152
5	Half doors on one side	ON	16	-20	N/A	114	147

Although test sequence #2 is still slightly above the 2-minute target by 2 seconds when considering setpoint as opposed to the average for the reference temperature, there is also a considerable thermal lag between the doors closing and the interior car temperature reaching its low temperature, as shown in Table 6.

Table 6 **Doors Open/Closed Thermal Lag, Heating Mode, -20°C**

Test Sequence	Doors Opened	Doors Closed	Low Temperature	Tim ± 1.5°C = Tic Achieved	Thermal Lag (s)
2	All doors on one side	17:11:00	17:11:41	17:13:02	41
5	Half doors on one side	16:58:54	16:59:40	17:00:48	46

The thermal lag can be clearly seen with the sensor plot below, taken from the NRC data where even toe sensors closest to the door take in excess of 30 seconds to report the lowest temperature after the doors close.

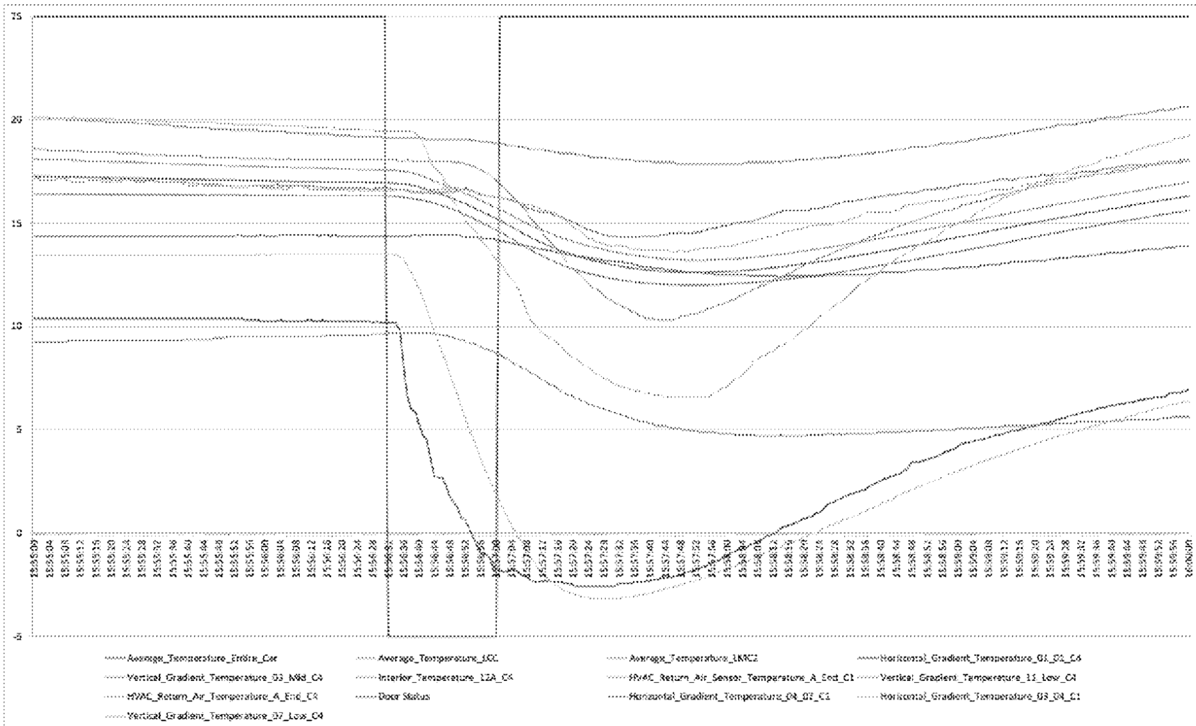


Figure 2 **Plot of temperature sensor responses to a door cycle**

It should also be noted that the thermocouples have an appreciable mass, as indicated below in the photo by the red arrow. This explains the slow response time.

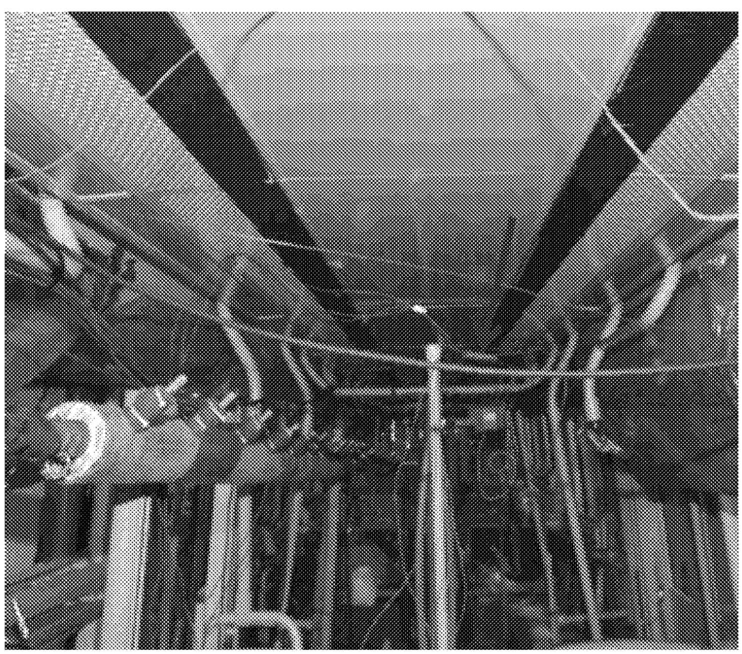


Figure 3 **Photo of thermocouple setup**

While the thermal lag may consider other aspects such as air circulation in the car etc., a portion of it logically can be attributed to the transient response of the thermal probes themselves. Since the apparent lag in thermal measurement, in time is greater than the recovery time even when compared to the interior average temperature, both doors cycling results are considered to be within the 2-minute target.

5.1.32 Tests with Doors Opening/Closing – Heating Mode, -22°C

Test with doors opening/closing was performed as specified in [R1] and [R7].

5.1.32.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.32.2 Acceptance Criteria

Description	Criteria	Results
Time required for T_{im} to achieve T_{ic} ± 1.5°C	Target of 2 minutes	NOK [1]

5.1.32.3 Test Conclusion

The climatic chamber results are detailed in §5.2.6 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The climatic test report defines setpoint T_{ic} as the average of the stabilized T_{im} prior to opening the doors rather than the HVAC heating setpoint of 16°C, as per procedure. As a result, the NRC calculations used a higher target temperature of 15.7°C instead of the required 14.5°C. The time values revised for the 16°C setpoint are presented in Table 5.

Table 7 **Doors Open/Closed Test Results for 16°C Setpoint, Heating Mode, -22°C**

Test Sequence	Doors Opened	Floor Heater	Temperatures (°C)		Humidity	T(s)	
			Int (T_{ic})	Ext (T_{em})		Time to Tset-1.5	Time to Tav-1.5
3	All doors on one side	ON	16	-22	N/A	134	166
6	Half doors on one side	ON	16	-22	N/A	124	158

Although both sequences are still slightly above the 2-minute target by 4 and 14 seconds, when considering setpoint as opposed to the average for the reference temperature, there is also a considerable thermal lag between the doors closing and the interior car temperature reaching its low temperature, as shown in Table 6.

Table 8 **Doors Open/Closed Thermal Lag, Heating Mode, -22°C**

Test Sequence	Doors Opened	Doors Closed	Low Temperature	Tim ± 1.5°C = Tic Achieved	Thermal Lag (s)
3	All doors on one side	16:12:11	16:12:52	16:14:25	41
6	Half doors on one side	15:57:01	15:57:52	15:59:05	51

While the thermal lag may consider other aspects such as air circulation in the car etc., a portion of it logically can be attributed to the transient response of the thermal probes themselves. Since the apparent lag in thermal measurement, in time is greater than the recovery time even when compared to the interior average temperature, both doors cycling results are considered to be within the 2-minute target.

5.1.33 Insulation Validation (K Factor Measurement)

Insulation validation was performed as specified in [R1] and [R7].

5.1.33.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.33.2 Acceptance Criteria

Description	Criteria	Results
K factor	The K factor is less than 2.5W/m²K. for the LMC2 car and cab	OK
K factor	The K factor is less than 2.22W/m²K. for the LCC car	NOK [1]

5.1.33.3 Test Conclusion

The climatic chamber results are detailed in §5.2.7 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] As explained in the NRC report, it was not possible to calculate a separate K factor for the individual cars due to them being connected. Although the overall value of 2.46 W/m²K is above the criterion for LCC car, the test is considered as passed on the basis that the insulation under the seat boxes has since been reinforced as part of the fire test modifications and the losses on production cars are reduced as a result. This impact is more pronounced on LCC because there are 2 bogie boxes compared to one on the LMCs and IMC. The fire test modifications were not part of the train configuration in the climatic chamber tests. With the reinforced insulation, it is expected that the LCC K factor will meet its criterion.

5.1.34 Auxiliary Power System Test - Winter Conditions, -38°C

Auxiliary power system test in winter conditions was performed as specified in [R3] and [R7].

5.1.34.1 Variations Compared with Test Procedure

Compressors were forced to restart as the first step in the sequence due to a variable lag between toggling the HVAC compressor breaker switches and the restart of the compressor.

5.1.34.2 Acceptance Criteria

Description	Criteria	Results
Steady consumption	120V output : <8KW	OK
Steady consumption	LV output : <16KW	OK
Steady consumption	440V output : < 54KW	OK
Peak consumption	440V output : < 83KW during t < 0.5s	OK

5.1.34.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.3.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.35 Auxiliary Power System Test - Summer Conditions, 38°C

Auxiliary power system test in summer conditions was performed as specified in [R3] and [R7].

5.1.35.1 Variations Compared with Test Procedure

Compressors were forced to restart as the first step in the sequence due to a variable lag between toggling the HVAC compressor breaker switches and the restart of the compressor.

5.1.35.2 Acceptance Criteria

Description	Criteria	Results
Steady consumption	120V output : <0KW	OK
Steady consumption	LV output : <16KW	OK
Steady consumption	440V output : < 62KW	OK
Peak consumption	440V output : < 109KW during t < 0.5s	OK

5.1.35.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.3.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.36 Windshield Wiper Test

Windshield wiper test was performed as specified in [R4] and [R7].

5.1.36.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.36.2 Acceptance Criteria

Description	Criteria	Results
State of the Visibility Area (70°) after 1 cycle (way out and back motion)	No dripping on the glass water For information : notation ≥8	NOK [1]
State of the Wipers Area (90°) after 1 cycle (way out and back motion)	No dripping on the glass water For information : notation ≥5	NOK [1]
State of the Visibility Area (70°) after 10 cycles	For information notation =10	NOK [1]
State of the Wipers Area (90°) after 10 cycles	For information notation ≥ 9	NOK [1]

5.1.36.3 Test Conclusion

The climatic chamber results are detailed in §5.4 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The test is considered as passed on the basis that the only readily available procedure (MIL-STD-810G) calls for the ice to be formed at -20°C and to be set and hardened for 4 hours, which is not representative of service conditions where the ice will be accumulating at most for 30 minutes before end to end change overs and even less time for the operational cycling of the windshield wipers. Therefore the test in some aspects is excessive, and the result at best shows the need to manage freezing rain conditions to prevent mal operation. It is important to note that vehicle storage is covered; therefore the need to “de-ice” a vehicle prior to service is not as severe as the conditions tested here.

5.1.37 Sanding Test, Low Temperature - -38°C

Sanding test was performed as specified in [R5] and [R7].

5.1.37.1 Variations Compared with Test Procedure

Due to one of six chamber compressors malfunctioning a minimum temperature of -35°C was achieved.

5.1.37.2 Acceptance Criteria

Description	Criteria	Results
Sand flow	600 ≤ flow ≤ 800 g/min	NOK [1]
Heaters activation (on sandbox and sand nozzle)	Activation when t° ≤ -5°C	Not tested [2]

5.1.37.3 Test Conclusion

The climatic chamber results are detailed in §5.5 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

[1] The calculated flow rates for the 4 nozzles varied from 957 to 1226 g/min. Although the measured values in the chamber are higher than expected, the test is considered as passed on the basis that it did prove that sand flow was not impeded by the cold conditions. The nominal performance of the sanding system will be evaluated and the flow rate adjusted, if necessary, in the sanding test at ambient temperature.

[2] The automatic activation of the heaters when the outside temperature drops below -5°C was not validated because the chamber was already at -35°C for the duration of the test.

5.1.38 Vehicle Battery Discharge Test - Aged Battery - -40°C

Vehicle battery discharge test, aged battery, was performed as specified in [R6] and [R7].

5.1.38.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.38.2 Acceptance Criteria

Description	Criteria	Results
During the whole test, supply voltage at the battery terminals has to be over 19V	During 90min at supply voltage > 19V.	OK
At 90 min, supply voltage at lowest voltage running equipment in in all body sections will be over 17V	Duration > 90min at supply voltage > 17V	OK
Time record of events to be given for information as they are done in complement of train functional test.	Check time record is compliant to Table 6 of NRC climatic test procedure	OK

5.1.38.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.6.1 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

5.1.39 Vehicle Battery Discharge Test - Train Start Test at -25°C

Train start test was performed as specified in [R6] and [R7].

5.1.39.1 Variations Compared with Test Procedure

No variation was required to complete the test.

5.1.39.2 Acceptance Criteria

Description	Criteria	Results
When HV voltage is shut down and train started , supply voltage at the battery terminals has to be over 19V	Supply voltage at the battery terminals has to be over 19V	OK
When HV voltage is shut down and train started, loads are supplied and operational according to Table 6 of the NRC climatic test procedure, column “Loss High Voltage”	According to Table 6 of NRC climatic test procedure, column “Loss High Voltage”	OK
When HV voltage is present and train started, loads are supplied and operational according to Table 6 of the NRC climatic test procedure, column “Normal mode before HV loss”	According to Table 6 of NRC climatic test procedure, column “Normal mode before HV loss”	OK

5.1.39.3 Test Conclusion

The test passed without issues. The climatic chamber results are detailed in §5.6.2 of the NRC Climatic Test Report [A1] attached in Appendix A of this report.

6 GENERAL CONCLUSION

Climatic testing of the Citadis Spirit 404 Light Rail Vehicle generally demonstrated that it can withstand Ottawa’s most severe weather conditions and provide a safe and comfortable ride to its passengers.

Where the test results failed to meet the expected criteria, engineering analysis concluded that any of the following factors could explain the anomalies:

- The test was not representative of operating conditions and provided, at best, a characterization of the LRV’s ability to cope with the most severe weather conditions.
- There were limitations and constraints imposed by the test setup or instrumentation.
- The simulated conditions exceeded the HVAC design capacity to heat or cool the car.
- There were known issues pertaining to other systems adversely affecting the performance in the climatic chamber.

Seeing that the majority of climatic tests passed without issues and a sound rationale explains each of the failed criteria, the overall climate comfort and climatic conditions test procedures are considered as passed.

7 APPENDIX A - CITADIS SPIRIT CARBODY CLIMATIC TEST REPORT

The following attachment is the Citadis Spirit Climatic Test Report [A1] published by NRC.

ST-R-TR-0080
Alstom Citadis Spirit 4

8 APPENDIX B - INVESTIGATION TEST PROCEDURE WINDSHIELD AND GRADIENT TESTS

This document attached describes 2 investigative tests:
The windshield test measures to confirm the thermal performance of the defrosting system and the gradient test to confirm the measured stratification observed in the CC car during the climate room tests.

Foxit Reader PDF
Document

9 APPENDIX C – INVESTIGATION TEST REPORT WINDSHIELD AND GRADIENT TESTS

This document attached describes the results obtained for the 2 investigative tests:
The windshield test measures to confirm the thermal performance of the defrosting system and the gradient test to confirm the measured stratification observed in the CC car during the climate room tests.

Foxit Reader PDF
Document

National Research Council Canada

Conseil National de Recherches Canada

Automotive and Surface Transportation

Automobile et transport de surface

NRC·CNRC

Citadis Spirit Carbody Climatic Test Report

Prepared for:
Lowell Goudge
ALSTOM Transportation, Inc.
1 Transit Drive
Hornell, NY
14843

Prepared by:
Todd Garrett, P.Eng.

Project A1-005651

Technical Procedure

Procedure technique

ST-R-TR-0080

2017-07-18

CONTROLLED
UNCLASSIFIED

CONTRÔLÉE
NON CLASSIFIÉE

Canada

REVISION CONTROL

REVISION	DATE	DESCRIPTION
A	2017-04-12	Draft Issued to client
B	2017-07-18	Final version issued to client

REPORT PREPARED BY:

TMGarrett July 18, 2017

Todd Garrett, P.Eng. **Date**
Test Engineer

REVIEWED AND APPROVED BY:

July 18, 2017

Medhat Hanna, P.Eng., PMP **Date**
Project Manager

Don LeBlanc July 18, 2017

Donald LeBlanc, P.Eng., PMP **Date**
Team Leader

Abstract

Automotive and Surface Transportation (a division of the National Research Council Canada) was contracted by Alstom Transport Canada Incorporated to perform a series of environmental conditions tests on the Citadis Spirit 404 light rail vehicle. This testing included climatic conditions, climate comfort, auxiliary power systems (APS), windshield wipers, sanding nozzles, and vehicle battery discharge.

Climatic conditions testing was intended to assess basic functionality of the light rail vehicle when exposed to environmental conditions including wind, rain and snow at temperatures ranging from -38°C to 38°C. Climatic comfort testing was intended to assess the Heating, Ventilation and Air Condition (HVAC) performance during both heating and cooling (with simulated passenger and solar loads) at temperatures ranging from -22°C to 35°C with varying humidity conditions.

Auxiliary power systems and vehicle battery discharge testing was intended to evaluate the power capacity of the APS and ensure that the light rail vehicle maintained all required auxiliary functions after the loss of high voltage power.

Windshield wiper and sanding nozzle testing was intended to ensure the functionality of specified hardware when exposed to severe environmental conditions.

This document contains a description of the test procedures that were undertaken during the climatic test program and the results of those tests.

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

1 INTRODUCTION

NRC Automotive and Surface Transportation (AST) was tasked by Alstom Transport Canada Incorporated (Alstom) to evaluate the capacity of a light rail Citadis Spirit 404 vehicle to withstand any ambient conditions.

The climatic test program was completed as described in the test documents provided by Alstom [1] - [6] and followed any applicable MIL [7] - [8] and SAE [9] standards when applicable.

The following tests were performed on the LMC2 and LCC car body sections:

Climatic Condition Tests

Test 1 - 10% RH, 0 kph Wind, 38°C, Solar Load Applied [1].
Test 2 - 10% RH, 100 kph Wind, 38°C, Solar Load Applied [1].
Test 3 - 10% RH, 180 kph Wind, 38°C, Solar Load Applied [1].
Test 4 - 30-50% RH, 0 kph Wind, -38°C [1].
Test 5 - 30-50% RH, 100 kph Wind, -38°C [1].
Test 6 - 30-50% RH, 180 kph Wind, -38°C [1].
Test 7 - 98% RH, 0 kph Wind, 38°C [1][2].
Test 8 - 98% RH, 100 kph Wind, 38°C [1][2].
Test 9 - 98% RH, 180 kph Wind, 38°C [1][2].
Test 13 - 30-50% RH, 100 kph Wind, 20°C, Rain 60mm/hr [1][7].
Test 14 - 30-50% RH, 180 kph Wind, 20°C, Rain 60mm/hr [1][7].
Test 15 - 30-50% RH, 0 kph Wind, -20°C, Freezing Rain 5mm/hr [1][8].
Test 16 - 30-50% RH, 0 kph Wind, -10 to -25°C, Snow 55mm/hr [1].
Test 17 - 30-50% RH, 100 kph Wind, -10 to -25°C, Snow 55mm/hr [1].
Test 18 - 30-50% RH, 180 kph Wind, -10 to -25°C, Snow 55mm/hr [1].

Climate Comfort Tests

Pre Heating Test - No passenger load, -22°C External Temp [2].
Climate Investigation Test - Thermal gradients [2].
Pre Cooling Test - No passenger load, 28.9°C, 48% RH, 15 kW Solar [2].
Performance and Regulation Tests [2].
Tests with Doors Open/Closed in the Saloon [2].
Insulation Validation (K Factor Measurement) [2].

Auxiliary Power Systems

Test in Winter Conditions, -38°C [3].
Test in Summer Conditions, 38°C [3].

Windshield Wipers

Test 3 - Effectiveness of Wiping in Cold Conditions [4].

Sanding

Test at Low Temperature - -38°C [5].

Vehicle Battery Discharge

Discharge Test, Aged Battery - -40°C [6].
Train Start Test at -25°C [6].

The testing was performed in January and February of 2017 and was completed by NRC personnel following the test procedures described within.

To facilitate testing and minimize the overall duration of testing, the test sequence as per Table 1 was planned, however as the test program unfolded adjustments were made and the sequence rearranged where required.

Table 1: Climatic Test Sequence

Test	Section	Type	Conditions				
			Solar kW	Snow/Rain mm/hr	Wind km/hr	Temp °C	Humidity %RH
1	5.2.3	Pre Cooling Tests	15	0	0	28.9	48
2	5.2.5	Performance and Regulation Tests Procedures D - E in Cooling Mode	15	0	0	28.9	48
3	5.2.6	Doors Opening/Closing Cooling Mode	0	0	0	28.9	48
4	5.2.5	Performance and Regulation Tests Procedures A - C in Cooling Mode	15	0	0	35	50
5	5.1.1	Test 1 Climatic Condition Tests	15	0	0	38	10
6	5.1.1	Test 2 Climatic Condition Tests	15	0	100	38	10
7	5.1.1	Test 3 Climatic Condition Tests	15	0	180	38	10
8	5.1.1	Test 7 Climatic Condition Tests	0	0	0	38	98
9	5.1.1	Test 8 Climatic Condition Tests	0	0	100	38	98
10	5.1.1	Test 9 Climatic Condition Tests	0	0	180	38	98
11	5.3.2	APS Test in Summer Conditions	0	0	0	38	NA
12	5.2.7	Insulation Validation	0	0	0	-20	NA
13	5.2.5	Performance and Regulation Tests Procedure I in Heating Mode	0	0	0	0	NA
14	5.2.5	Performance and Regulation Tests Procedure F in Heating Mode	0	0	0	-10	NA
15	5.2.5	Performance and Regulation Tests Procedure G in Heating Mode	0	0	0	-20	NA
16	5.2.1	Pre Heating Test	0	0	0	-22	NA
17	5.2.5	Performance and Regulation Tests Procedure H in Heating Mode	0	0	0	-22	NA
18	5.2.5	Performance and Regulation Tests Procedure J Layover Heating	15	0	0	-22	NA
19	5.2.6	Doors Opening/Closing Heating Mode	0	0	0	-20	NA
20	5.2.6	Doors Opening/Closing Heating Mode	0	0	0	-22	NA
21	5.2.2	Climate Investigation Tests	0	0	0	-22	NA
22	5.6.2	Train Start Test	0	0	0	-25	NA
23	5.6.1	Discharge Test, Aged Battery	0	0	0	-40	NA
24	5.1.1	Test 4 Climatic Condition Tests	0	0	0	-38	30-50
25	5.1.1	Test 5 Climatic Condition Tests	0	0	100	-38	30-50
25	5.1.1	Test 6 Climatic Condition Tests	0	0	180	-38	30-50
27	5.5	Sanding Test at Low Temperature	0	0	0	-38	NA
28	5.3.1	APS Test in Winter Conditions	0	0	0	-38	NA
29	5.1.3	Test 15 Climatic Condition Tests Defrost & Door Cycling	0	5 (Rain)	0	-20	30-50
30	5.4	Windshield Wiper & Demisting Testing	0	60 (Rain)	0	-5	NA
31	5.1.4	Test 16 Climatic Condition Tests	0	50 (Snow)	0	-10 to -25	30-50
32	5.1.4	Test 17 Climatic Condition Tests	0	50 (Snow)	100	-10 to -25	30-50
33	5.1.4	Test 18 Climatic Condition Tests	0	50 (Snow)	180	-10 to -25	30-50
34	5.1.2	Test 13 Climatic Condition Tests	0	60 (Rain)	100	20	30-50
35	5.1.2	Test 14 Climatic Condition Tests	0	60 (Rain)	180	20	30-50

Dates on which particular climatic tests were performed are shown in Table 2.

Table 2: Climatic Test Performance Dates

Section	Type	Date of Performance
5.2.7	Insulation Validation	January 23, 2017
5.2.5	Performance and Regulation Tests - Procedure G in Heating Mode	January 23, 2017
5.2.5	Performance and Regulation Tests - Procedure J Layover Heating	January 24, 2017
5.2.2	Climate Investigation Tests	January 26, 2017
5.5	Sanding Test at Low Temperature	January 27, 2017
5.4	Windshield Wiper & Demisting Testing	February 1 & 14, 2017
5.1.3	Test 15 Climatic Condition Tests Defrost & Door Cycling	February 2 & 14, 2017
5.1.4	Test 16 Climatic Condition Tests	February 3, 2017
5.1.4	Test 17 Climatic Condition Tests	February 3, 2017
5.1.4	Test 18 Climatic Condition Tests	February 3, 2017
5.2.5	Performance and Regulation Tests - Procedure I in Heating Mode	February 5, 2017
5.2.3	Pre Cooling Tests	February 6, 2017
5.2.5	Performance and Regulation Tests - Procedures A - C in Cooling Mode	February 6, 2017
5.2.5	Performance and Regulation Tests - Procedures D - E in Cooling Mode	February 7, 2017
5.2.6	Doors Opening/Closing Heating Mode	February 7, 2017
5.3.2	APS Test in Summer Conditions	February 7, 2017
5.1.1	Test 1 Climatic Condition Tests	February 8, 2017
5.1.1	Test 2 Climatic Condition Tests	February 8, 2017
5.1.1	Test 3 Climatic Condition Tests	February 8, 2017
5.1.1	Test 7 Climatic Condition Tests	February 8, 2017
5.1.1	Test 8 Climatic Condition Tests	February 8, 2017
5.1.1	Test 9 Climatic Condition Tests	February 8, 2017
5.2.4	Condensation Test, 15°C	February 9, 2017
5.2.6	Doors Opening/Closing Cooling Mode	February 10, 2017
5.2.1	Pre Heating Test	February 10, 2017
5.2.5	Performance and Regulation Tests - Procedure H in Heating Mode	February 10, 2017
5.1.1	Test 4 Climatic Condition Tests	February 13, 2017
5.1.1	Test 5 Climatic Condition Tests	February 13, 2017
5.1.1	Test 6 Climatic Condition Tests	February 13, 2017
5.2.5	Performance and Regulation Tests - Procedure F in Heating Mode	February 14, 2017
5.6.2	Train Start Test	February 15, 2017
5.3.1	APS Test in Winter Conditions	February 16, 2017
5.6.1	Discharge Test, Aged Battery	February 16, 2017
5.1.2	Test 13 Climatic Condition Tests	February 20, 2017
5.1.2	Test 14 Climatic Condition Tests	February 21, 2017

2 TEST SETUP

NRC received the Alstom light rail vehicle trainset on December 19th and proceeded to install resistive heaters to simulate passenger (sensible) and solar loads, the piping necessary to simulate passenger (latent) loads, and thermocouples and relative humidity probes to monitor HVAC, car and chamber environmental conditions as shown in the following Figures.

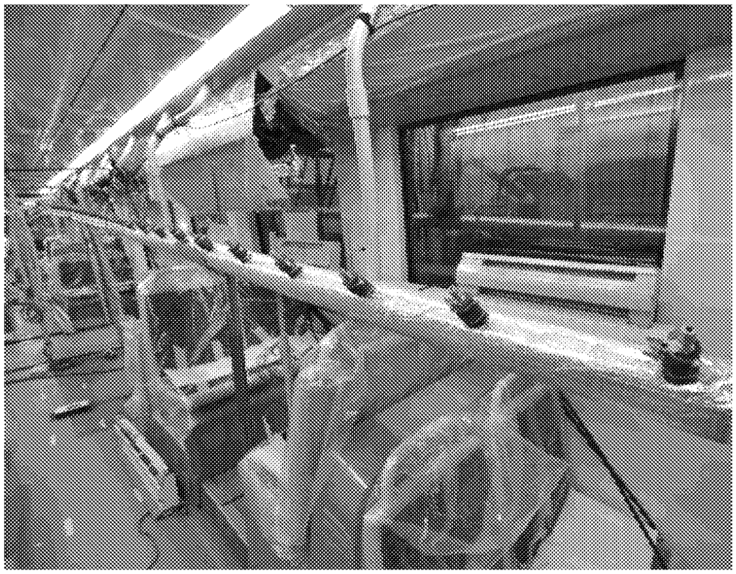


Figure 1 - Passenger and Solar Load Simulation

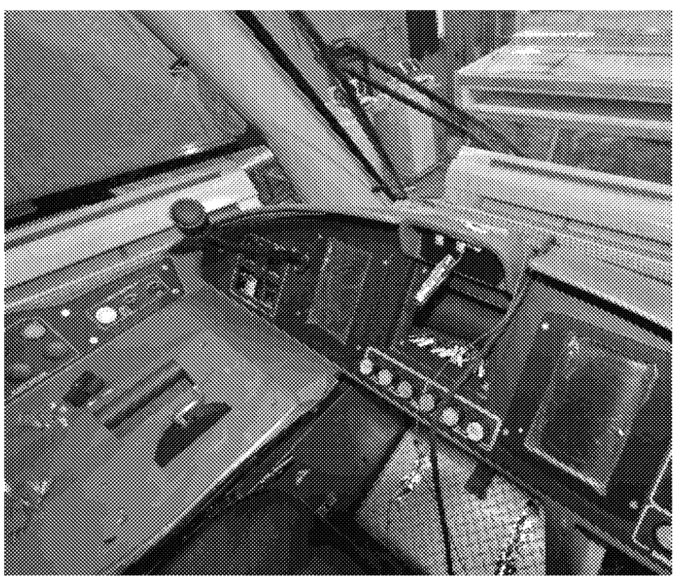


Figure 2 - Cabin Thermocouples and Loads Simulation

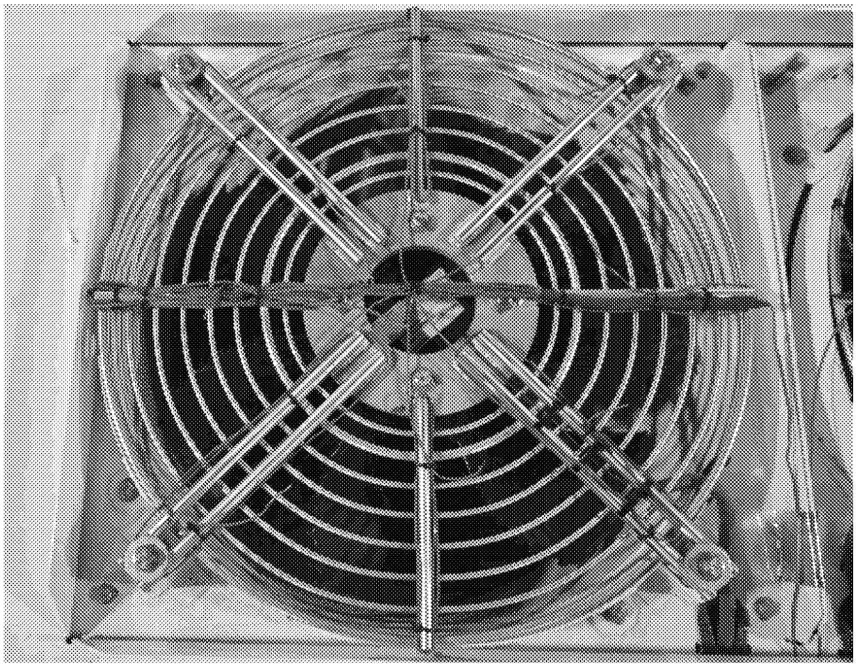


Figure 3 - Thermocouple Grid, HVAC Condenser Outlet

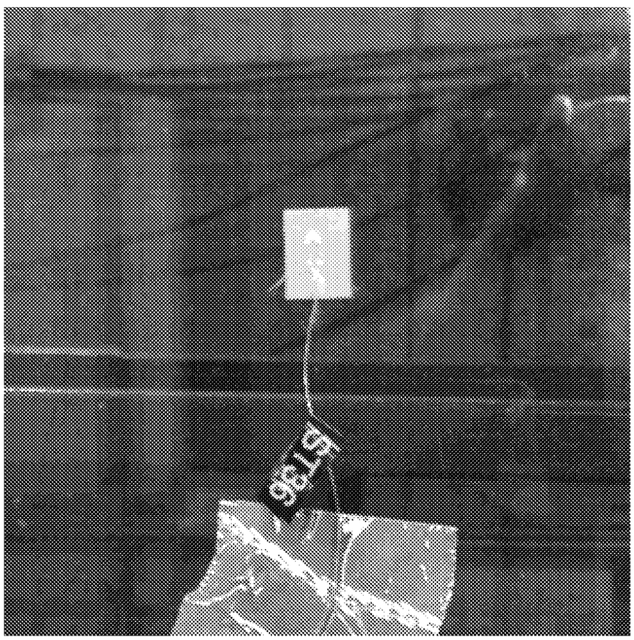


Figure 4 - Thermocouple, Window Glass Surface Temperature

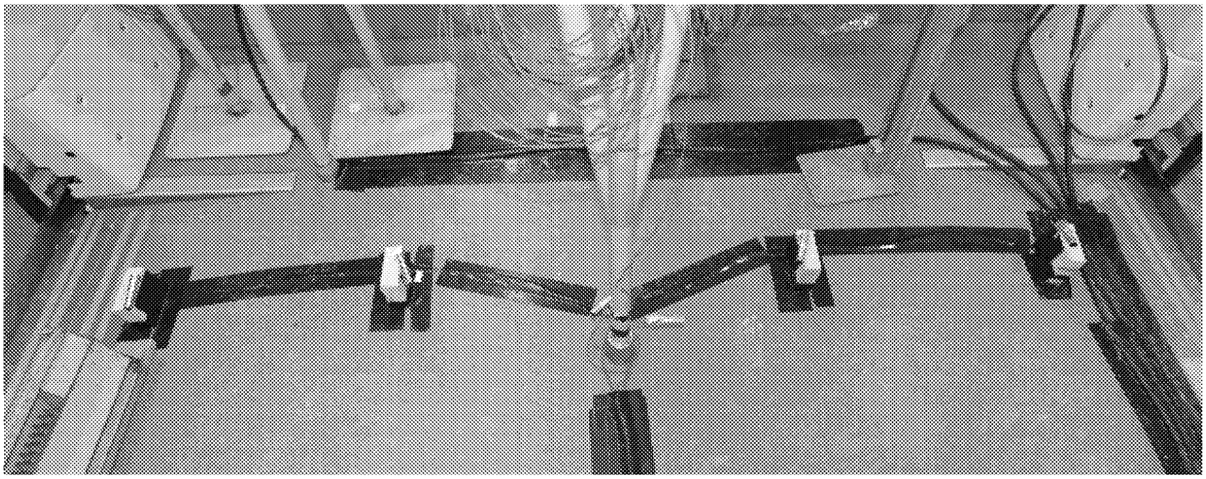


Figure 5 - Horizontal Gradient, Five Thermocouples @ 0.1m Height

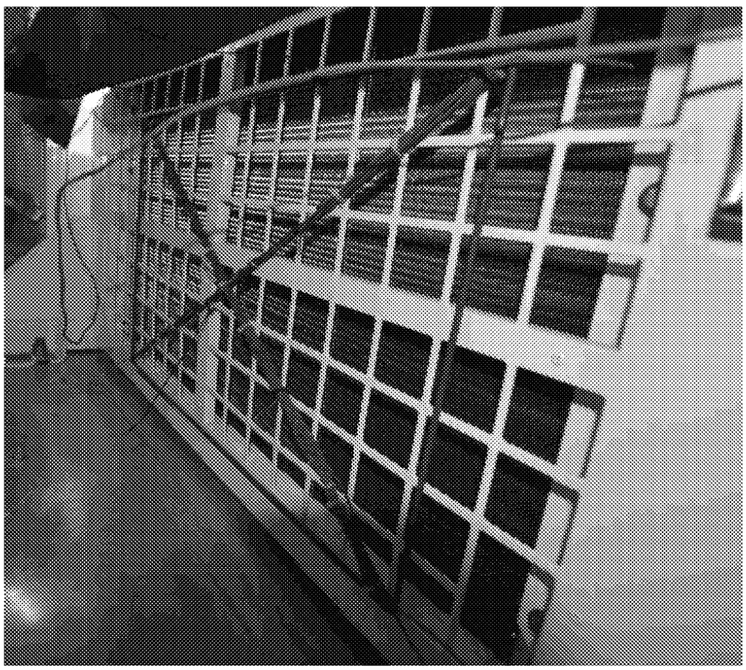


Figure 6 - Thermocouple Grid, HVAC Condenser Inlet

Electrical transducers were installed as specified to allow measurement of electrical inputs and outputs of the Auxiliary Power Supply (APS) system.

3 TEST INSTRUMENTATION

3.1 404 Trainset

The Citadis Spirit light rail vehicle 404 trainset is comprised of four car body sections; NRC received two of these car body sections from the 404 trainset for assessment (Figure 7); specifically the Long Motor Car (LMC2) and the Long Central Car (LCC).

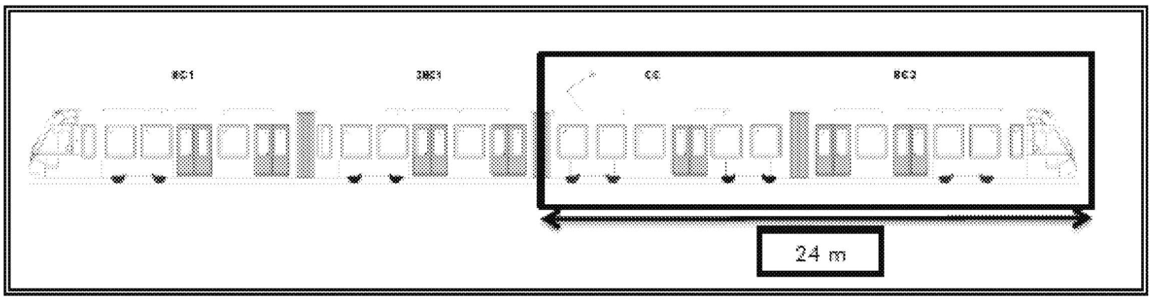


Figure 7 - 404 Trainset

The car under test was a complete vehicle from a structural and fitment standpoint with doors, lighting, air conditioning units and heating floors functional (Figure 8).

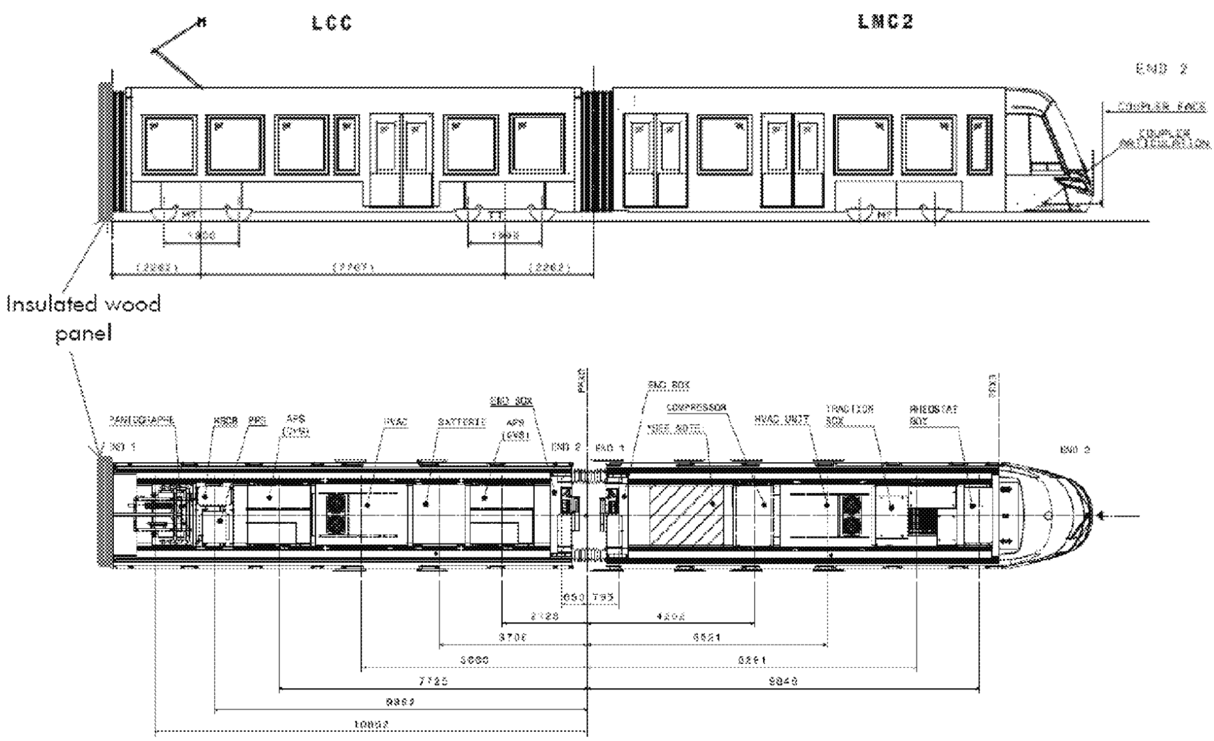


Figure 8 - LCC and LMC2 of 404 Trainset

3.2 Instrumentation

The NRC laboratory is equipped with the necessary instruments to ensure accurate measurements of all data recorded during the tests outlined in this document. To ensure continued accuracy, each instrument is recalibrated for the testing as required.

All test equipment used to conduct the tests is listed in Table 3.

- Instrument Type (i.e. Digital Voltmeter)
- Manufacturer, Model Number, and Serial Number
- Range Used (if applicable) and Accuracy
- Calibration Expiration Date

Table 3: Equipment and Instrumentation

INSTRUMENT	Serial #	RANGE	ACCURACY	CAL. EXPIRY
Data Acquisition system: 2 x IMC CRONOS	141862	NA	NA	08/18/18
	141863	NA	NA	08/18/18
Frequency Transducers: 3 x OSI AFT-FTA-002-01E	8051704 8051705 8031915	3 - 575V, 0-100 Hz	0.05% FS	08/27/17
Voltage Transducers: OSI 3VTR-004E	10071418	0-600V RMS	0.25% FS	08/24/2017
OSI 3VTR-002E	10071600	0-300V RMS	0.25% FS	08/24/2017
2 x OSI VT7-003E	6080968 06080969	0-50 VDC	0.25% FS	11/07/2018 10/28/2018
OSI VTH-020E	16110556	0-2500 VDC	±0.5% F.S.	11/01/2017
Current Transducers: 6 x OSI CTL-200T/CTA115	7112389 16103343 7112379 7112384 Y2882	0-200 A	0.5% FS	11/21/2018
2 x OSI CTL-202TS-1000/CTA201	11123403 11123404	0-1000 A	±0.5% F.S.	11/21/2018 06/16/2017

INSTRUMENT	Serial #	RANGE	ACCURACY	CAL. EXPIRY
Power Transducers: Moore PWV/600/5A/3E Moore PWV/240/5A/1E	1121991 1175163	0-600VAC, 5A, Three phase 0-240VAC, 5A, Single phase	0.19% of Reading/cos ϕ ± 0.01% FS	11/14/2018 09/08/2017
Thermocouples: *Interior of Car:* 25 at 5 positions down length of car for horizontal gradient @ 100mm height. 33 at 11 positions down length of car for vertical gradient @ 0.15m / 1.1m / 1.7m heights 24 at 4 positions down length of car for surface temperature 20 x duct interior *Exterior of Car:* UL Grid (6X 9 point) @ each fresh air and return air inlets UL Grid (8X 9 point) @ each condenser air inlet/outlet UL Grid (4X 9 point) @ each Mixed Air & Post-Heater 2 x APS internal temperature 2 x APS battery temperature 4 x HVAC suction/discharge temperature *Cabin:* 8 total in cabin *Chamber/Ambient:* 7 total spaced around car	Various	-270°C to + 400°C	Type T	05/17
Relative Humidity Probes: 6 x Vaisala HM337	E3630003 E4150235 E4150236 E4540204 E4540205 F1110127	-40°C to + 180°C, 0-100% RH	±0.2°C, ±(1.5+0.015 X Reading) % FS	08/24/17

3.3 Thermocouples

Type T thermocouples were positioned throughout the rail cars to measure temperatures in the following locations and configurations.

3.3.1.1 Vertical Gradient

At eleven separate cross sectional locations down the length of the LCC and LMC2 cars, three thermocouples were placed at 0.15m/1.7m heights from the floor and 0.2m from the ceiling as per Figure 9.

3.3.1.2 Horizontal Gradient

At five separate cross sectional locations down the length of the LCC and LMC2 cars, five thermocouples were placed at 0.1m height as per Figure 9.

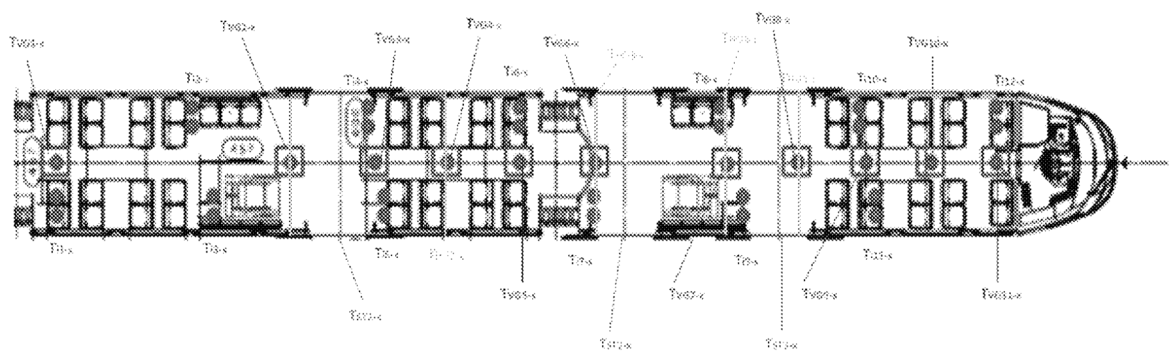


Figure 9 - Horizontal & Vertical Thermocouple Installations - Overview

3.3.1.3 Surface Temperature

At three separate cross sectional locations down the length of the LCC and LMC2 cars, a total of 24 thermocouples were placed as shown in Figure 10. Each of the end cross sections included six thermocouples and the middle cross section included twelve, with locations duplicated on each side (window frame, glass and side wall), floor and roof of the ceiling.

3.3.1.4 Cabin

Thermocouples were placed at the following locations:

- Head of driver
- Middle of both eyes of the driver
- Middle of both shoulders of the driver
- Right knee of the driver
- Left knee of the driver
- Right foot of the driver
- Left foot of the driver
- Middle of both hands of the driver, on the driver desk.

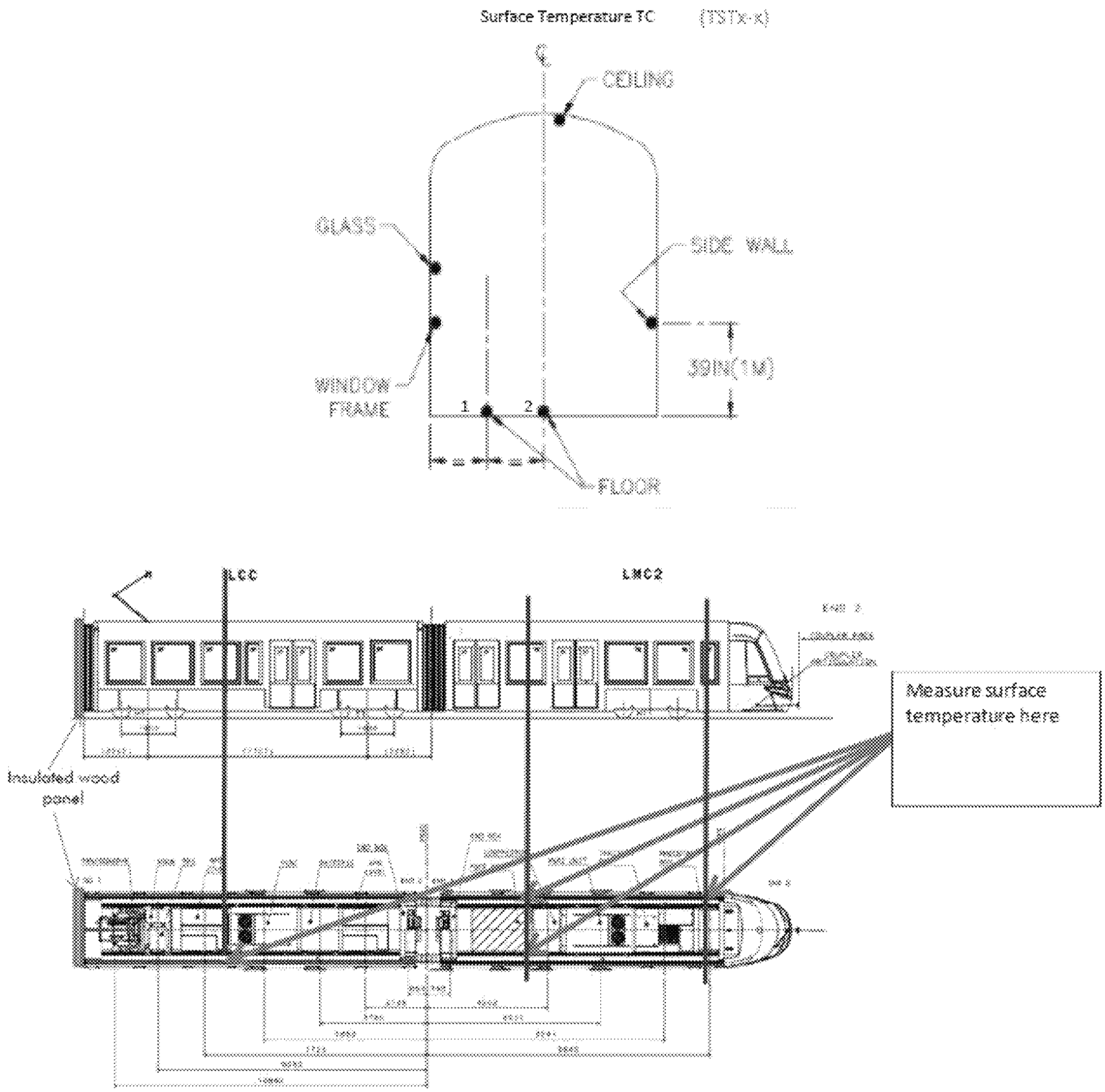


Figure 10 - Surface Temperature Thermocouple Placement - Cross Sections and Top View

4 DATA ACQUISITION

4.1 Data Acquisition System

Two multi-channel IMC Cronos Compact data acquisition systems coupled together (DAS) were used to record the instrumentation signals for these tests (Figure 11). The DAS is equipped with 24-bit sigma-delta converters that provide a 16-bit final resolution. All channels were simultaneously sampled at 1 Hz and filtered using a low-pass, analog 8-pole Butterworth anti-alias filter set at a cut-off frequency of 100 Hz. The DAS control software, Studio V5.0 by IMC was used to configure the DAS and record data during all tests.

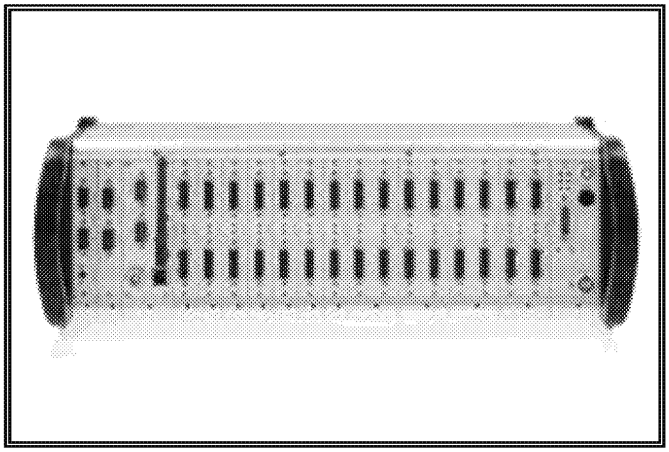


Figure 11 - Data Acquisition System

5 RESULTS

5.1 Climatic Conditions Tests

Chamber stabilization is achieved when the rate of change of the chamber temperature is less than 2°C per hour and the relative humidity is within ±5% of target. A steady state car internal condition is achieved when the rate of change of the temperature is less than 2°C per hour. Data recorded, where applicable, included the following.

- Temperature (°C)
- Relative Humidity (exterior and interior) (%)
- Power (W)
- Voltage (V)
- Frequency (Hz)

Water tightness checks where required were made in accordance with the methodology as per Table 4 and in locations as per Table 5.

Table 4: Water Tightness Controls

#	Description of the Control Mean
1	Visual Examination
2	Hand wiping showing traces of moisture on a finger
3	Wiping with a dry cloth or blotter

Table 5: Key Locations of Water Tightness Control

Element to Check	Type of Water Tightness Control	Comment
Booster on cab	3	
Side windows on cab	3	
Sliding windows on cab	3	
Windshield	3	
Third light and marker lights	2	Condensation water admitted on glass screen
Compartment windows	3	
Double Leaf doors (except junction between two leaves)	2	With isolated drops admitted
Junction of the bottom part of passenger door	1	Admitted water on the threshold
Mounting screws of the promontories bars	3	
End ring junction/roof	3	End ring / roof transversal beam + tightness of the closing sheet of the cantrail
End ring junction / side posts	3	
End ring junction / underframe	3	
Roof junction / side posts	3	

Element to Check	Type of Water Tightness Control	Comment
Cab end ring	3	
Interior of compartment and cab	3	
Gangway mounting profile/end ring	3	
Gangway bellow sewing	3	
Low voltage cabin cabinet	2	Condensation water admitted on inner wall
Low voltage end box	2	Condensation water admitted on inner wall
High voltage end connector box	2	Condensation water admitted on inner wall
Battery box	2	Condensation water admitted on inner wall
Traction/braking cubicle	2	Condensation water admitted on inner wall
APS (CVS) cubicle	2	Condensation water admitted on inner wall
HSCB box	2	
LV connections intercar cables boxes	2	
Carbody bogie connectors	2	
Tightness of side panels and fairing of bottom side panel	3	Inside car control
Compressor	2	Condensation water admitted on inner wall
Intercar Low Voltage Connection box	3	
Underframe low voltage connection boxes	2	
Cab cubicle and desk connections	2	
Upper part of the cab FRP	1	
Inlet of the sand boxes	3	
External crew switch and EAD	2	

5.1.1 *Climatic Conditions Test 1 thru Test 9*

For each test specified in Table 6, stabilization of environmental conditions was followed by a 10 minute interval during which the train was energized and visually inspected to assess functionality. Doors were cycled, all lights were activated (upper and lower headlights, marker lights), the HVAC unit was cycled through each mode and water tightness checks performed where applicable.

Table 6: Climatic Conditions Tests 1 - 9

Test Description	Date	Conditions				
		Solar kW	Snow/Rain mm/hr	Wind km/hr	Temp °C	Humidity %RH
Test 1 Climatic Condition Tests	Feb 8	15	0	0	38	10
Test 2 Climatic Condition Tests	Feb 8	15	0	100	38	10
Test 3 Climatic Condition Tests	Feb 8	15	0	180	38	10
Test 4 Climatic Condition Tests	Feb 13	0	0	0	-38	30-50
Test 5 Climatic Condition Tests	Feb 13	0	0	100	-38	30-50
Test 6 Climatic Condition Tests	Feb 13	0	0	180	-38	30-50
Test 7 Climatic Condition Tests	Feb 8	0	0	0	38	98
Test 8 Climatic Condition Tests	Feb 8	0	0	100	38	98
Test 9 Climatic Condition Tests	Feb 8	0	0	180	38	98

To demonstrate HVAC functionality, during each test the HVAC was cycled through its eight modes (four each in partial and full mode). The step changes in frequency, voltage and power as shown in Figure 12 show the full mode activations followed by partial mode activations at 45/50/55/60Hz.

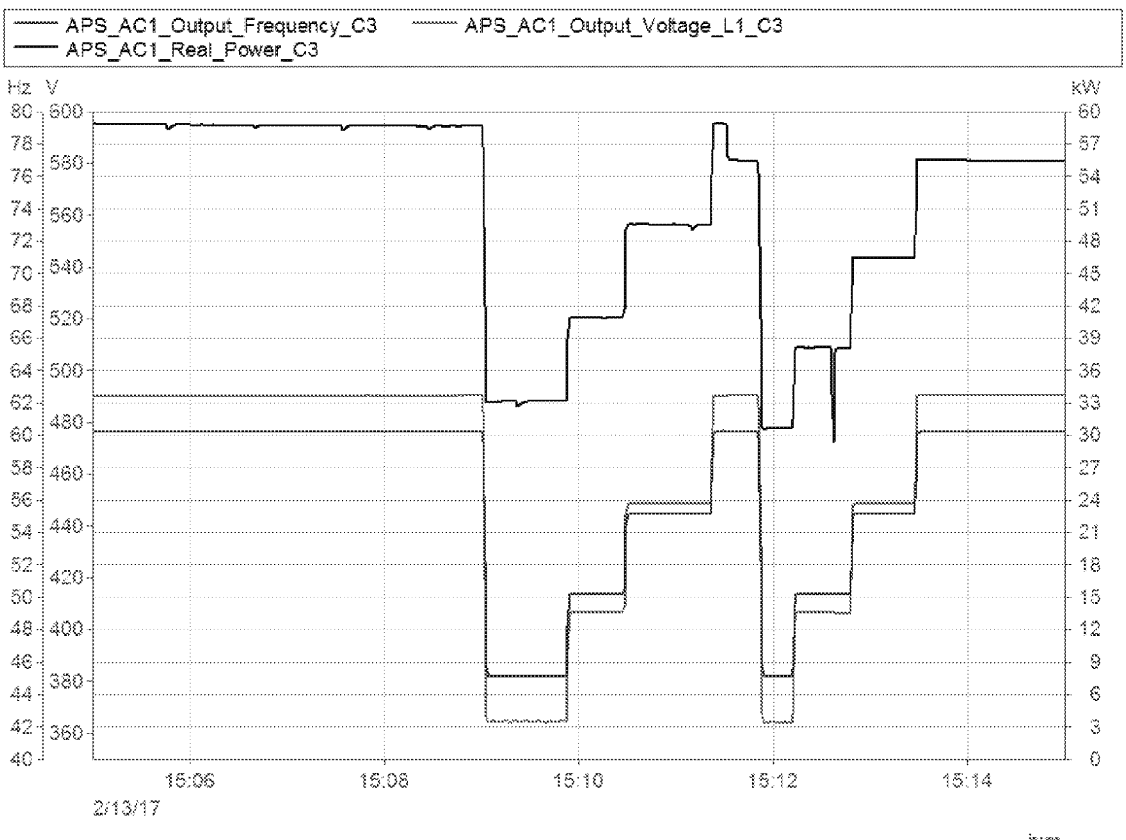


Figure 12 - Test 4, HVAC Functionality @ 45/50/55/60Hz Full and Partial Modes

To demonstrate Heated Floor functionality during Tests 7 to 9, it is observed that 6.0kW of power was drawn on the 120V circuit as shown in Figure 13

Figure 13 - Test 4, Heated Floor Functionality

With respect to moisture ingress as shown in Figure 14, water drops were observed during Test 7 at the LMC2 Doors and at the sliding doors in the LMC2 cab during Test 9 with 100+ km/hr wind directed at the nose of the LMC2 car.

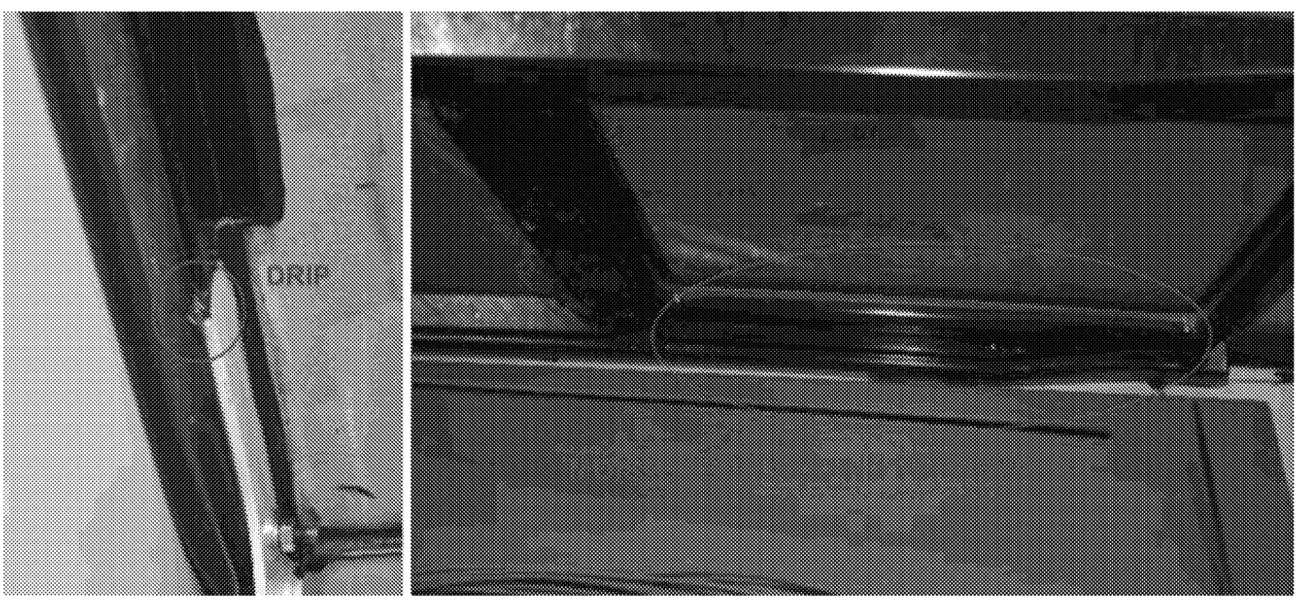


Figure 14 - Tests 7 and 9, Moisture Ingress

5.1.2 ***Test 13 and 14 - 30-50% RH, 0-100 kph Wind, 20°C, Rain 60mm/hr***

Chamber temperature set points were set to achieve 20°C and 30-50% RH with wind at approximately 100+ km/hr generated and targeted at a small area on the nose of the car at the bottom of the windshield. After stabilization of environmental conditions, rain for 20 minutes at a rate of 60mm/hr was directed over the length of the Long Motor Car (LMC2) in 2m sections on both sides and the roof in accordance with MIL–STD-810G, Test Methods 506.5, Rain, Procedure II, using nozzles arranged in a square pattern approximately 48cm from the test surface as shown in Figure 15.

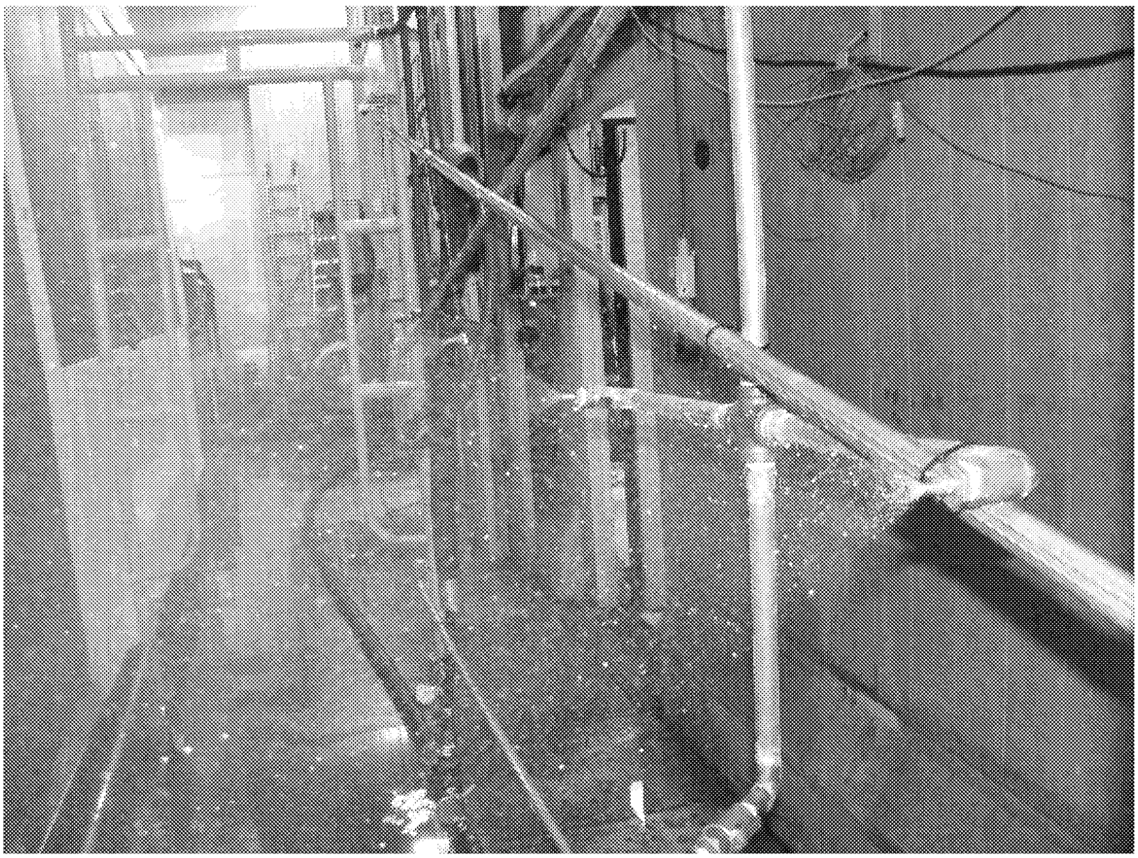


Figure 15 - Test 13, Rain @ 60mm/hr

Subsequently the rain and wind was terminated and the train energized and visually inspected to assess functionality and water tightness. Doors were cycled and all lights were activated (upper and lower headlights, marker lights). With instrumentation removed from the train, electrical measurements were not available to demonstrate full HVAC functionality.

With respect to moisture ingress as shown in Figure 16 and Figure 17, water drops or pooling were observed throughout both the LMC2 and LCC at window and door seals, as well as the gangway promontory bar and the cab sliding doors. Water tightness checks on the external of the cars including the various rooftop electrical and mechanical boxes revealed no water ingress.

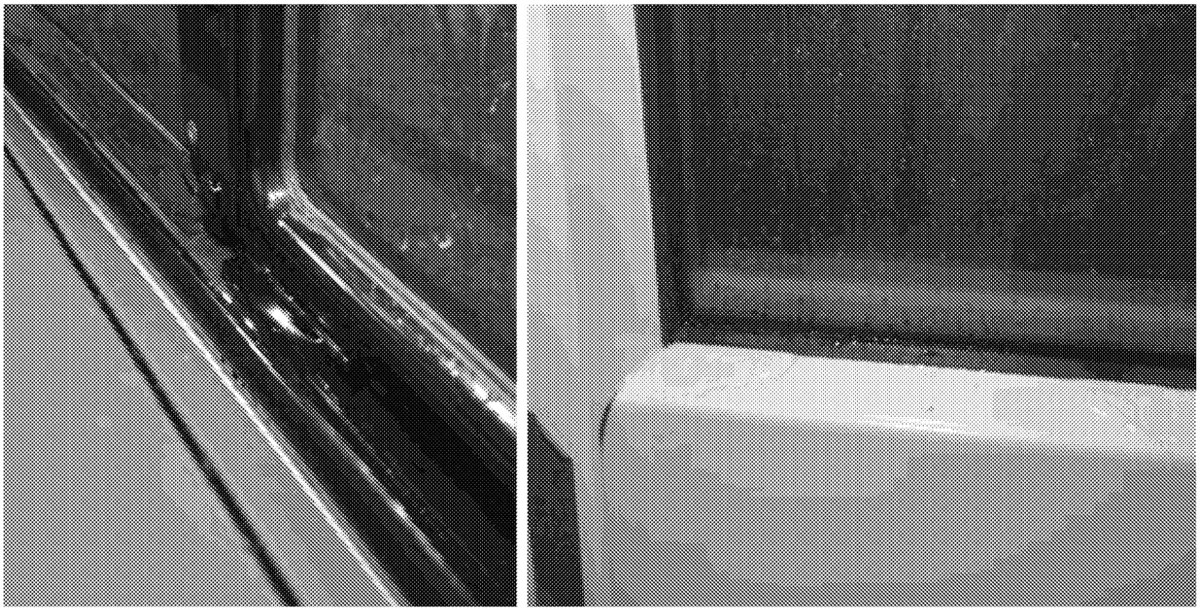


Figure 16 - Water Ingress at Cab Sliding Doors and LMC2 Window

Figure 17 - Water Ingress at LCC Door and Gangway Promontory Bar

5.1.3 ***Test 15 - 30-50% RH, 0 kph Wind, -20°C, Freezing Rain 5mm/hr***

Freezing Rain testing was performed February 2nd as per the original test plan with 6mm of ice accumulated on the doors and the windshield frosted as per the SAE specification. Subsequently, Alstom instructed the door ice accumulation test be repeated on February 14th with 3mm of ice accumulated on the door at -10°C.

Chamber temperature set points were set to achieve -20°C, with ice applied to the LMC2 doors in accordance with MIL–STD-810G, Test Methods 521.3, Icing/Freezing Rain, Procedure 4.5.2 starting at 07:05 on February 2nd. Average Chamber, Car and Cab temperatures through the duration of the test are shown in Figure 18.

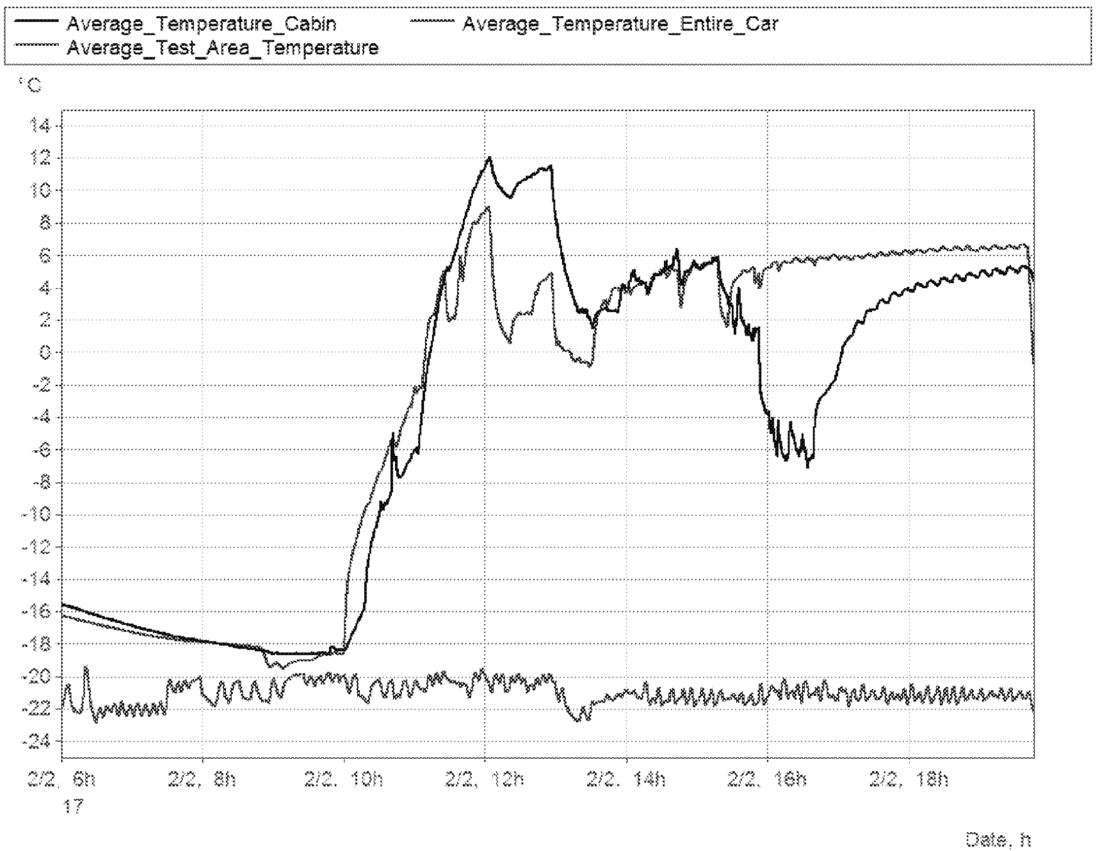


Figure 18 - Test 15, Average Temperatures

In approximately 190 minutes, 6mm ice had accumulated as shown in Figure 19. At the conclusion of the icing, at 10:00 the HVAC was set in layover mode to increase the car temperature to 4°C to 8°C.

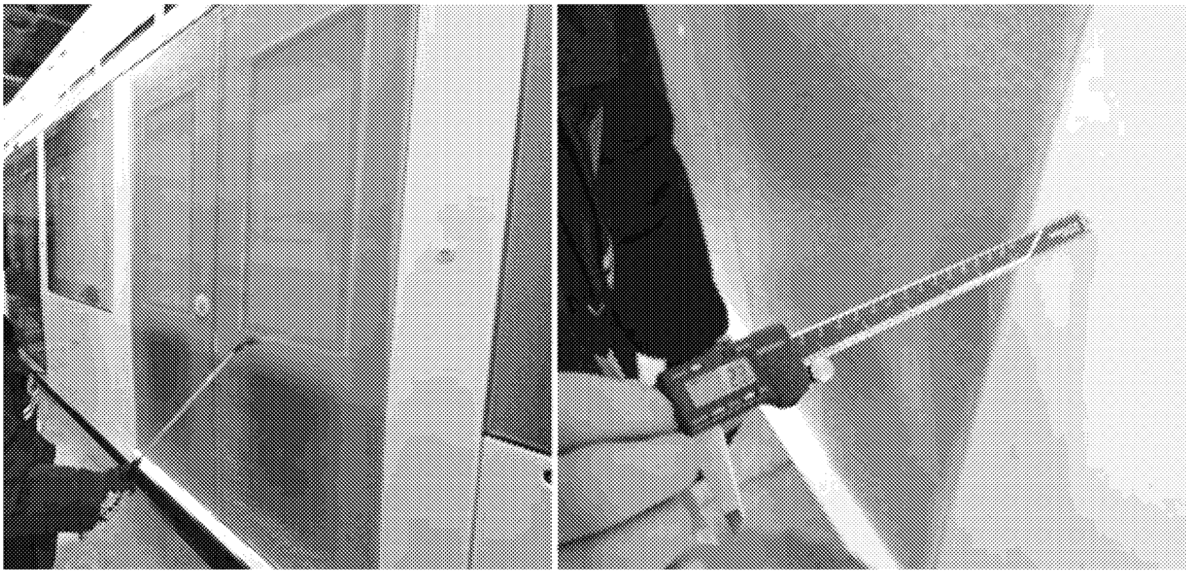


Figure 19 - 6mm Ice Door Application

Simultaneously, the external surface of the windshield was frosted using a handheld sprayer as per SAE J381 to spray 0.05mL of water per square centimeter and form an even coating of ice over the entire glass surface as shown in Figure 20.

Figure 20 - Nominal Defrost Test, Windshield Frosted

At 10:55, within 40 minutes of completing the windshield frosting, the defrost commenced with the defroster set In nominal mode. The evolution of the defrost is shown In the Figures below, with pictures spaced five minutes apart starting at 25 minutes when visible signs of defrost were evident until the defrost was deemed complete after approximately 68 minutes at 12:03. After approximately 50 minutes a first wipe attempt was made.

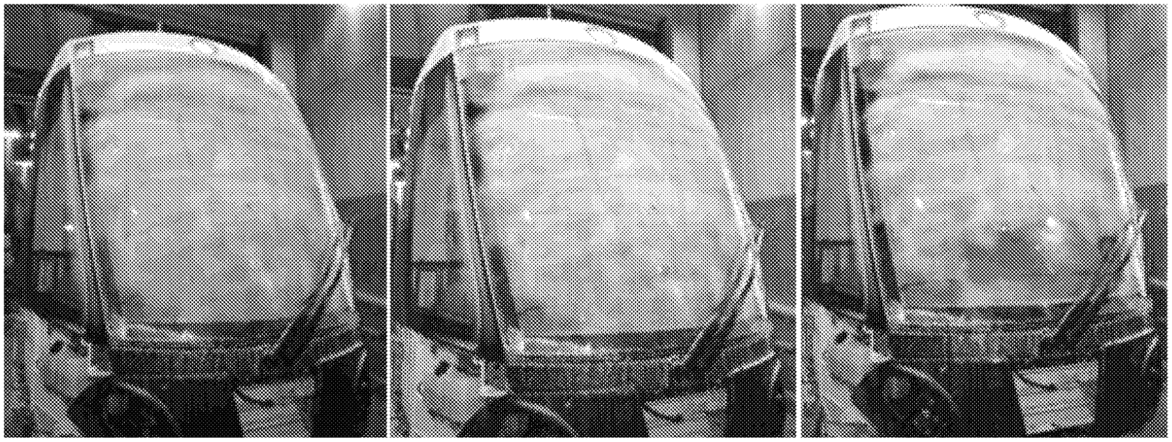


Figure 21 - Defrost Nominal Mode, 25/30/35 Minutes

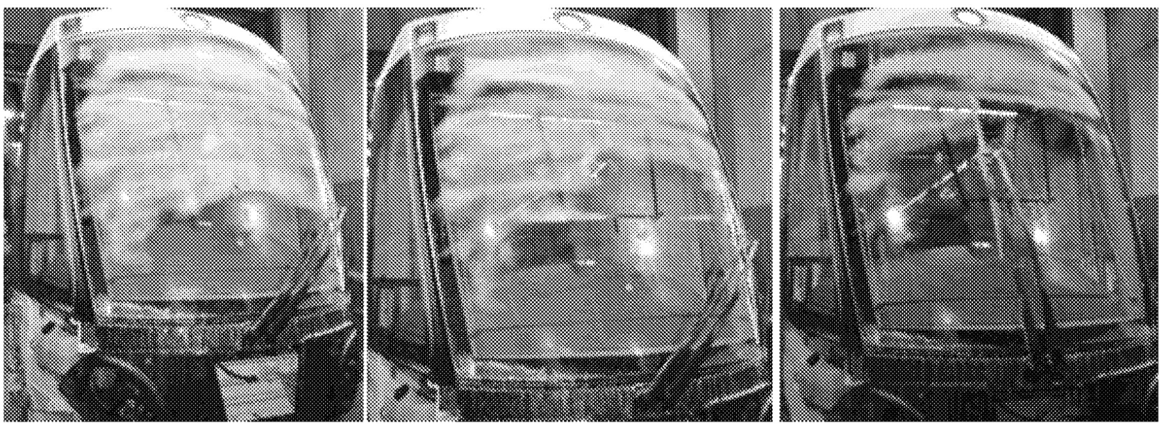


Figure 22 - Defrost Nominal Mode, 40/45/50 Minutes

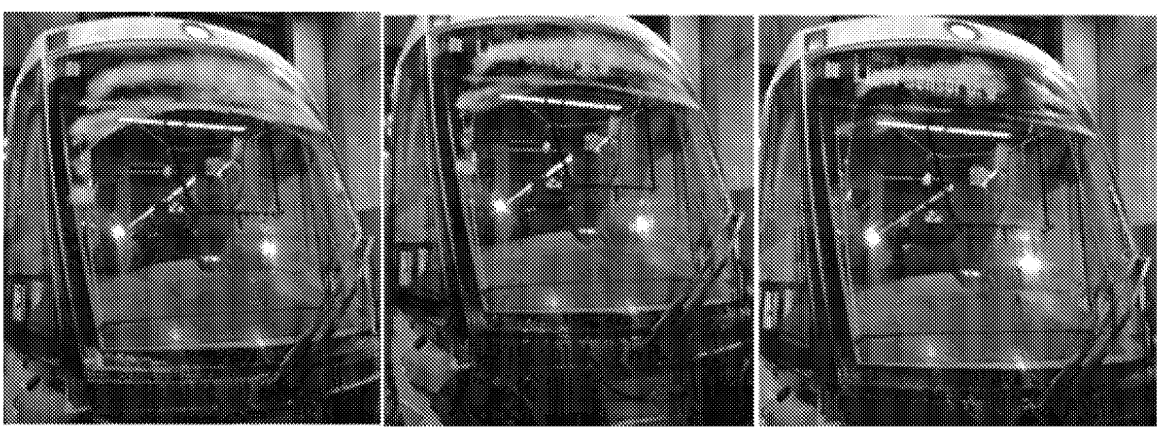


Figure 23 - Defrost Nominal Mode, 55/60/68 Minutes

At 11:01 the first of multiple door cycling attempts was made without the doors opening as shown in Figure 24.

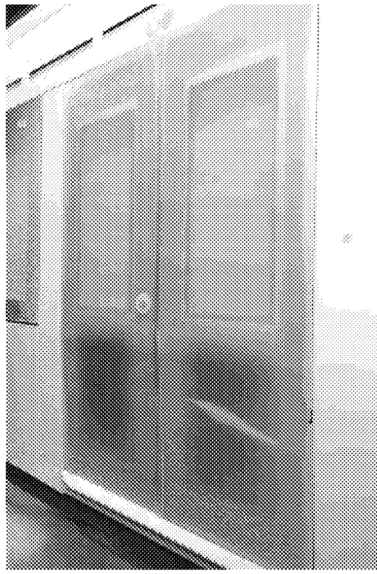


Figure 24 - Door Opening Attempt

At 16:10, with the cab temperature at -5°C (measured 2.5cm from the windshield) as instructed by Alstom, the external surface of the windshield was frosted a second time as shown in Figure 25 and allowed to harden until 16:50, at which time defrost was activated in degraded mode (without cab heater).

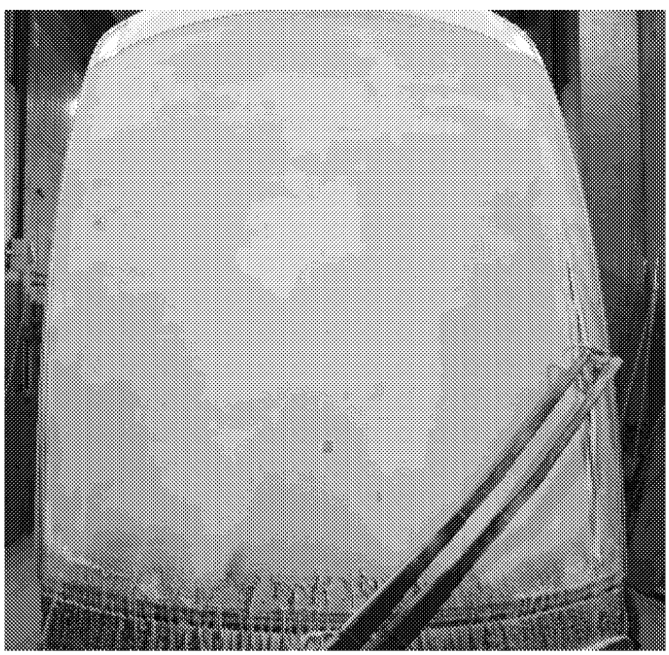


Figure 25 - Degraded Mode Defrost Test, Windshield Frosted

The evolution of the defrost is shown In the Figures below, with pictures starting at 60 minutes and spaced 30 minutes apart until the defrost was deemed complete after approximately 162 minutes at 19:32. After approximately 131 minutes a first wipe attempt was made.

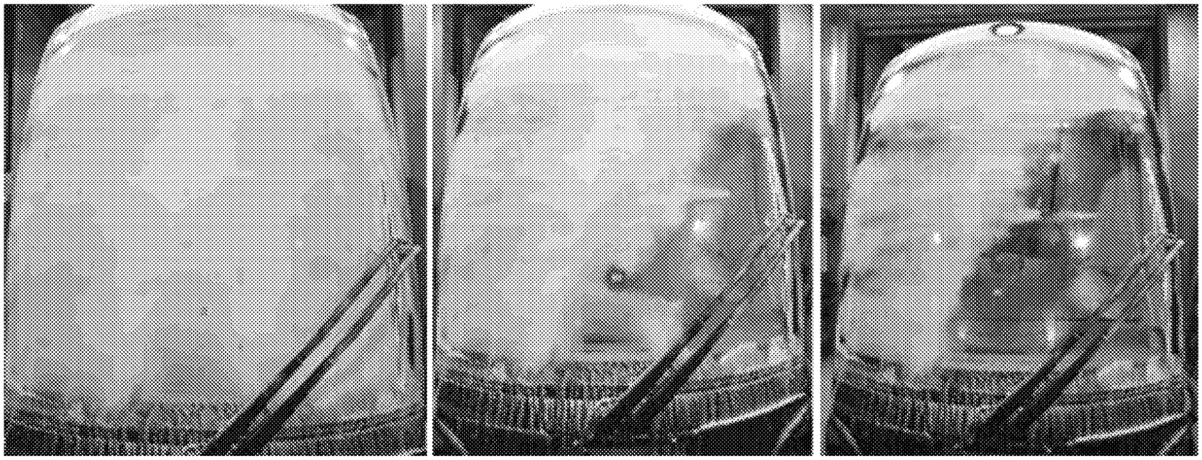


Figure 26 - Defrost Degraded Mode, 60/90/120 Minutes

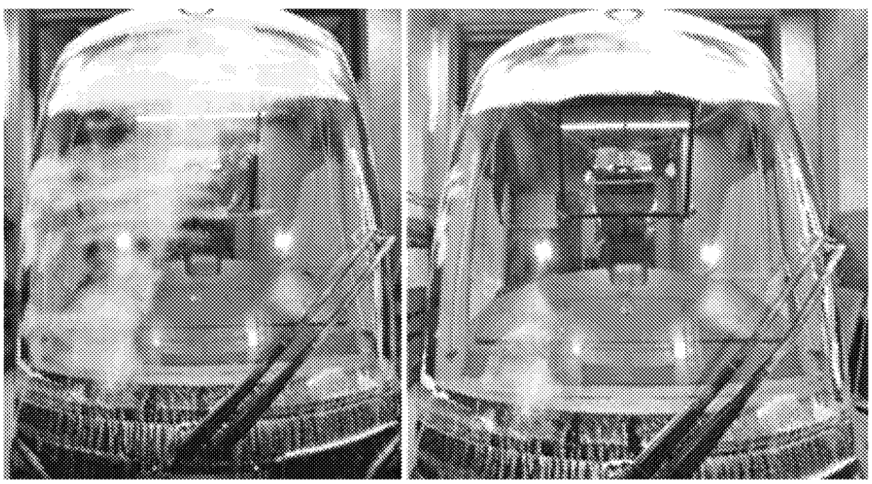


Figure 27 - Defrost Degraded Mode, 150/180 Minutes

On February 14th, the door ice accumulation test was repeated, with the car in layover mode, the Car Temperature at 5°C and the Chamber Temperature at approximately -10°C as shown in Figure 28.

Initial attempts to accumulate ice on the door at 08:00 were unsuccessful due to the temperature being above 0°C. An external fan was directed at the door, subsequently in approximately 120 minutes, 2.7mm ice had accumulated as shown in Figure 29. At 10:33 the second door cycling attempt was made with the doors successfully opening.

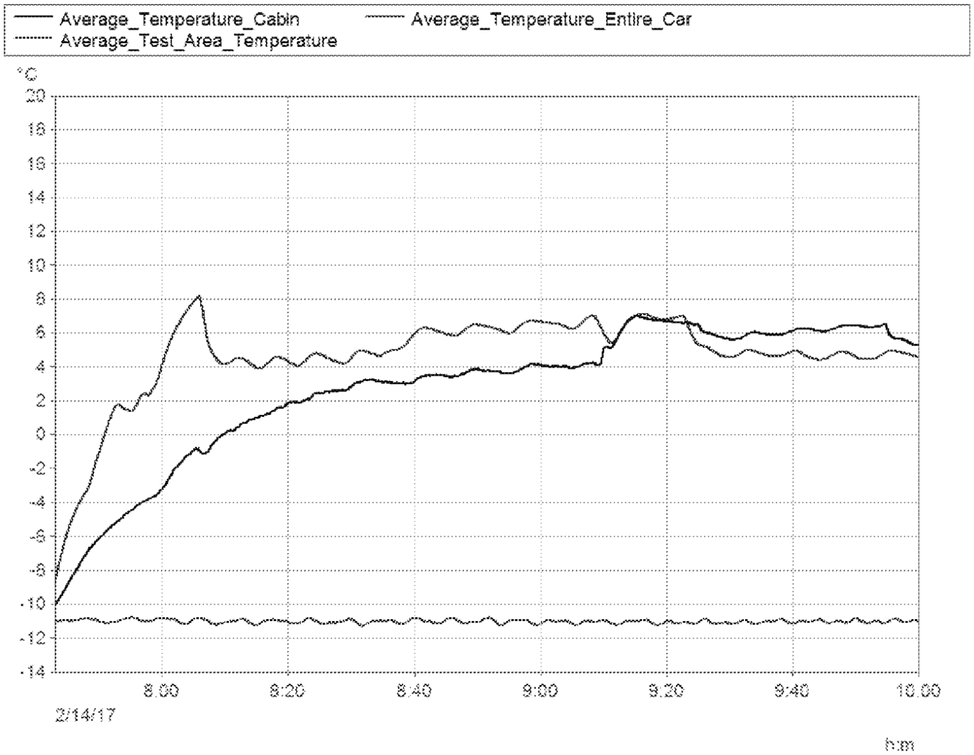


Figure 28 - Test 15 Repeat, Average Temperatures

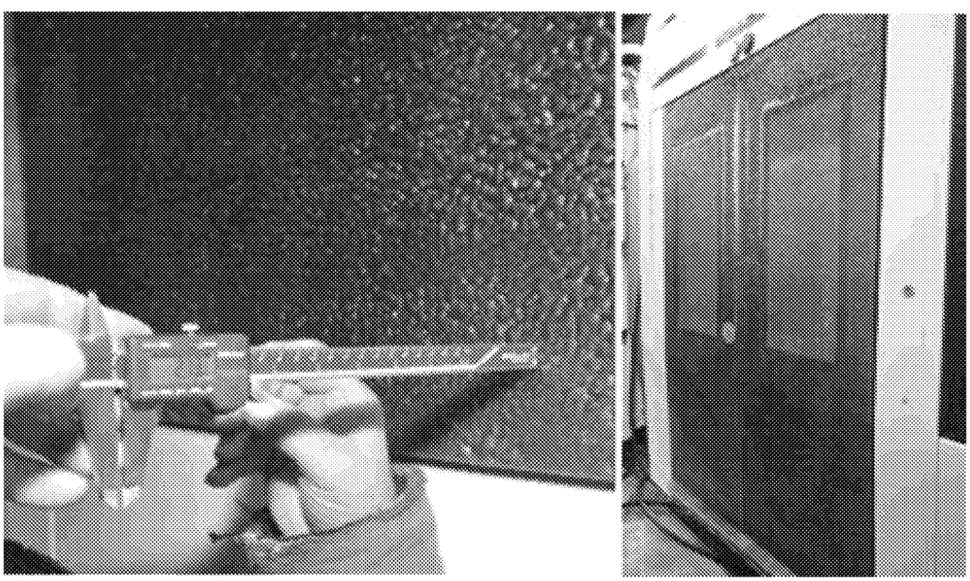


Figure 29 - 2.7mm Ice Door Application

5.1.4 *Test 16 thru Test 18 - 30-50% RH, 0-100 kph Wind, -10°C to -25°C, Snow 55mm/hr*

Chamber temperature set points were set to achieve -10°C to -25°C, with snow at a rate of 55mm/hr directed over the entire Long Motor Car (LMC2) and specifically at the following locations;

- HVAC fresh air inlet
- Horn - performance assessed when packed with snow
- Condenser
- Passenger doors
- Driver's window

Average Chamber, Car and Cab temperatures through the duration of the test are shown in Figure 30.

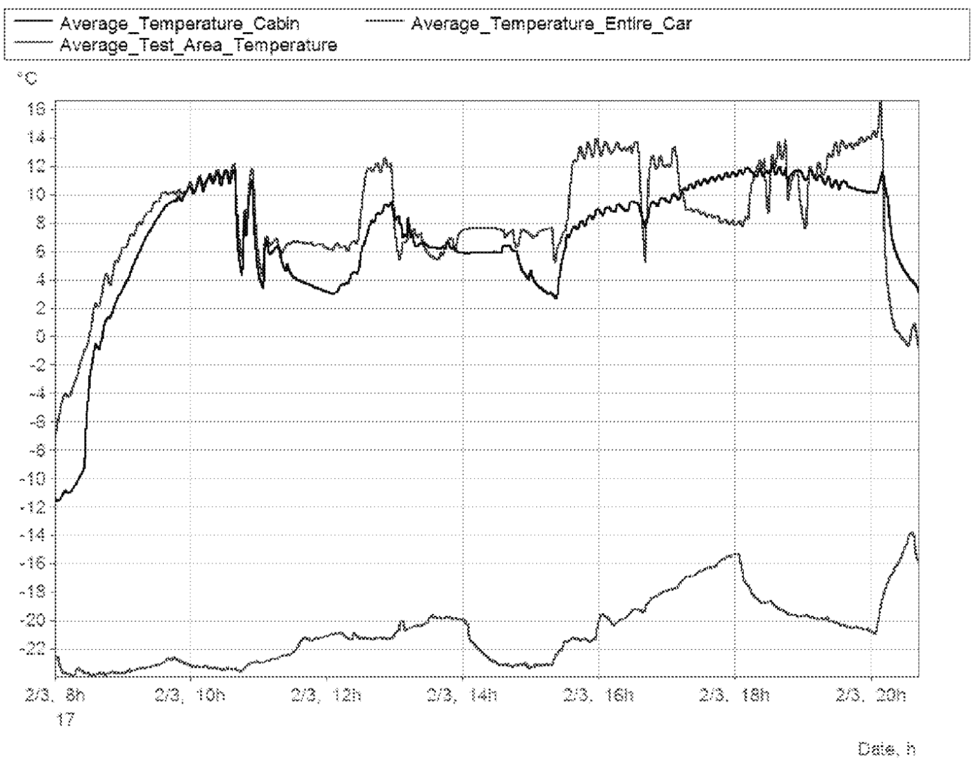


Figure 30 - Test 16 to 18, Average Temperatures

Subsequently the snow was terminated and the train energized and visually inspected to assess functionality and water tightness. The windshield wipers were activated with approximately 7cm of snow accumulation as shown in Figure 31 for three minutes.

Figure 31 - Windshield Snow Accumulation and Wipe

With the Horn packed as shown at the top in Figure 32, it was operated and audible.

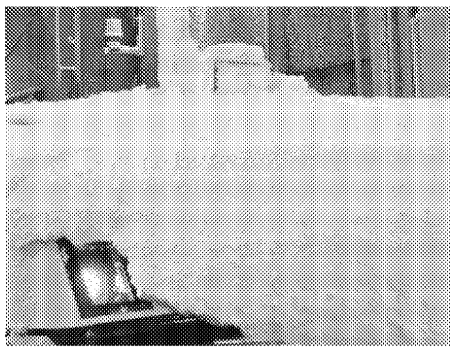


Figure 32 - Horn Packed with Snow

Accumulation of snow on the LMC2 door is shown in Figure 33, subsequent water tightness checks indicated no moisture ingress to the car interior.

Figure 33 - LMC2 Door Snow Accumulation

Accumulation of snow on the HVAC condenser fan and HVAC fresh air inlet is evident in Figure 34 and Figure 35, with the fresh air proportion difficult to ascertain based on the extent of snow ingress.

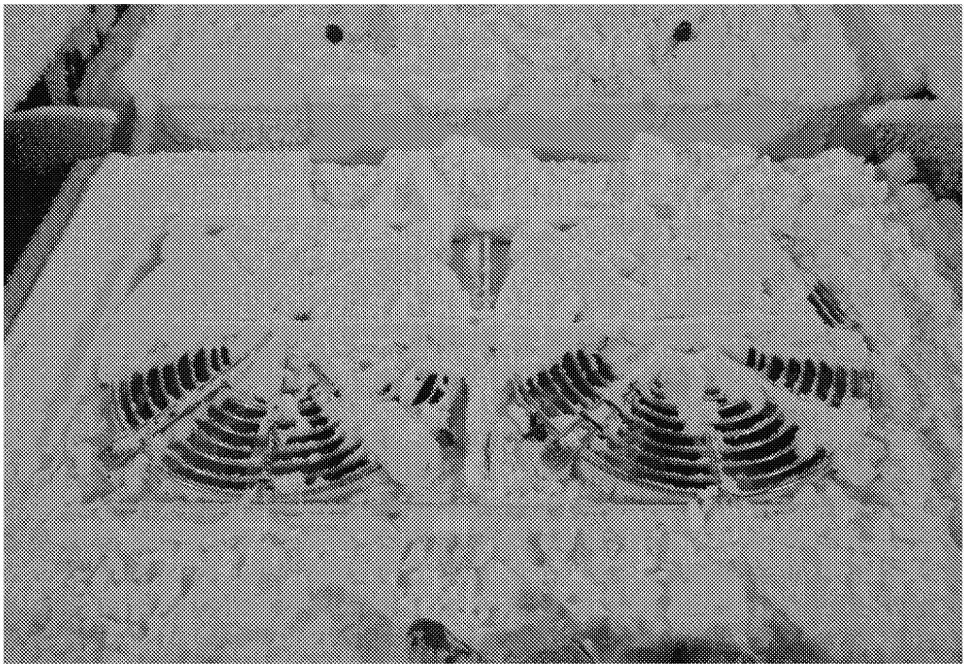


Figure 34 - HVAC Condenser Fan Snow Accumulation

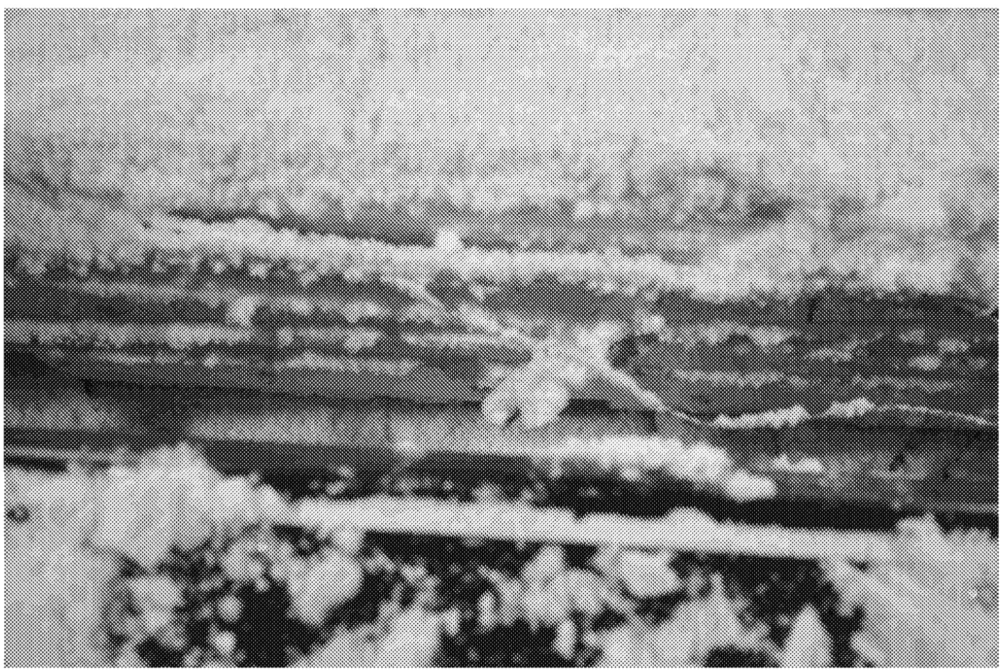


Figure 35 - HVAC Fresh Air Inlet Snow Accumulation

5.2 Climate Comfort Tests

Tests within this section were performed to ensure that the capacity of the climatic comfort equipment is acceptable. Resistive heaters installed within each car body were used to simulate sensible heat exhausted by passengers, and vapour generators were used to simulate latent heat exhausted by passengers (combined total of 132W/passenger, or 450Btu/hr/passenger, with different ratios of sensible to latent heat). Data recorded, where applicable, included the following;

- Temperature
- Relative Humidity (exterior and interior)
- Solar power
- Sensible heat
- Latent heat

After reviewing preliminary test results, Alstom made a modification to the HVAC diffusers to reduce the saloon diffuser area by approximately 1/3 using tape as shown in Figure 36 in an effort to improve the gradient differentials. This modification was made on February 4th, accordingly all testing except §5.2.2 Climate Investigation Test, §5.2.5.7 Procedure G and 5.2.5.10 Procedure J occurred after this modification was implemented.

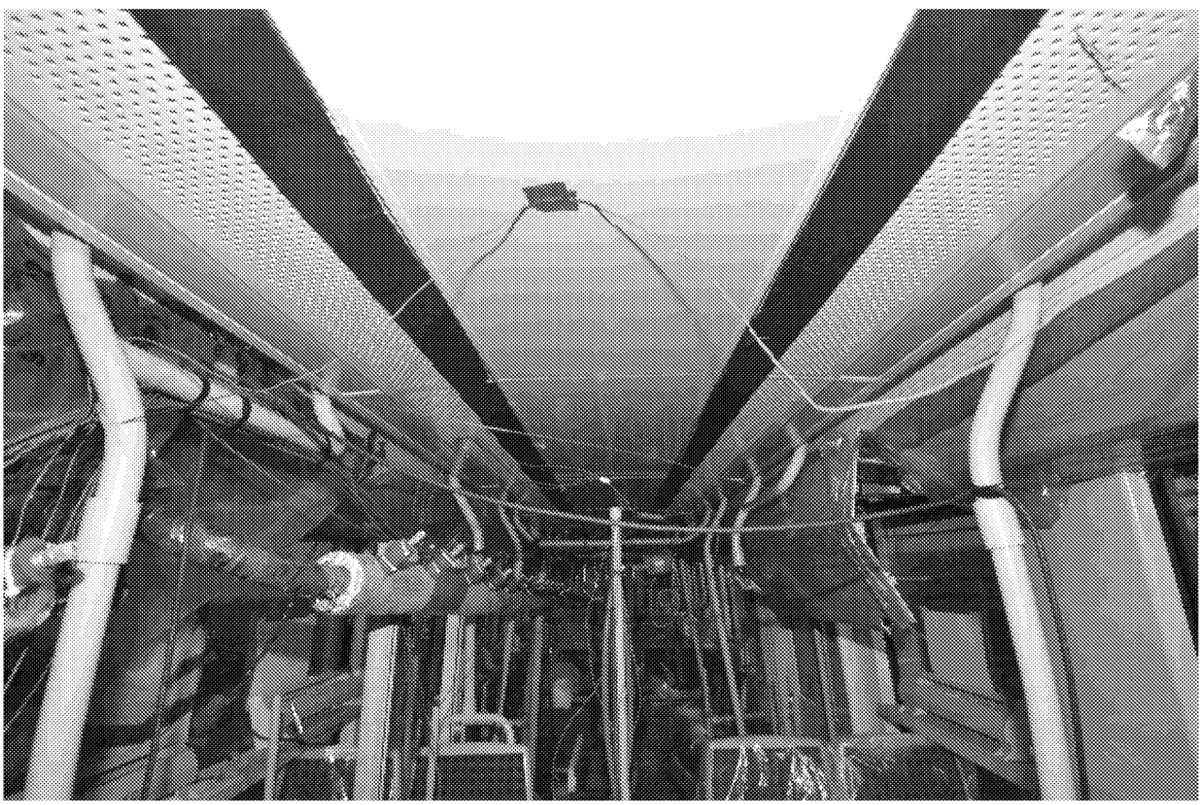


Figure 36 - Diffuser Modification, Area Reduction Using Tape

5.2.1 ***Pre-Heating Test - No passenger load, -22°C External temperature***

5.2.1.1 Purpose

The purpose of the Pre Heating Test was to ensure a minimum interior temperature of 16°C can be reached and record the time required to do so upon start-up.

5.2.1.2 Results

Chamber temperature set points were set to achieve a temperature of -22°C, with no passenger load applied, fresh air dampers and doors closed. Prior to starting the pre-heating test and following a minimum eight hour soak period, the Mean Interior Temperature (T_{im}) and Surface Temperatures (-20.5°C < T_{im} & T_s < -22.5°C) were stabilized for at least 15 minutes within ±2°C of the Mean Exterior Temperature (T_{em} = -22.4°C average) as shown in Figure 37.

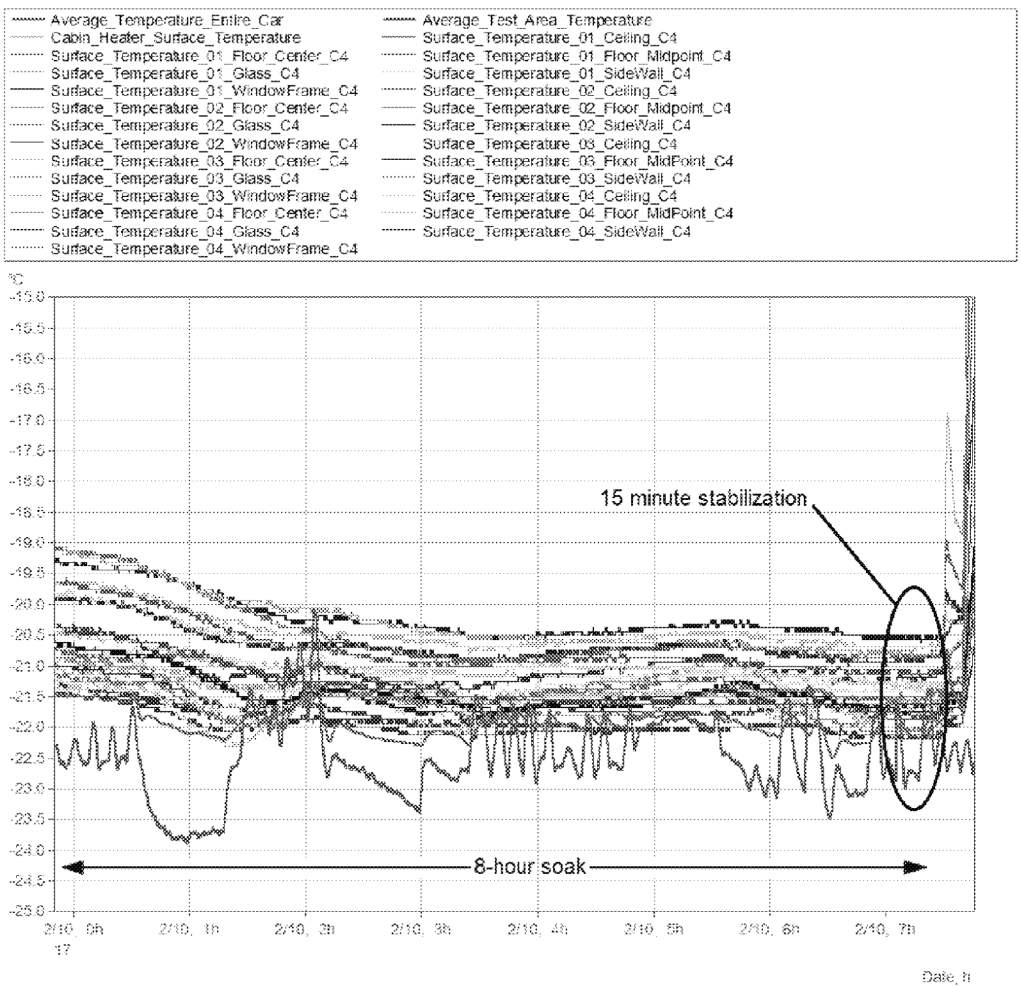


Figure 37 - Pre-Heating Test Temperatures, 8 Hour Soak Period

After energizing the train at 07:44, the Saloon and Booster Unit were set on low speed, with the Cabin Auxiliary Heater On and set to High Speed and High Temperature. As shown in Figure 38 at 11:03, after 199 minutes, T_{im} exceeded and remained above 16°C. The average temperature in the Cabin, LMC2 and LCC exceeded and remained above 16°C at 09:46, 10:21, and 13:12 respectively.

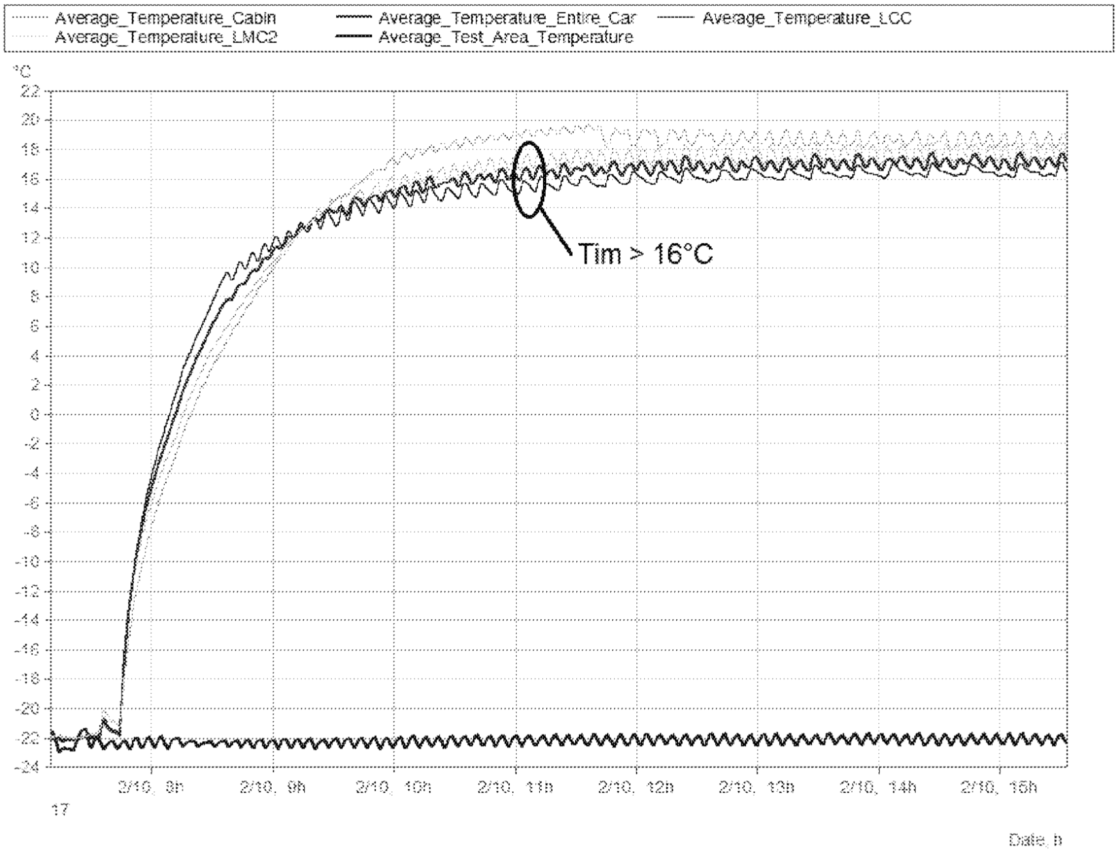


Figure 38 - Pre-Heating Test, Average Temperatures

5.2.2 *Climate Investigation Test - Thermal Gradients*

5.2.2.1 Purpose

The purpose of the Climate Investigation Test, for information only, was to evaluate the performance of additional heaters placed in the vestibule/handicap accessible area with respect in particular to vertical thermal gradients and the configuration of the HVAC system. The Climate Investigation Test was performed prior to the diffuser modifications which were made on February 4th.

5.2.2.2 Results

Chamber temperature set points were set to achieve a temperature of -22°C, with no passenger load applied, fresh air dampers and doors closed. Four 220V resistive heaters were installed, two each in the LMC2 and LCC cars in the handicap zones, with total power <2kW per car (<4kW in total) as shown in Figure 39, and supplied by an external source.

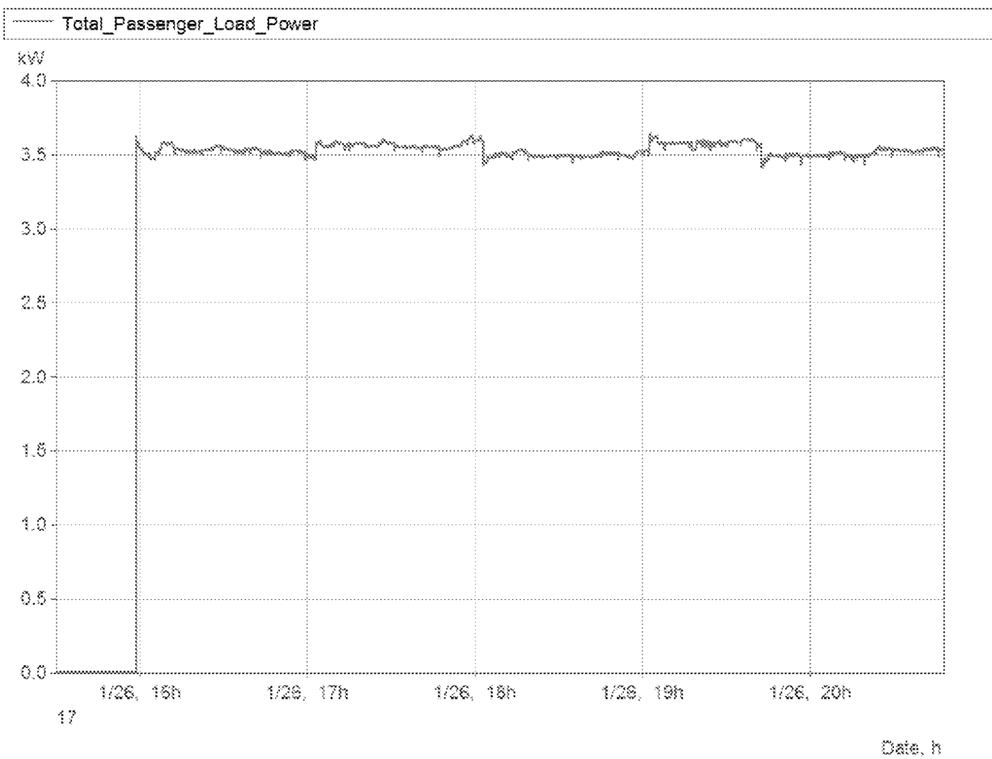


Figure 39 - Power Output, Additional Heaters in LMC2 and LCC cars

After an aborted attempt to complete the Pre-Heating Test due to power supply instability, the low voltage circuit breakers were used to disable the heated floor and the doors opened to remove residual heat from the floors at 14:56 as shown in Figure 40. At 15:58 the doors were closed and the HVAC energized, with temperature gradients recorded. Vertical gradients at T_{VG2} and T_{VG7} located as shown in Figure 9 are nearest to the handicap zones, and were used to assess the performance of the added heaters in comparison to the heated floors. At 20:48 the temperatures were deemed sufficiently stabilized for comparison, with minimal difference observed between the gradients achieved with heated floors (at 13:49) versus without heated floors and the additional resistive heaters (at 20:48).

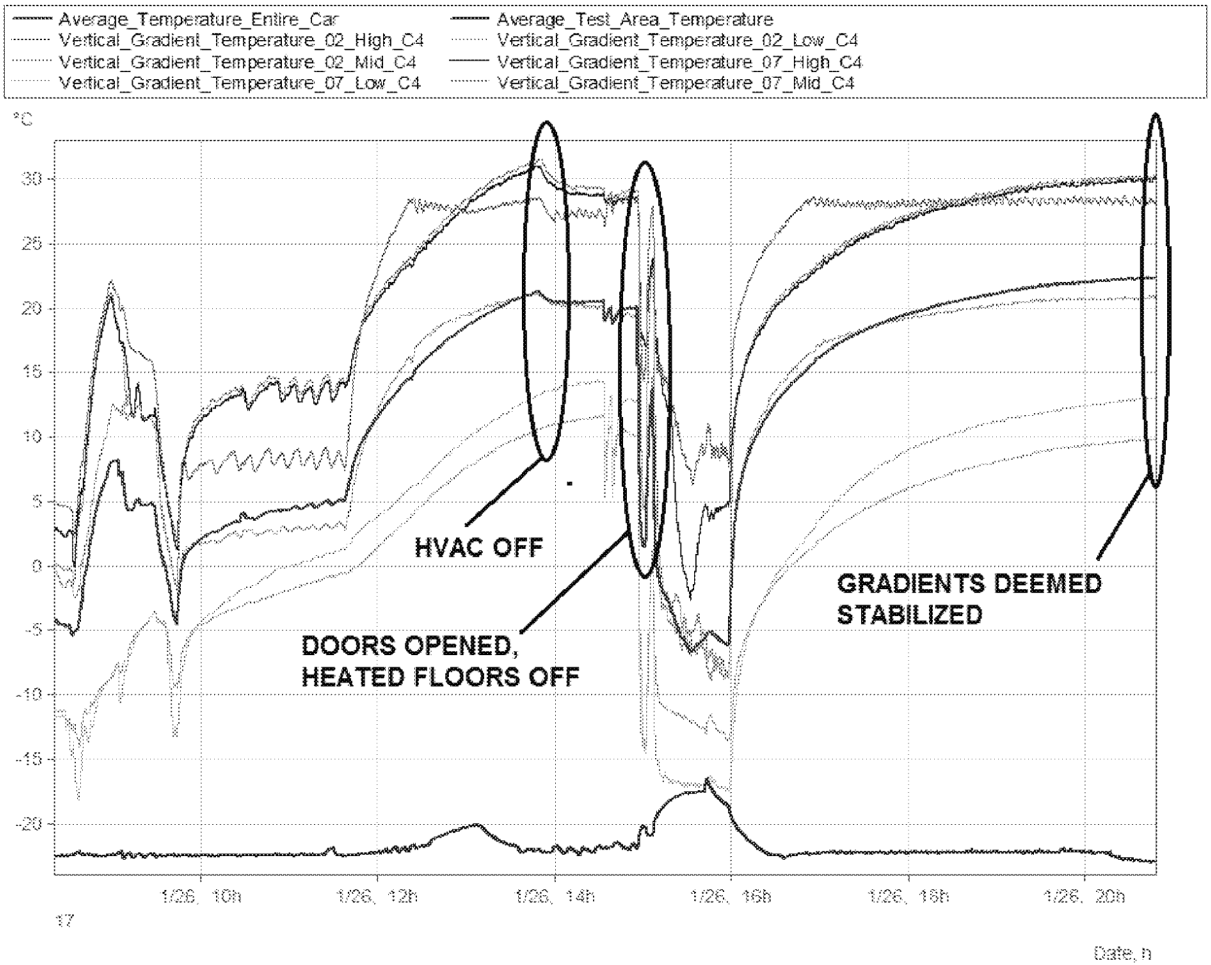


Figure 40 - Climate Investigation Test, Interior Average and Vertical Gradient Temperatures

5.2.3 ***Pre-Cooling Test - No passenger load, 28.9°C, 48% RH, 15 kW Solar***

5.2.3.1 Purpose

The purpose of the Pre Cooling Test was to record the time required to reach a T_{im} (Mean Interior Temperature) of 22°C with the T_{em} (Mean Exterior Temperature) set at 28.9°C, 15kW of solar load applied and no passenger load.

5.2.3.2 Results

Subsequent to the chamber achieving steady state conditions at a T_{em} of 28.9°C, the fresh air dampers and doors were closed and the train was soaked for eight hours as shown in Figure 41.

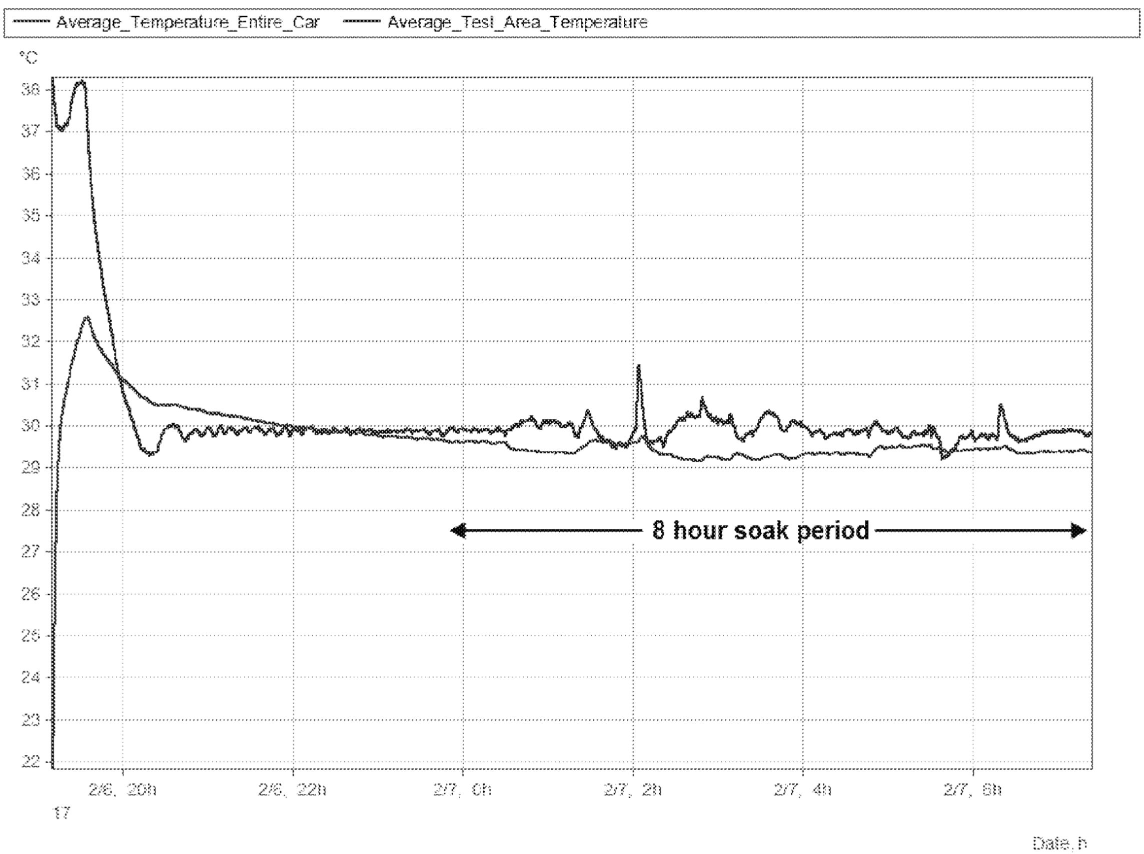


Figure 41 - Pre-Cooling Test Temperatures, 8 Hour Soak Period

At the conclusion of the soak period at 07:41, with no passenger load, 14.5kW of solar was applied for two hours with external humidity conditions controlled to 48% RH as shown in Figure 42.

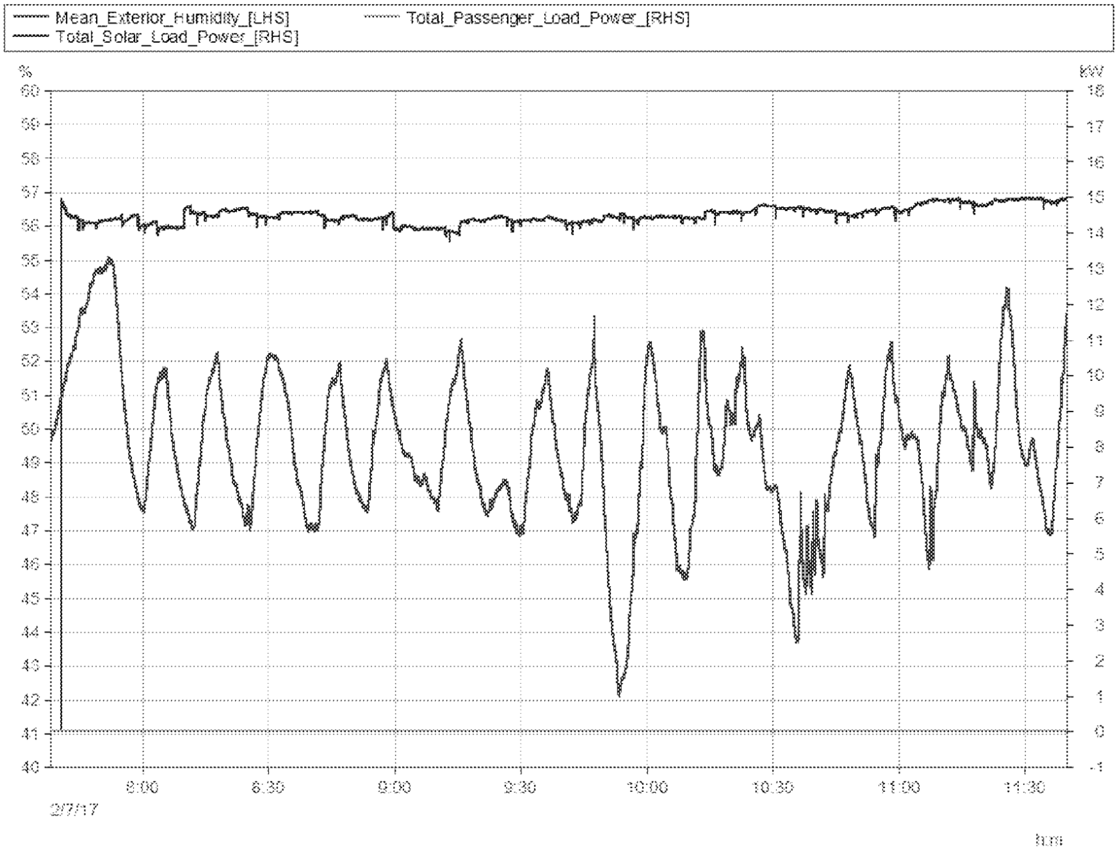


Figure 42 - Pre-Cooling Test, Mean Exterior Humidity, Passenger and Solar Loads

Solar load remained on and the train was then energized at 09:47, switching the HVAC on and confirming the Cabin Auxiliary Heater was off and the Booster was set on low speed. As shown in Figure 43, at 10:28, after 41 minutes, T_{im} dropped below and remained below 22°C. The average temperature in the LCC dropped below and remained below 22°C at 10:17, while in the Cabin it never dropped below 22°C and in the LMC2 did not remain below 22°C for the duration of the test.

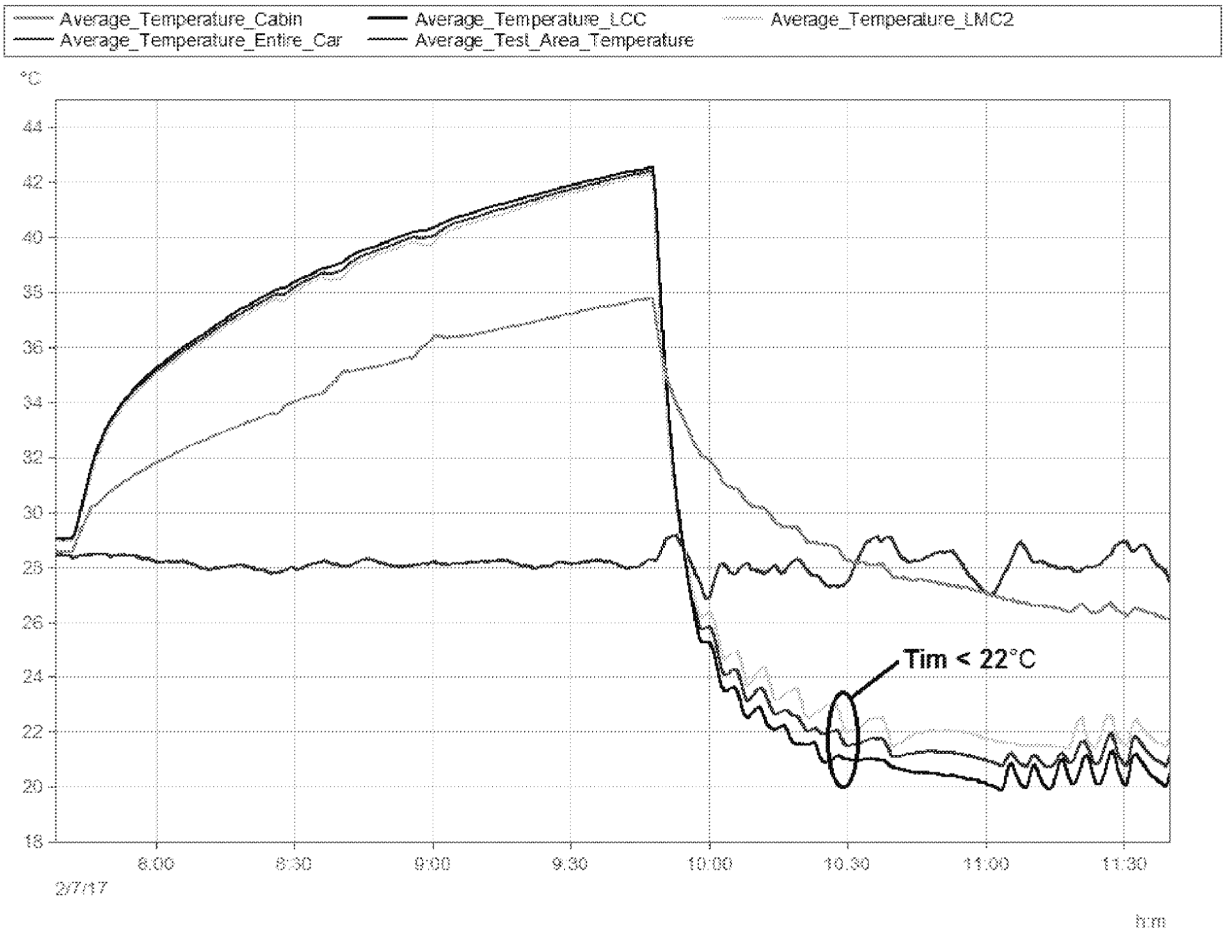


Figure 43 - Pre-Cooling Test, Average Temperatures

5.2.4 ***Condensation Test, 15°C With Passengers***

5.2.4.1 Purpose

A Condensation Test, not defined in the original Test Plan, was added with the purpose of assessing whether, under specific environmental and passenger load conditions, condensation would form on the interior windows throughout the rail cars.

5.2.4.2 Results

Chamber temperature set points were set to achieve a temperature of 15°C, with passenger loads applied at 10:19 of 13.0kW (sensible) and 97ml/min (latent) and lights turned on. Humidified air was provided by steamers installed in the chamber to achieve the target psychometric condition of 50% RH as shown in Figure 44.

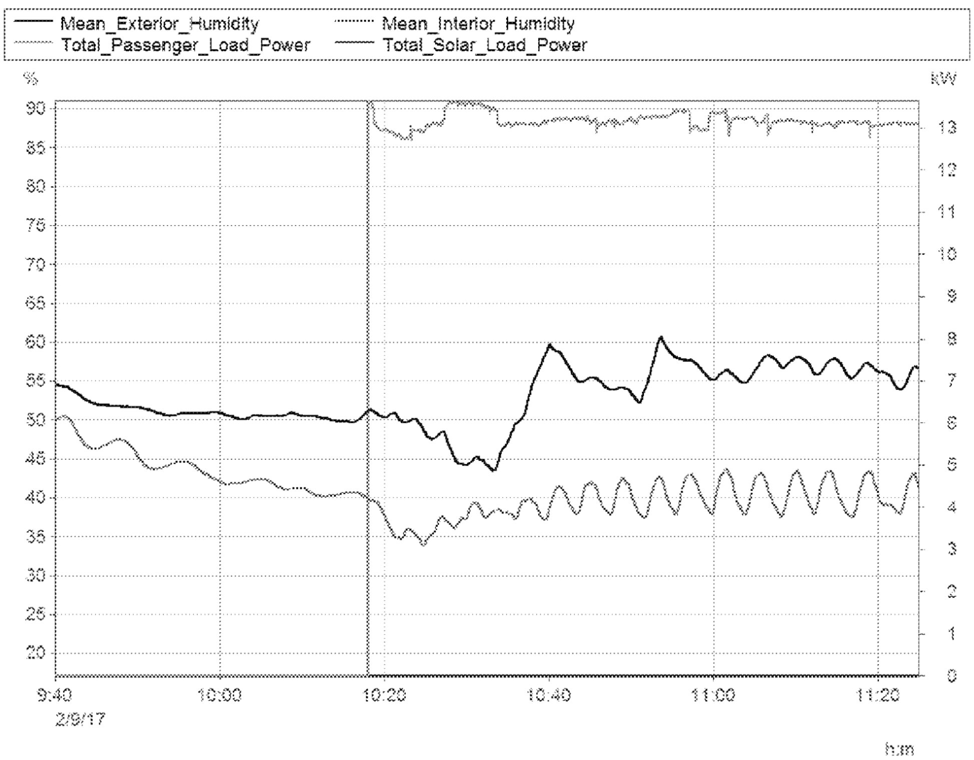


Figure 44 - Condensation Test, Mean Humidities, Passenger and Solar Loads

With the Temperature Setpoint T_{ic} at 22°C, a steady state condition was achieved and data was recorded for 30 minutes between 10:45 and 11:15 as shown in Figure 45. Over the 30 minute test duration, internal humidity remained between 35% and 45%, the Mean Interior Temperature T_{im} remained between 20.5°C and 22°C, while the Cabin Temperature remained between 18.5°C and 19.5°C.

An inspection of the Cabin, LMC2 and LCC rails cars indicated no presence of condensation on any of the interior windows, as shown in Figure 46 as an example.

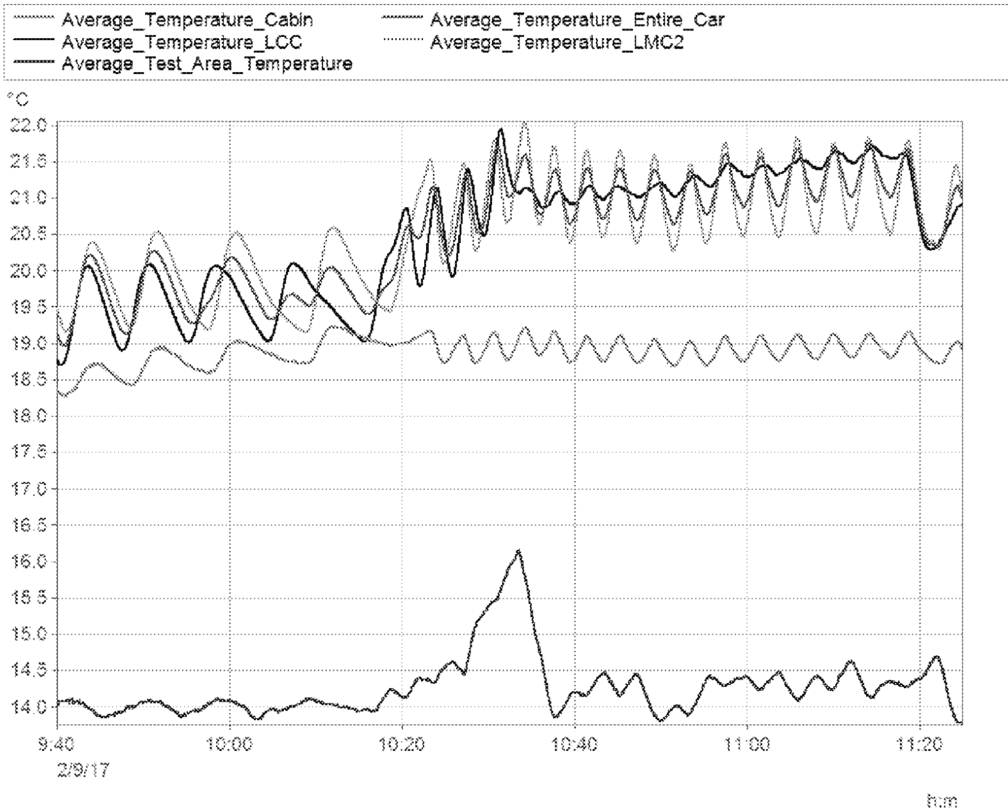


Figure 45 - Condensation Test, Average Temperatures

Figure 46 - LMC2 Interior Window

5.2.5 ***Performance and Regulation Tests***

The purpose of the Performance and Regulations Tests was to evaluate the performance of the HVAC system under a range of climatic conditions. After stabilization for each test, the following data was recorded for 30 minutes.

- Mean Interior Temperature (T_{im}) and Setting Temperature (T_{ic}),
- Thermocouples individually as per §3.3 to allow for gradient and mean calculations to be performed,
- Internal relative humidity, supply air temperature, return air temperature and temperature at diffusers,
- Surface temperatures (wall, ceiling, windows, doors).

5.2.5.1 Procedure A - Regulation in Cooling Mode Without Passengers

Chamber temperature set points were set to achieve a temperature of 35°C, with lights turned on, and 14.5kW of solar load applied at 08:50. Although the Simulated Solar Loads as per Appendix A specify 15kW total, it was agreed to reduce the solar load in the cab by ~0.5kW such that the total solar load was 14.5kW for all testing. Humidified air was provided by steamers installed in the chamber to achieve the target psychrometric condition of 50% RH as shown in Figure 47.

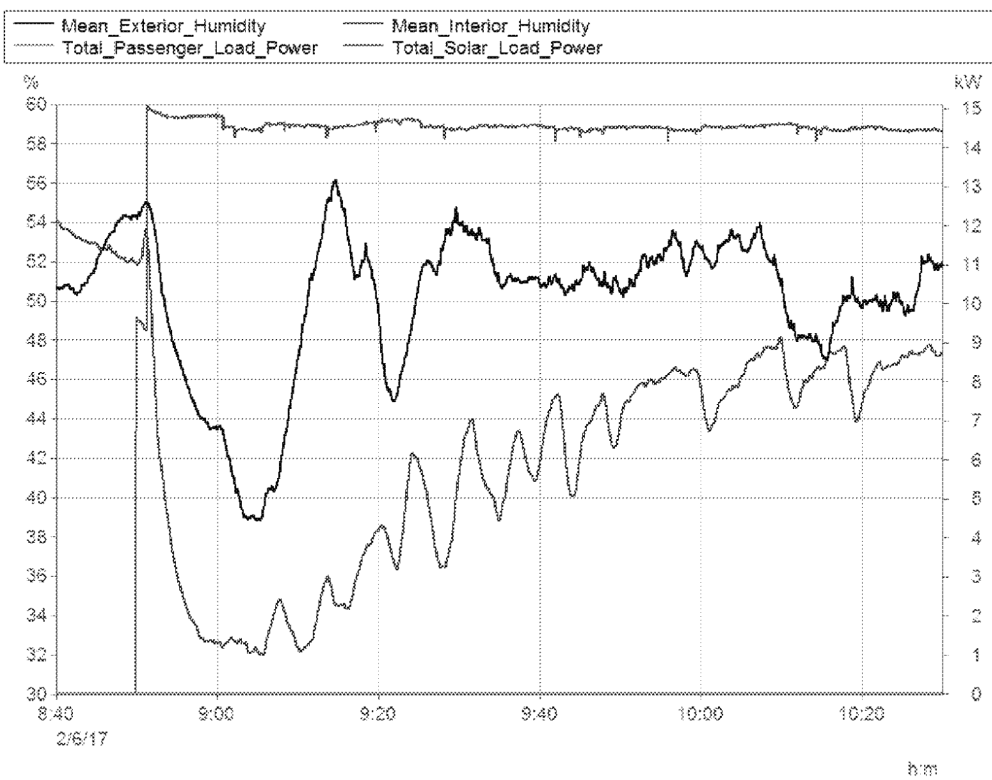


Figure 47 - Procedure A, Mean Humidities, Solar Load

With the Temperature Setpoint T_{ic} set to 22°C, the Cabin Heater Off and Booster set to Low speed, a steady state condition was achieved and data was recorded for a period of 30 minutes between 10:00 and 10:30 as shown in Figure 48. Over the 30 minute test duration, internal humidity remained between 30% and 50%, the Mean Interior Temperature T_{im} remained with ±2°C of the T_{ic} while the Cabin Temperature remained above the ±2°C tolerance of the set point.

With the HVAC operational, it was determined that chamber conditions should be adjusted based on the measured Fresh Air Inlet Temperatures rather than the Average Test Area Temperature to give a better representation of HVAC performance. In some instances, based on HVAC load and chamber conditions, these measured temperatures will vary considerably.

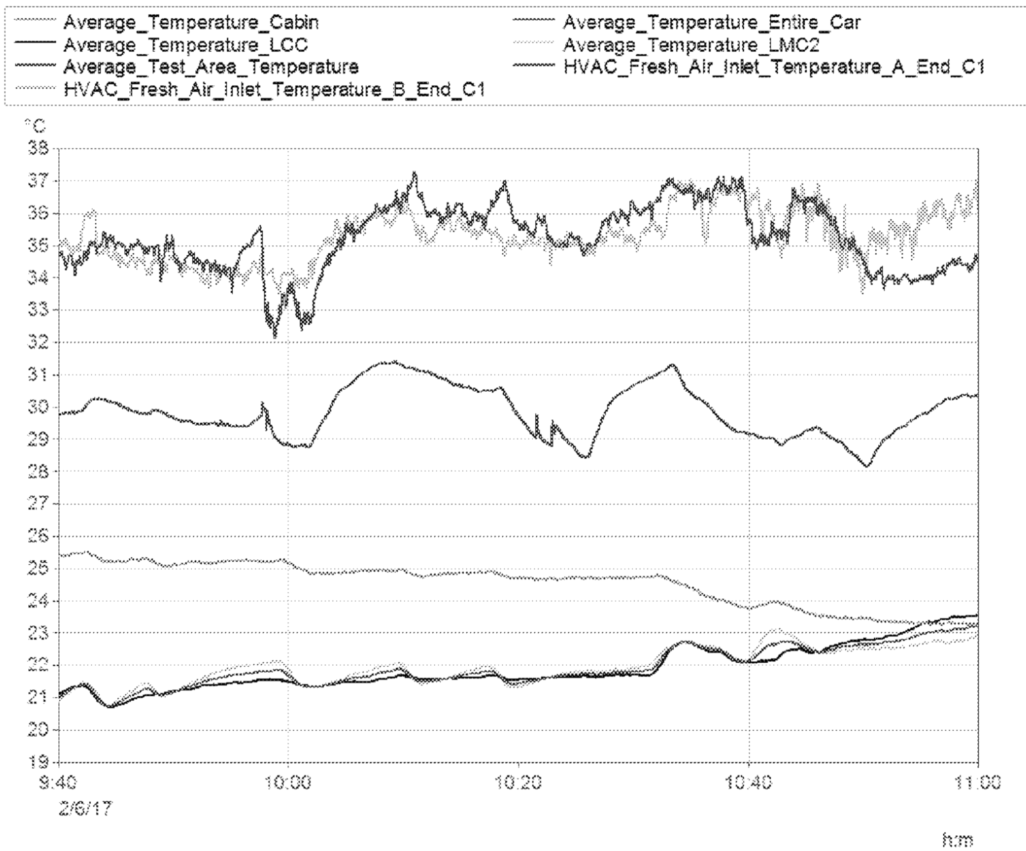


Figure 48 - Procedure A, Average Temperatures

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 49. Looking globally at all 25 locations, the temperature differential at no time exceeded the 6°C specification for the duration of the test as shown in Figure 50.

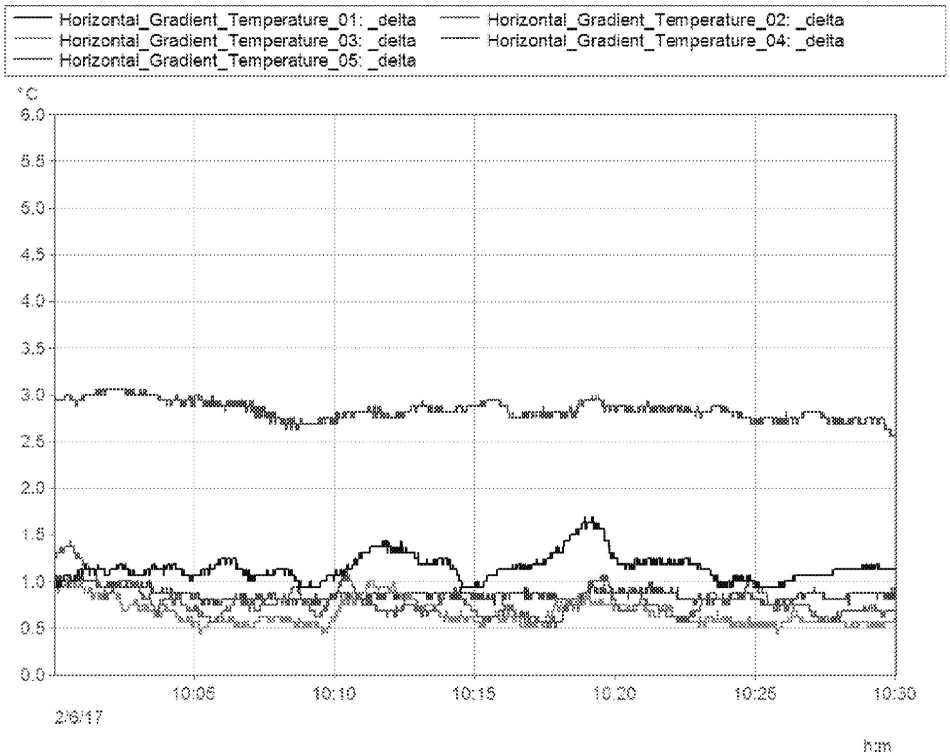


Figure 49 - Procedure A, Local Horizontal Gradients, Max Temperature Δ

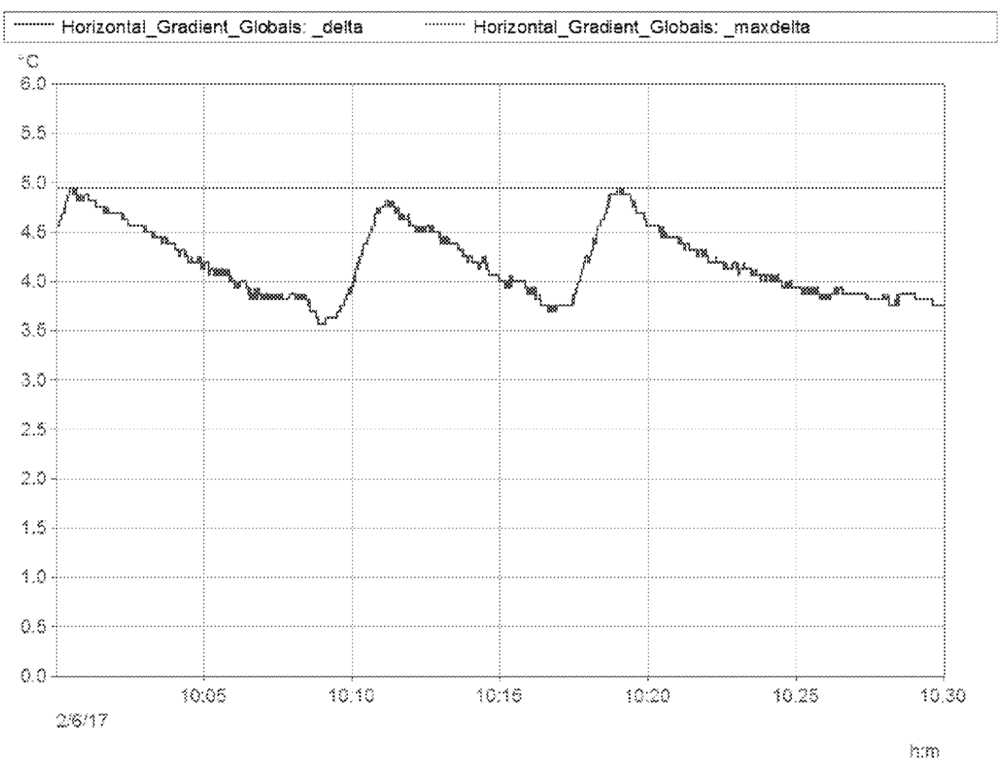


Figure 50 - Procedure A, Global Horizontal Gradients, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 51. Looking globally at all 33 locations, the temperature differential at no time exceeded the 6°C specification for the duration of the test as shown in Figure 52.

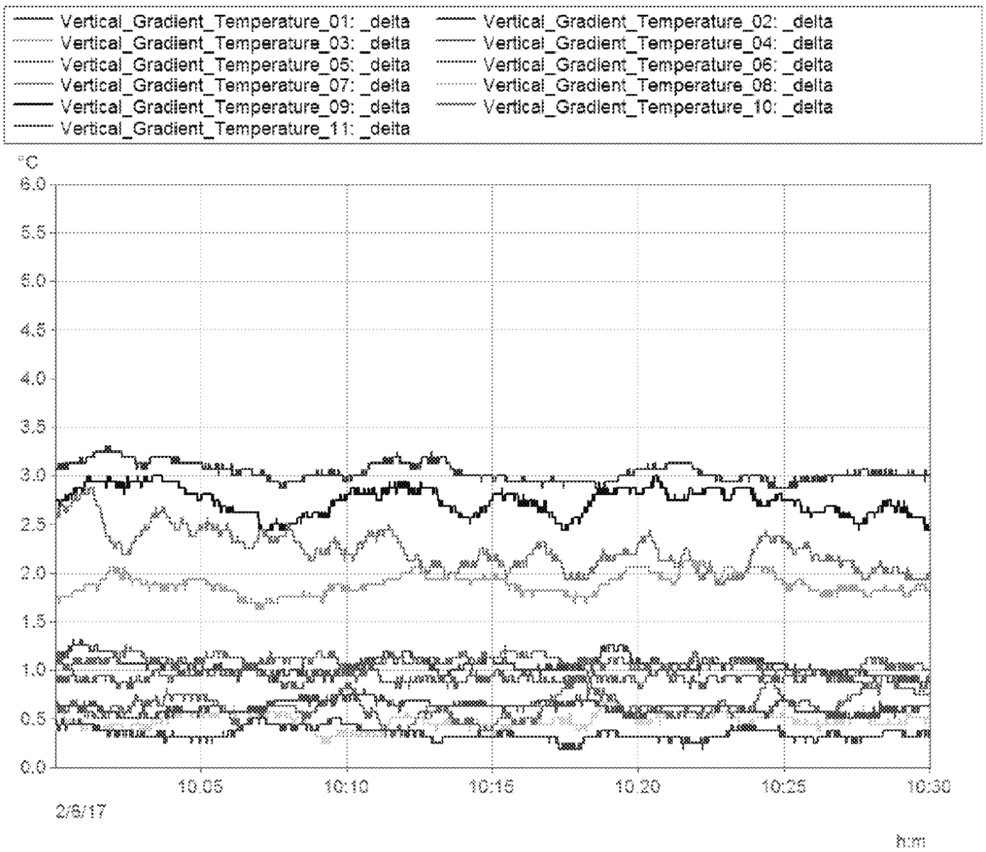


Figure 51 - Procedure A, Local Vertical Gradients, Max Temperature Δ

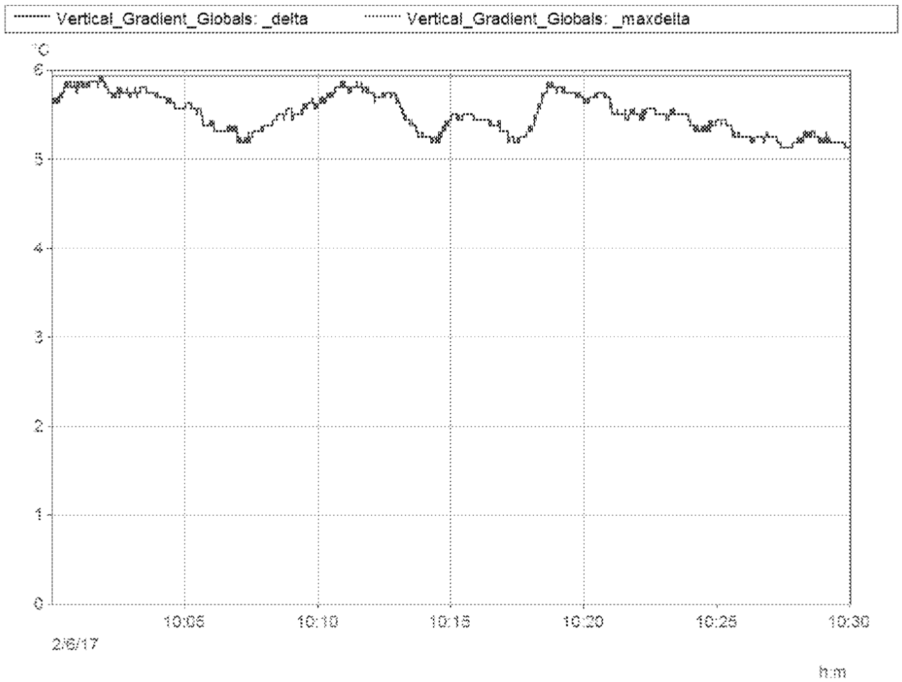


Figure 52 - Procedure A, Global Vertical Gradients, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 53 and Figure 54.

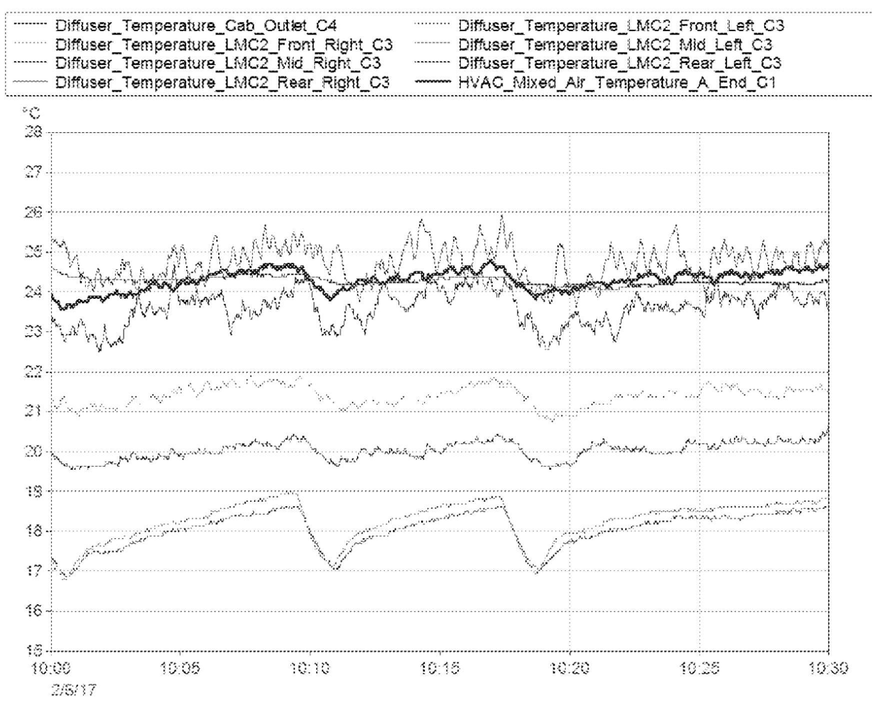


Figure 53 - Procedure A, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

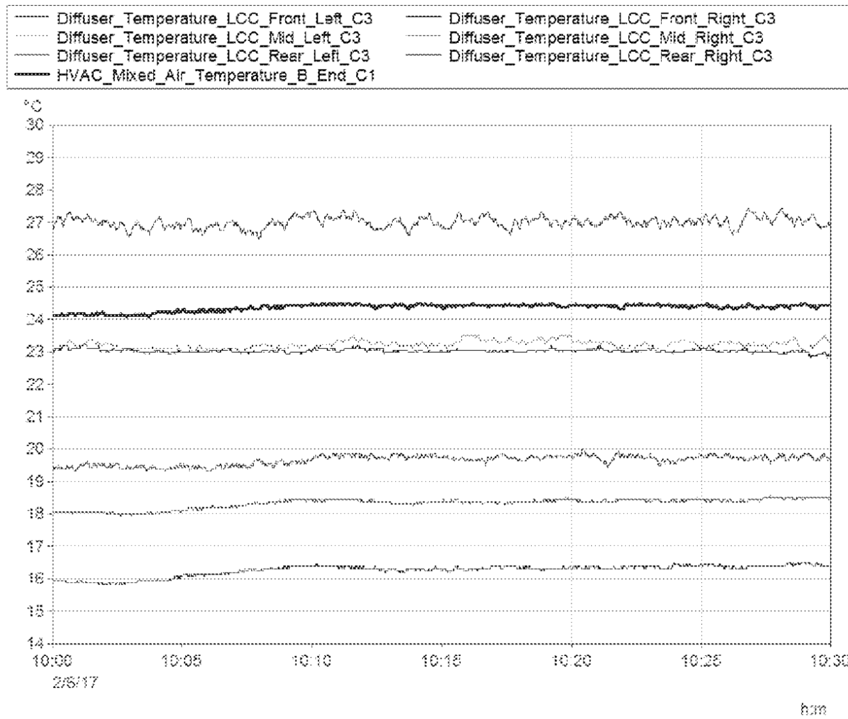


Figure 54 - Procedure A, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperature in the LMC2 car was stable at approximately 13.5°C while in the LCC car fluctuated between approximately 9°C and 14°C, remaining in excess of 12°C for the majority of the 30 minute test as shown in Figure 55.

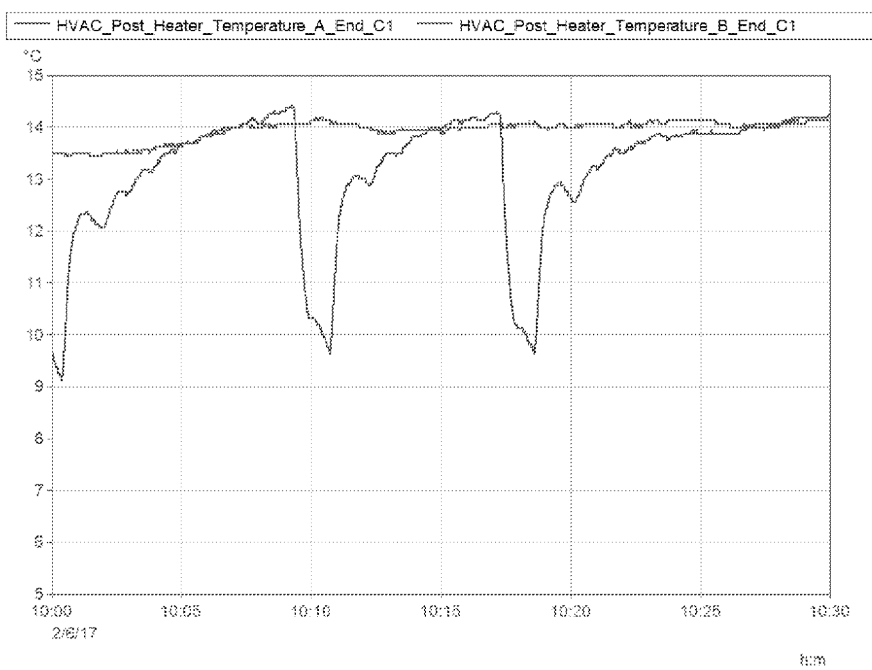


Figure 55 - Procedure A, HVAC Supply Air Temperatures, Evaporator Exit

5.2.5.2 Procedure B - Regulation in Cooling Mode With Passengers

Chamber temperature set points were set to achieve a temperature of 35°C, with lights turned on, passenger loads of 13.0 kW (sensible) and 97ml/min of steam (latent) applied at 10:31, and 14.5 kW solar load applied. Humidified air was provided by steamers installed in the chamber to achieve the target psychrometric condition of 50% RH as shown in Figure 56.

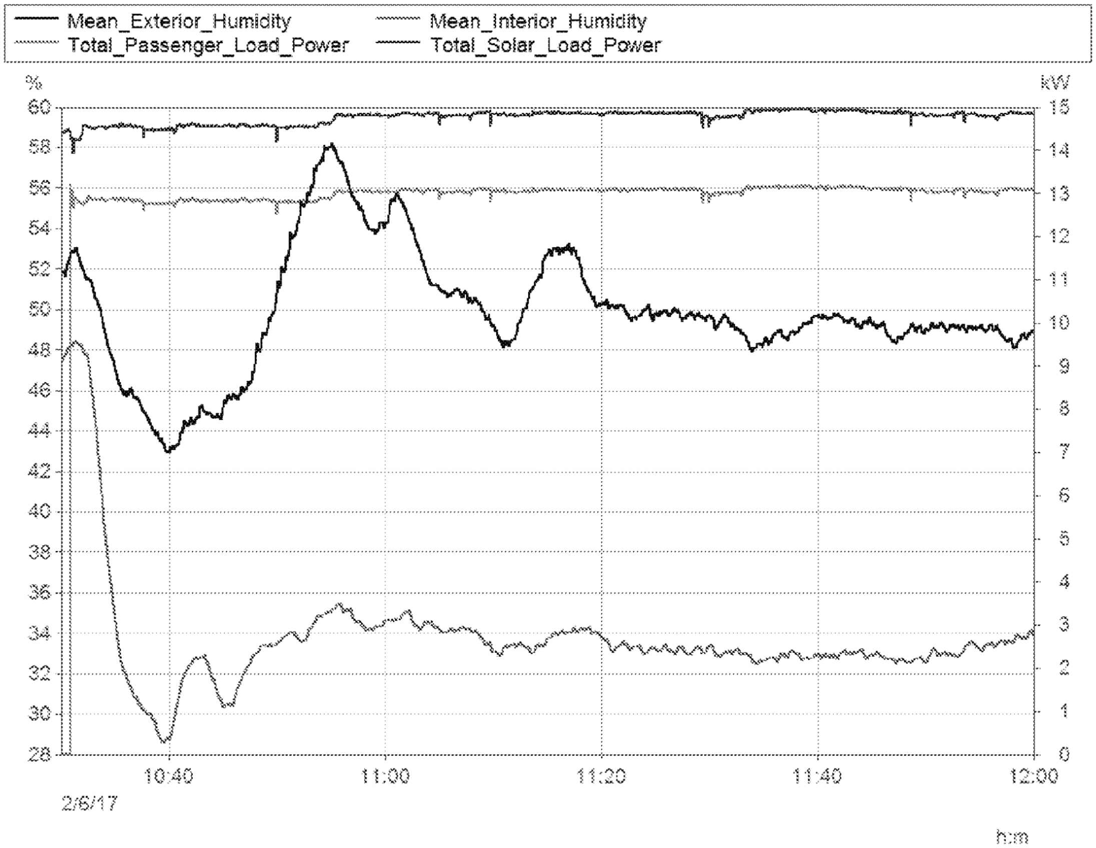


Figure 56 - Procedure B, Mean Humidities, Passenger and Solar Loads

With the Temperature Setpoint T_{ic} at 22°C, the Cabin Heater Off and Booster set to Low speed, a steady state condition was achieved and data was recorded for 30 minutes between 11:20 and 11:50 as shown in Figure 57. Over the 30 minute test duration, internal humidity remained between 30% and 50%, the Mean Interior Temperature T_{im} and the Cabin Temperature remained within ±2°C of the T_{ic}.

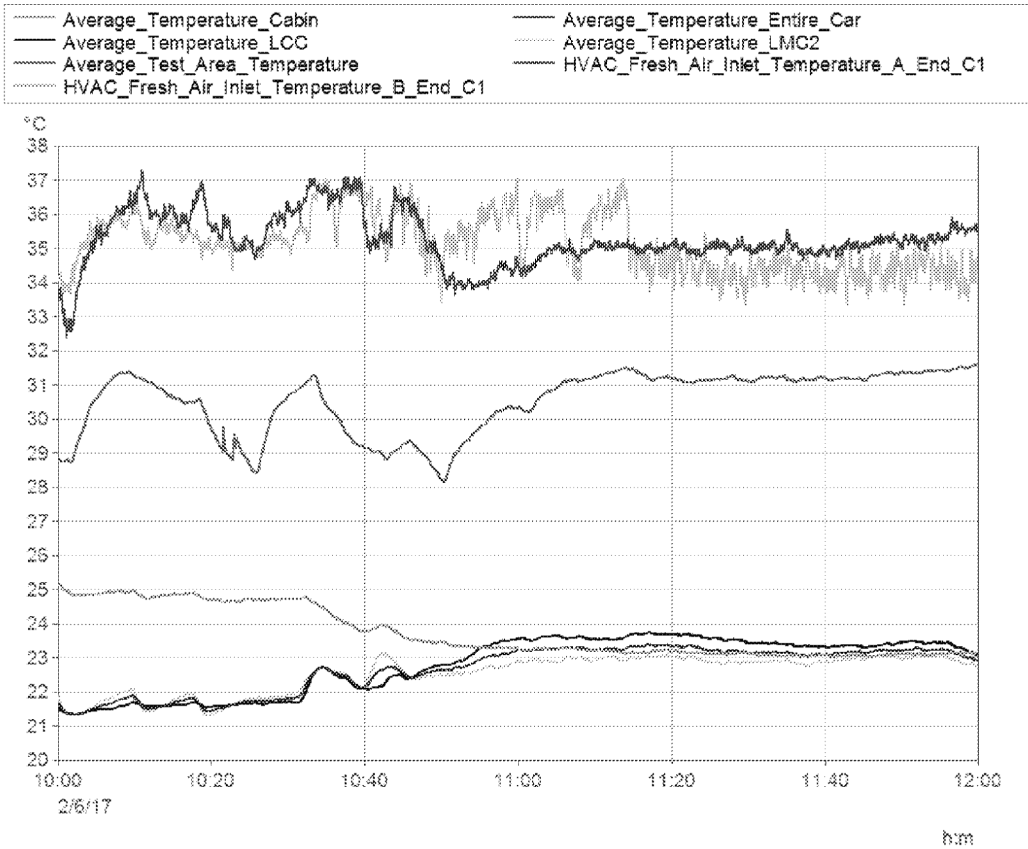


Figure 57 - Procedure B, Average Temperatures

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 58. Looking globally at all 25 locations, the temperature differential exceeded the 6°C specification for approximately two-thirds of the duration of the test as shown in Figure 59.

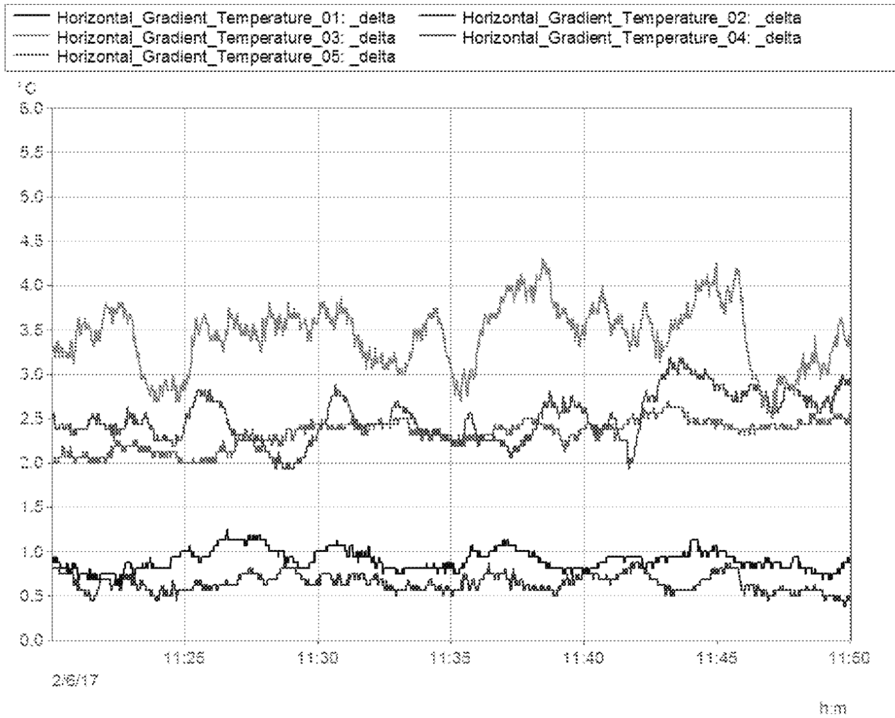


Figure 58 - Procedure B, Local Horizontal Gradients, Max Temperature Δ

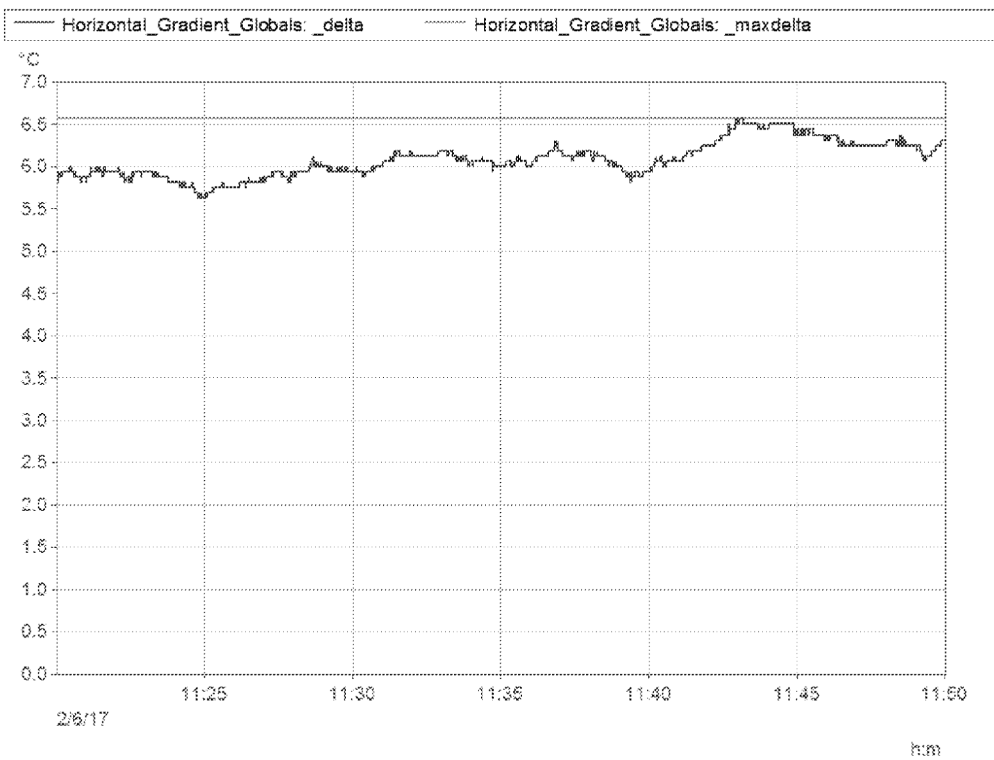


Figure 59 - Procedure B, Global Horizontal Gradients, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at one location, VG10, exceeded the 6°C specification as shown in Figure 60. However this differential is suspect as the thermocouple measuring the “Low” location shows a rise in temperature coincident with the application of passenger loading as shown at 10:30 as shown in Figure 61. Accordingly the proximity of this particular thermocouple to a baseboard heater simulating the passenger load likely caused an erroneous measurement.

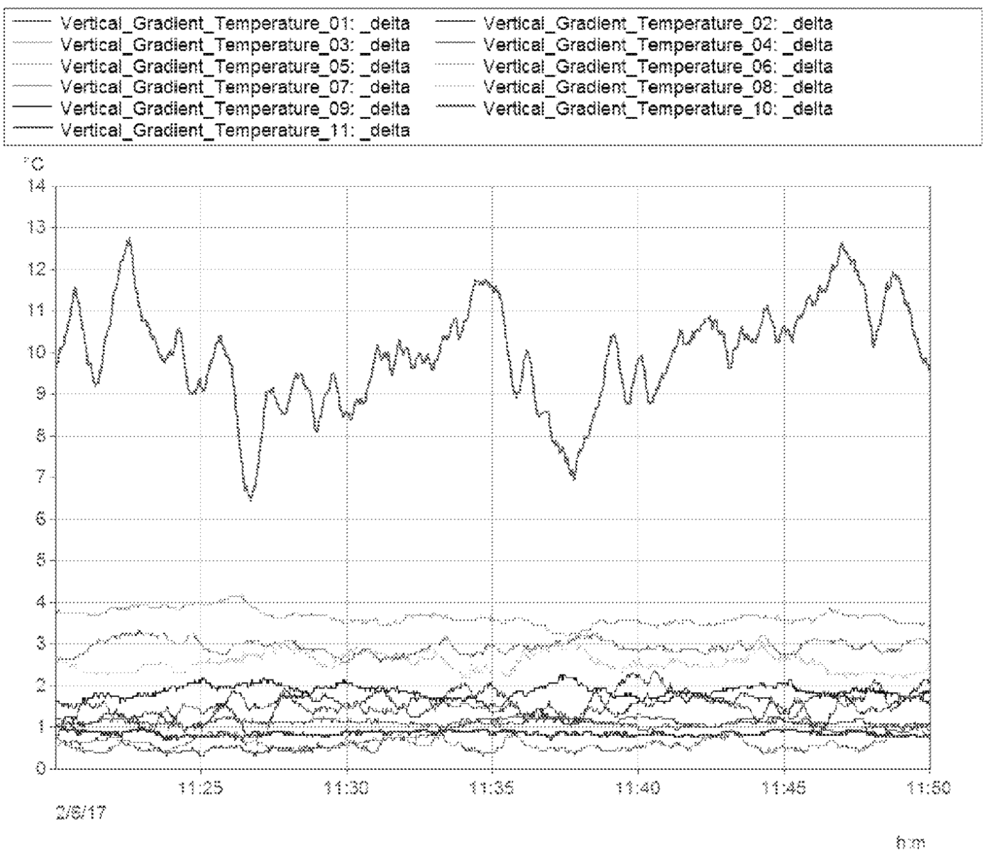


Figure 60 - Procedure B, Local Vertical Gradients, Max Temperature Δ

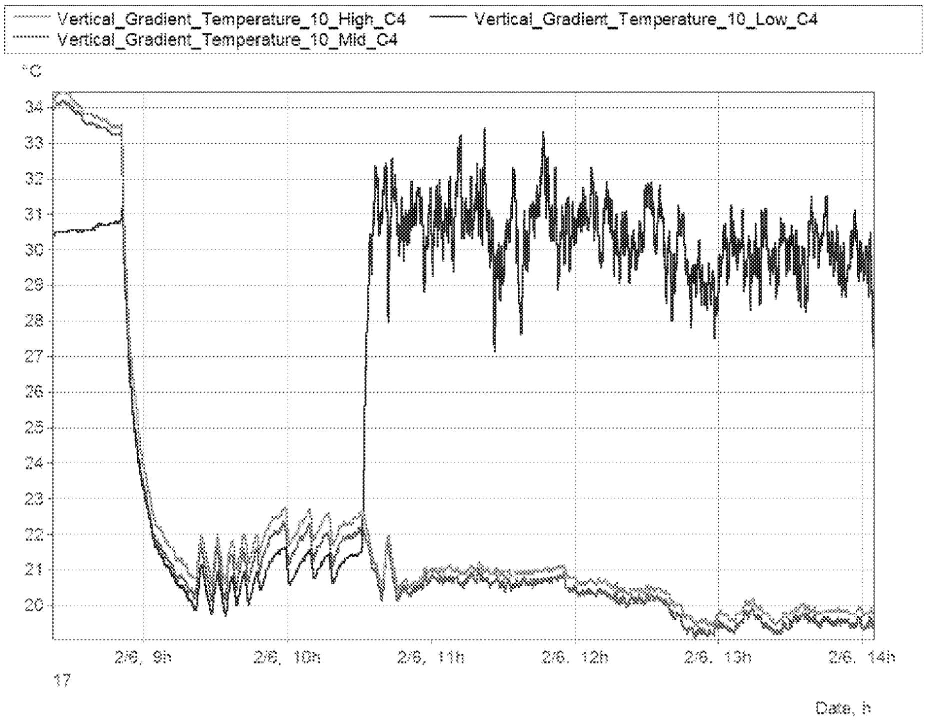


Figure 61 - Procedure B, Location VG10 Vertical Gradient, Max Temperature Δ

Looking globally at all 32 locations (with VG10 "Low" removed), the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 62.

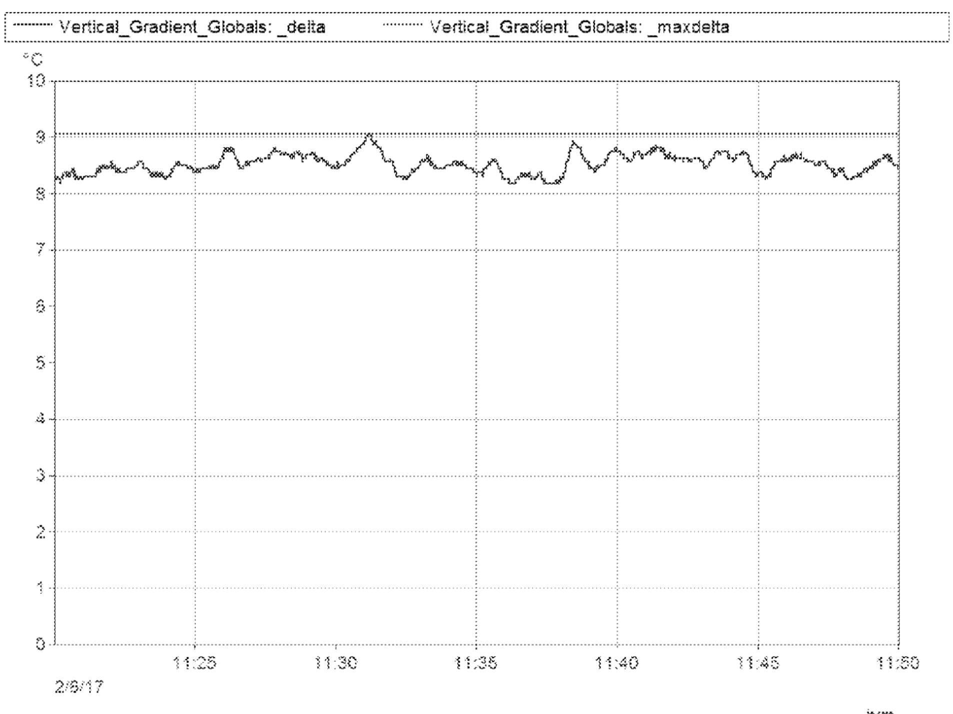


Figure 62 - Procedure B, Global Vertical Gradients, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 63 and Figure 64.

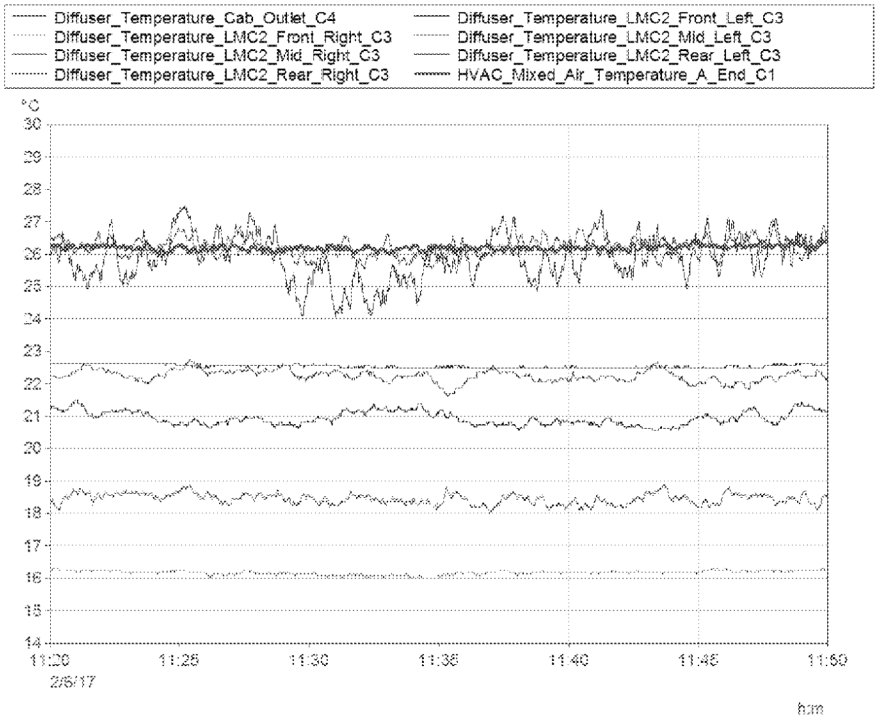


Figure 63 - Procedure B, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

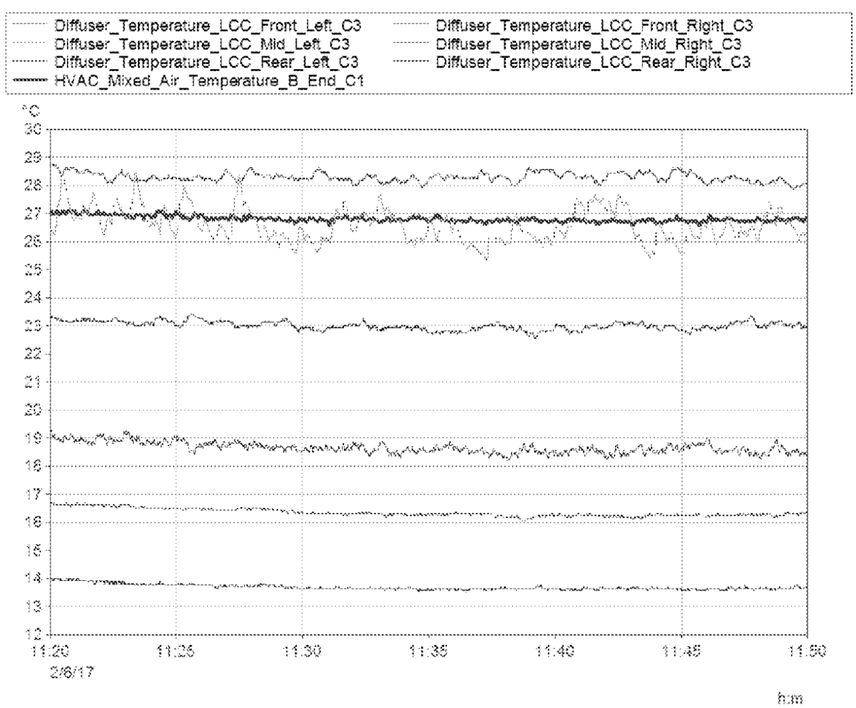


Figure 64 - Procedure B, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperature in the LMC2 car was stable at approximately 10.5°C and in the LCC car stable at approximately 11°C, remaining below 12°C for the duration of the 30 minute test as shown in Figure 65.

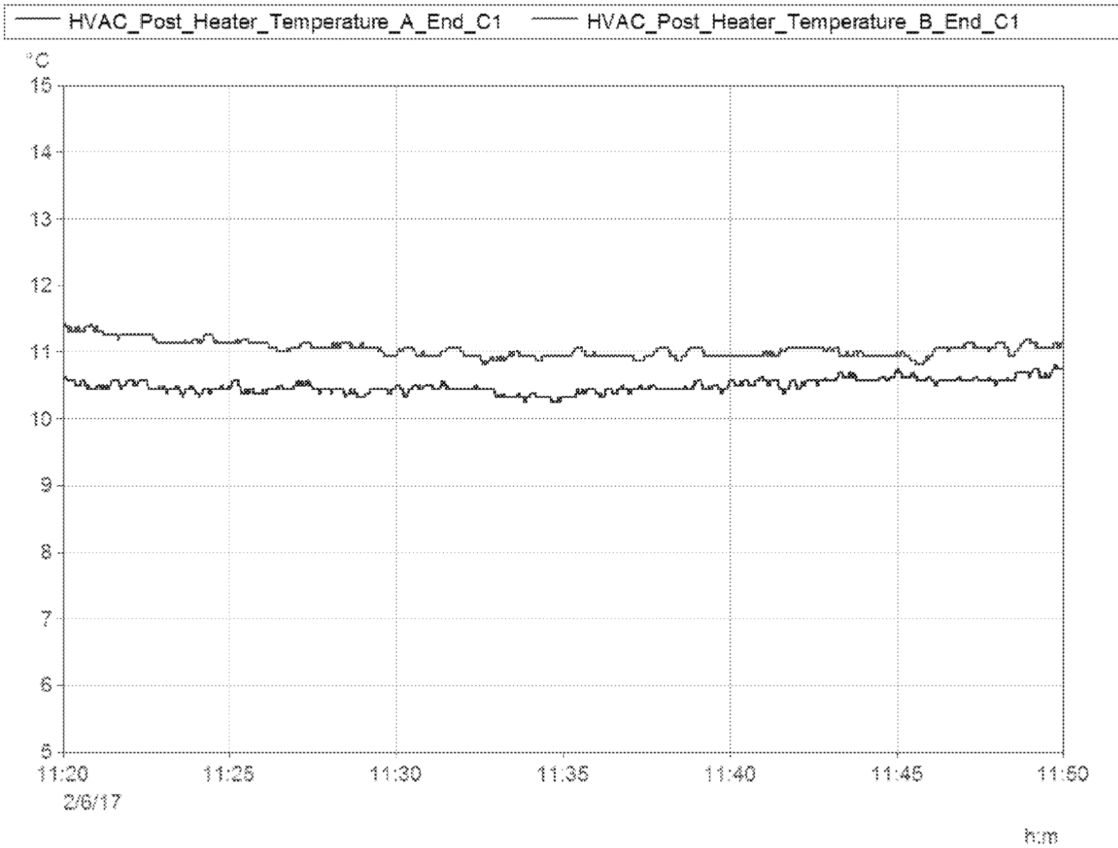


Figure 65 - Procedure B, HVAC Supply Air Temperatures, Evaporator Exit

5.2.5.3 Procedure C - Performance in Cooling Mode Without Passengers

Chamber temperature set points were set to achieve a temperature of 35°C, with lights turned on, passenger loads of 13.0 kW (sensible) and 97ml/min of steam (latent), and 14.5 kW solar load applied. Humidified air was provided by steamers installed in the chamber to achieve the target psychrometric condition of 50% RH as shown in Figure 66.

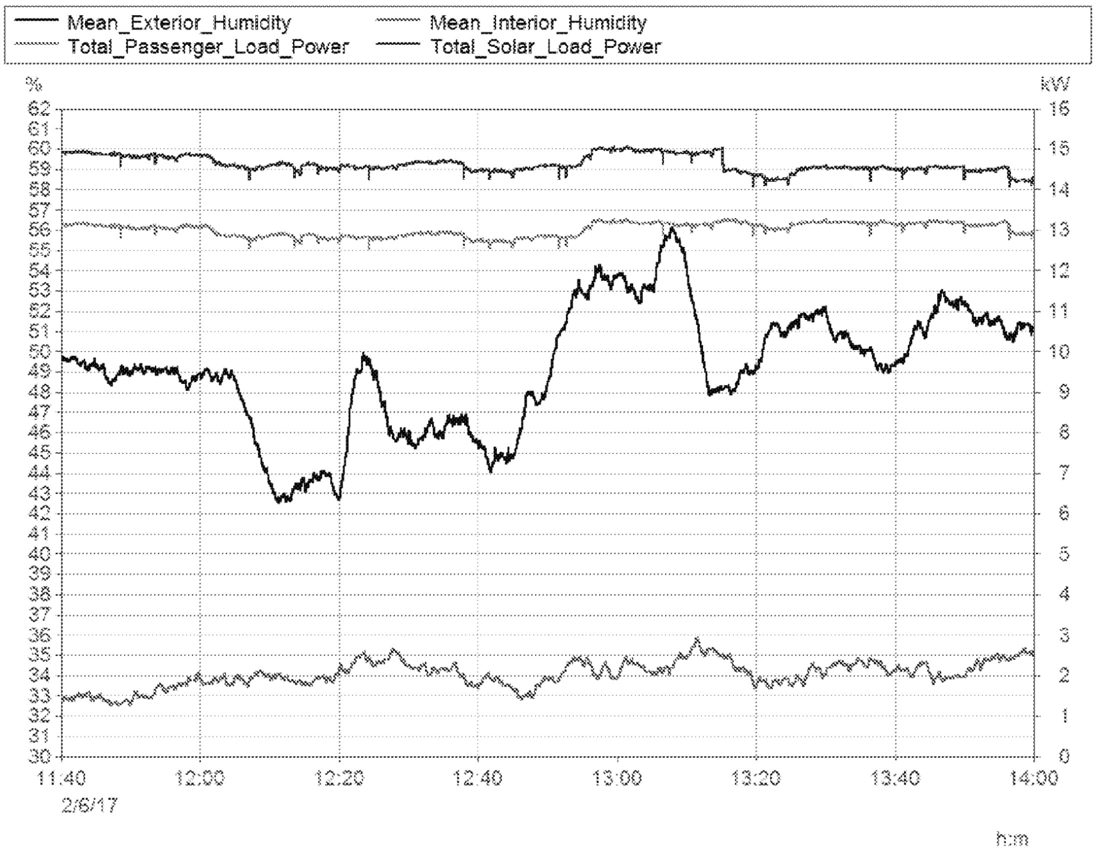


Figure 66 - Procedure C, Mean Humidities, Passenger and Solar Loads

With the Temperature Setpoint T_{ic} set to a minimum at 16°C at 12:00 such that the minimum achievable temperature was attained, the Cabin Heater Off and Booster set to Low speed, a steady state condition was achieved and data was recorded for two hours between 12:00 and 14:00 as shown in Figure 67. Over the 2 hour test duration, the Mean Interior Temperature T_{im} dropped by approximately 0.5°C from 23°C to 22.5°C.

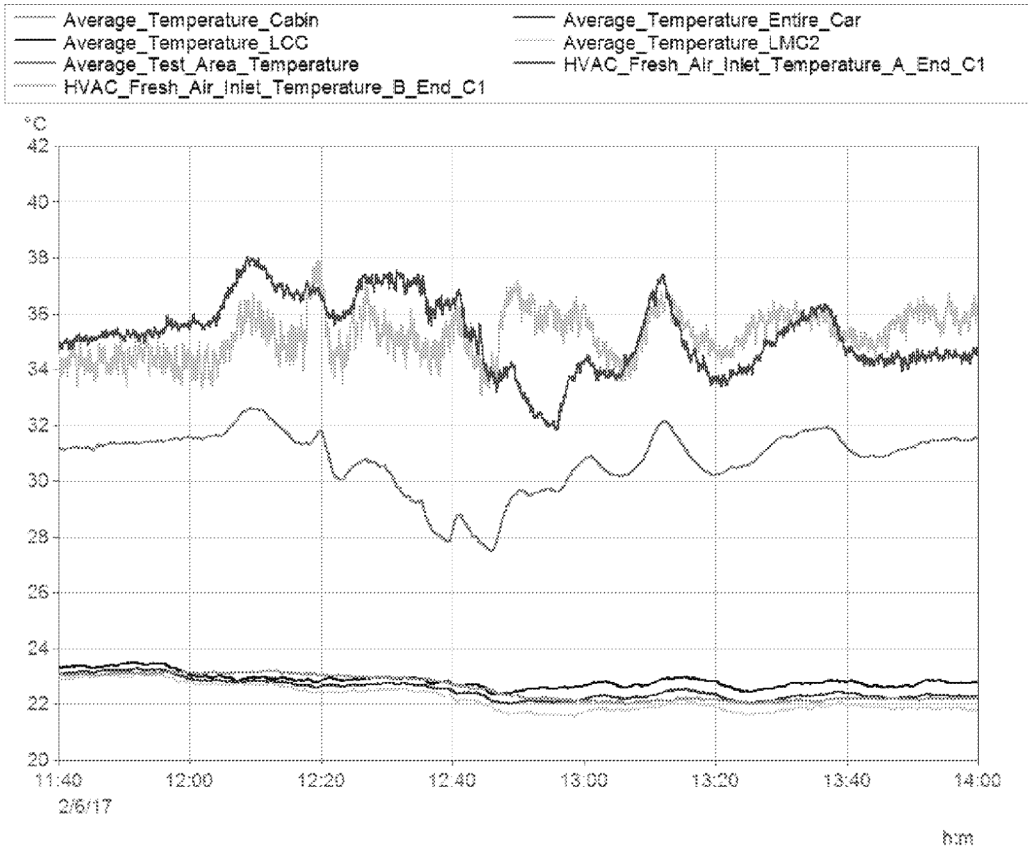


Figure 67 - Procedure C, Average Temperatures

5.2.5.4 Procedure D - Regulation in Cooling Mode With Passengers

Chamber temperature set points were set to achieve a temperature of 28.9°C, with passenger loads applied at 11:47 of 13.0 kW (sensible) and 97ml/min of steam (latent), lights turned on, and 14.5kW of solar load applied. Humidified air was provided by steamers installed in the chamber to achieve the target psychrometric condition of 48% RH as shown in Figure 68.

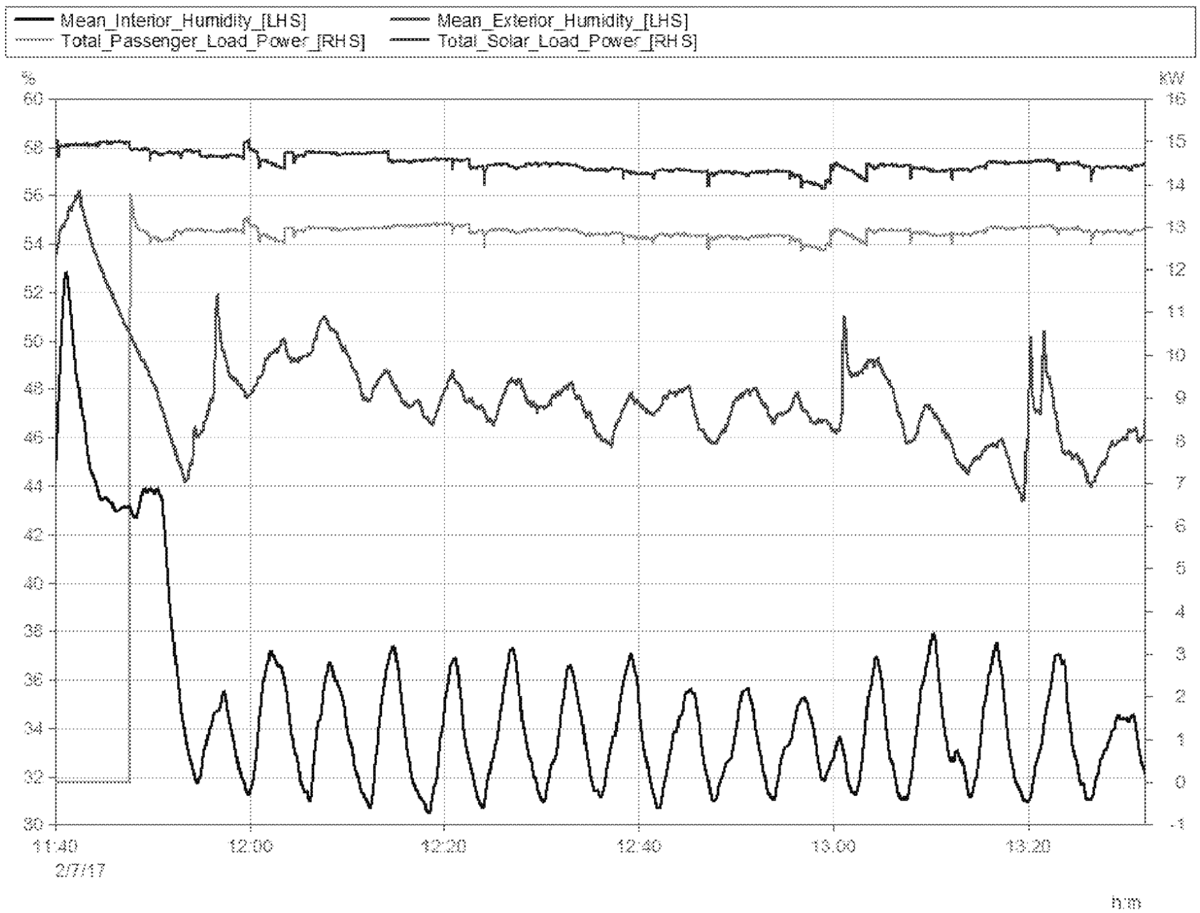


Figure 68 - Procedure D, Mean Humidities, Passenger and Solar Loads

With the Temperature Setpoint T_{ic} at 22°C, the Cabin Heater Off and Booster set to Low speed, a steady state condition was achieved and data was recorded for 30 minutes between 13:02 and 13:32 as shown in Figure 69. Over the 30 minute test duration, internal humidity remained between 30% and 50%, the Mean Interior Temperature T_{im} remained within ±2°C of the T_{ic}, while the Cabin Temperature crossed within the ±2°C tolerance at 13:23.

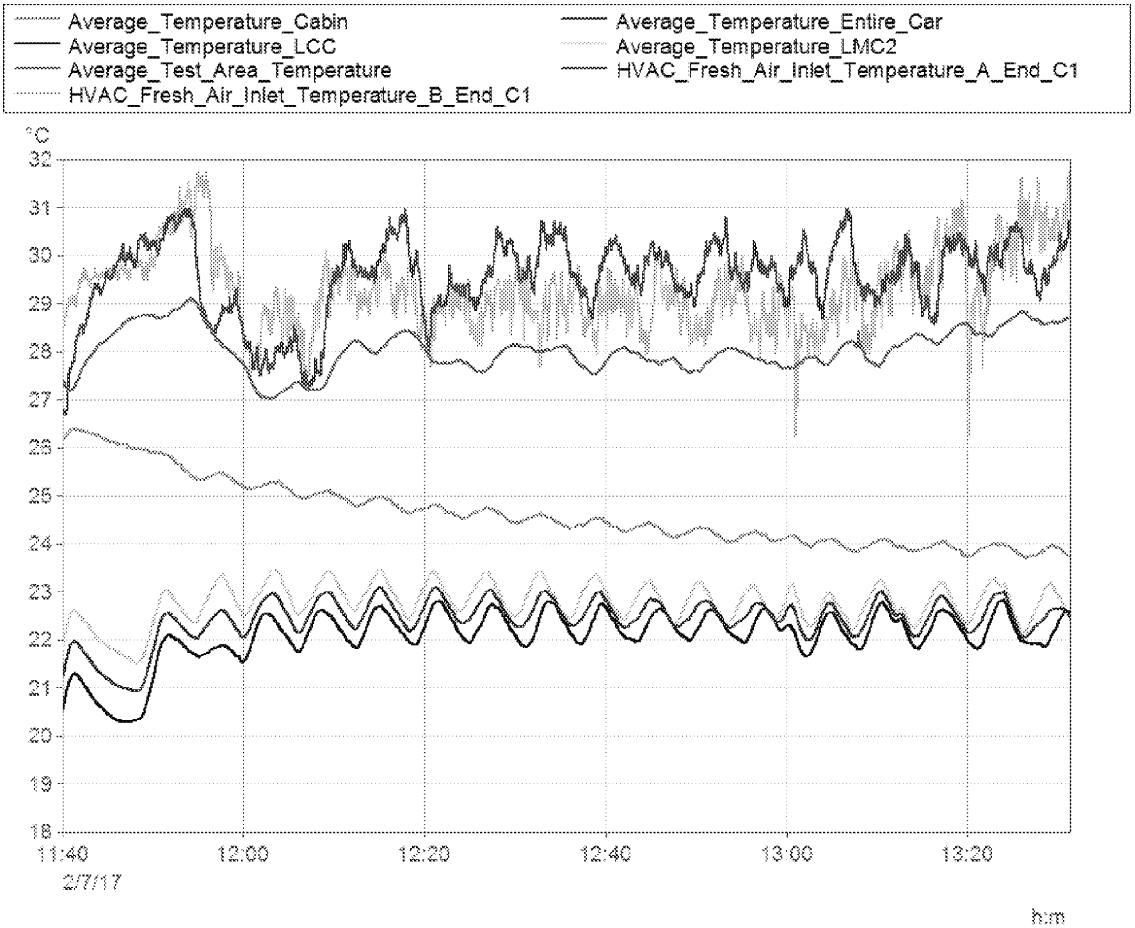


Figure 69 - Procedure D, Average Temperatures

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 70. Looking globally at all 25 locations, the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 71.

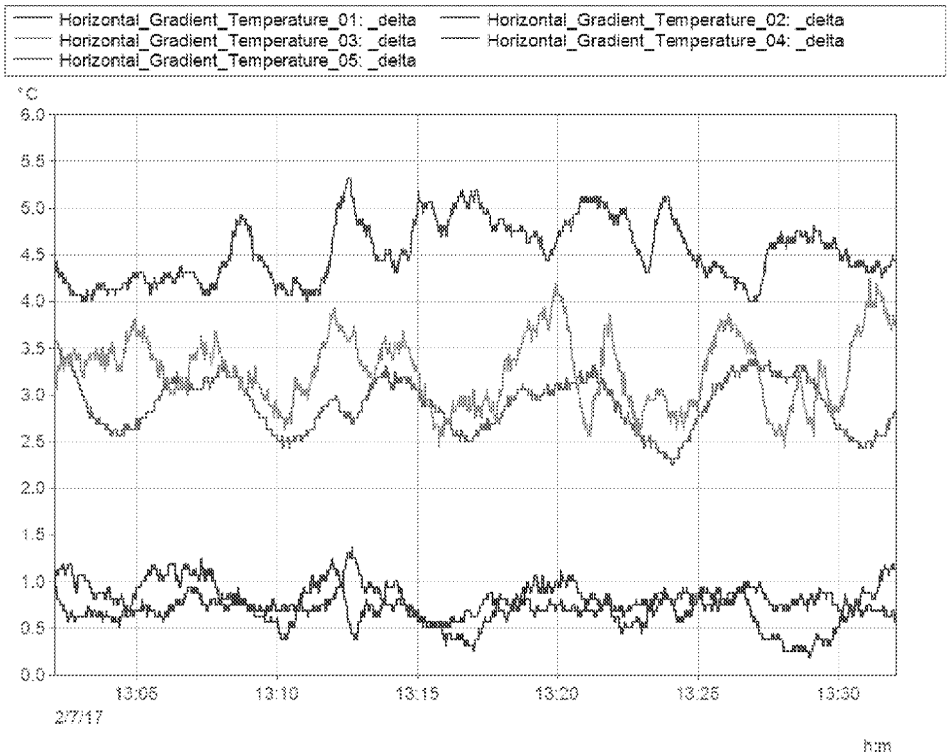


Figure 70 - Procedure D, Local Horizontal Gradients, Max Temperature Δ

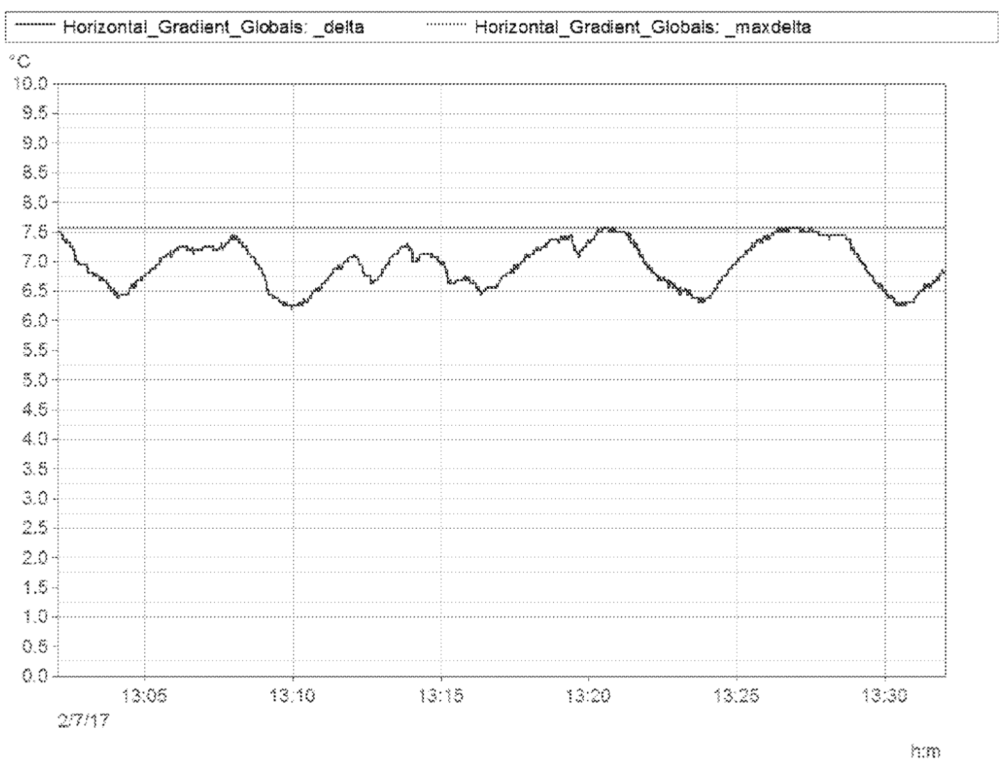


Figure 71 - Procedure D, Global Horizontal Gradient, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 72. Looking globally at all 33 locations, the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 73.

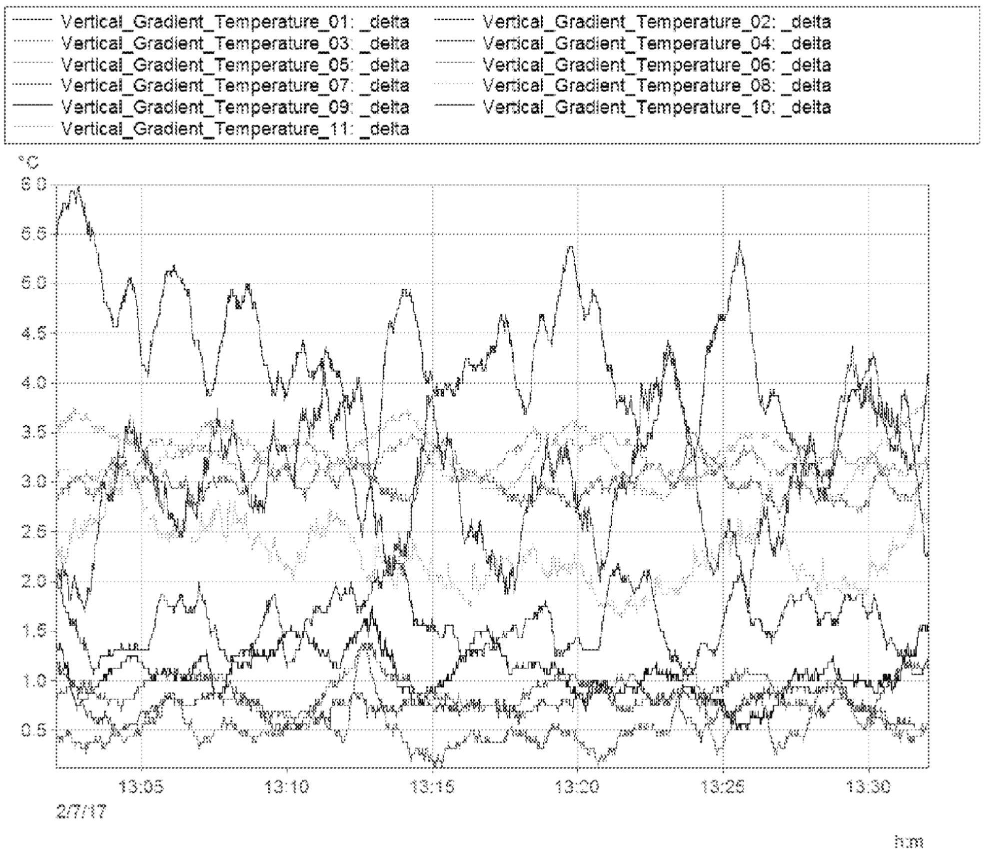


Figure 72 - Procedure D, Local Vertical Gradients, Max Temperature Δ

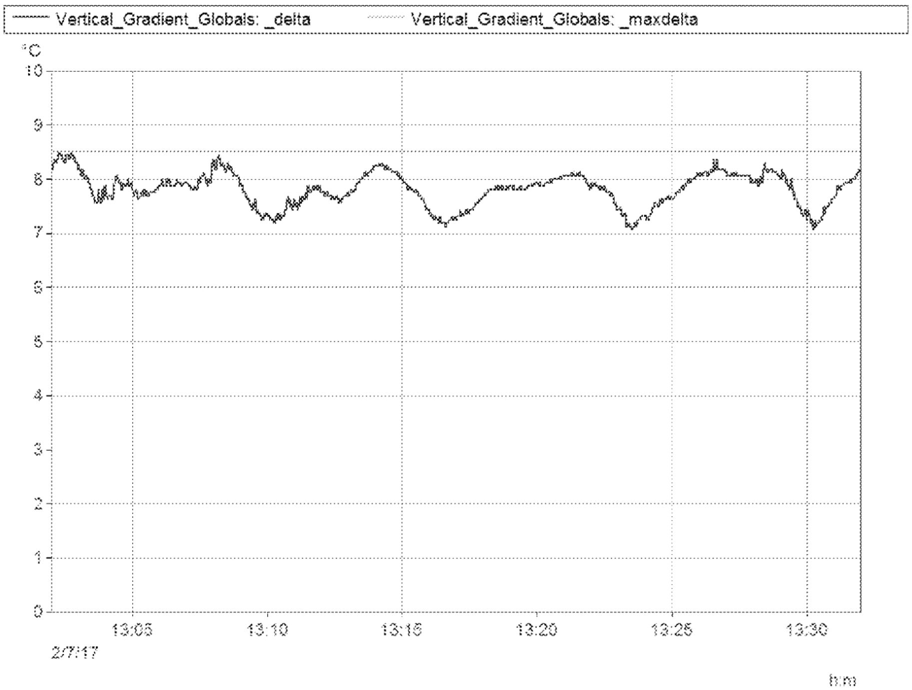


Figure 73 - Procedure D, Global Vertical Gradient, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 74 and Figure 75.

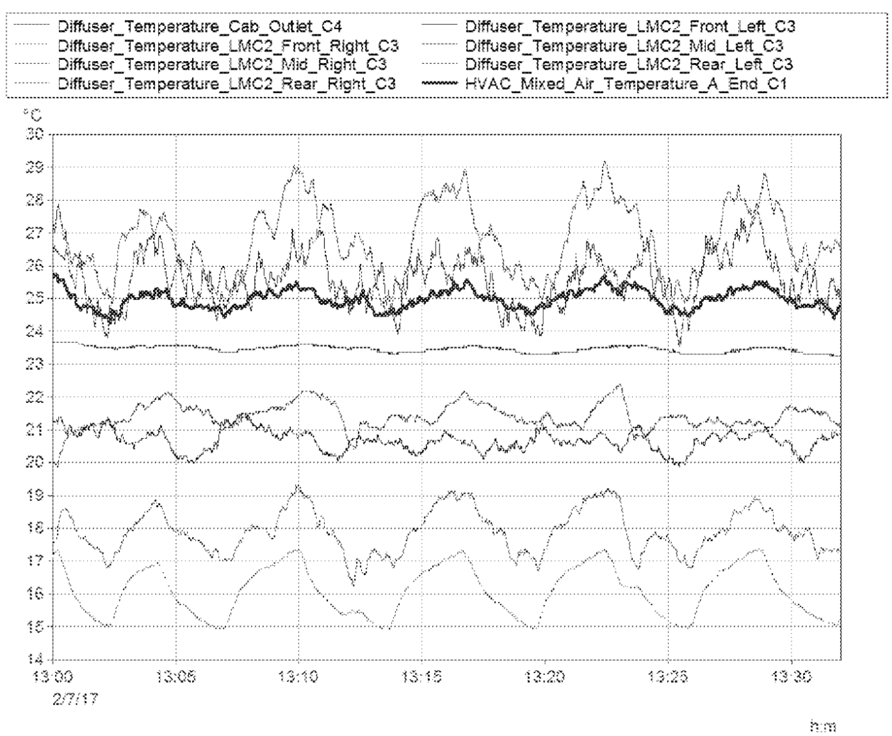


Figure 74 - Procedure D, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

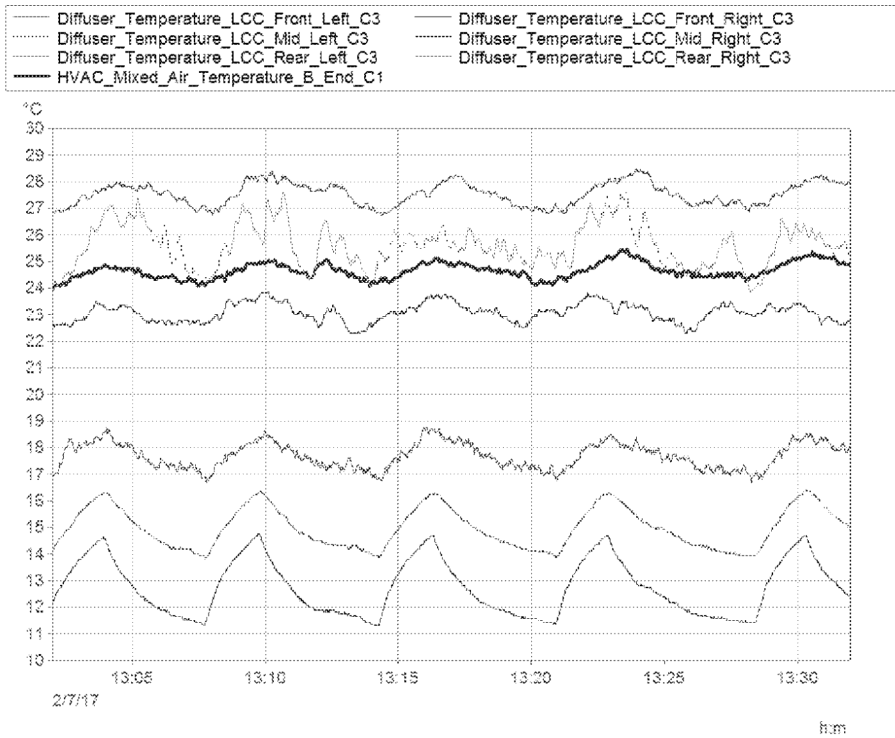


Figure 75 - Procedure D, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperatures in both the LMC2 and LCC cars fluctuated between approximately 8°C and 13°C, remaining in excess of 12°C only periodically during the 30 minute test as shown in Figure 76.

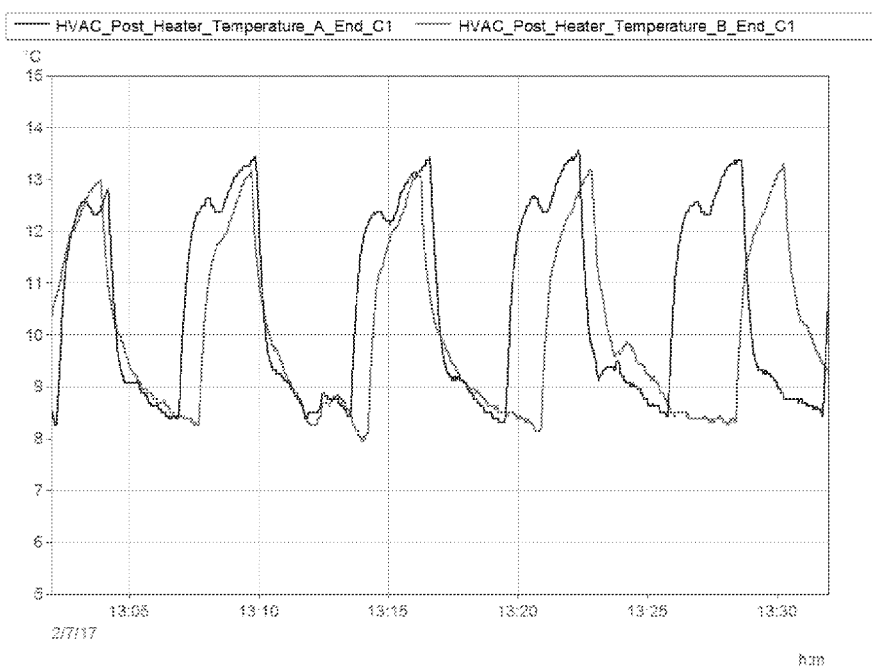


Figure 76 - Procedure D, HVAC Supply Air Temperatures, Evaporator Exit

5.2.5.5 Procedure E - Performance in Cooling Mode

Chamber temperature set points were set to achieve a temperature of 35°C, with lights turned on, passenger loads of 13.0 kW (sensible) and 97ml/min of steam (latent), and 14.5 kW solar load applied. Humidified air was provided by steamers installed in the chamber to achieve the target psychrometric condition of 50% RH as shown in Figure 77.

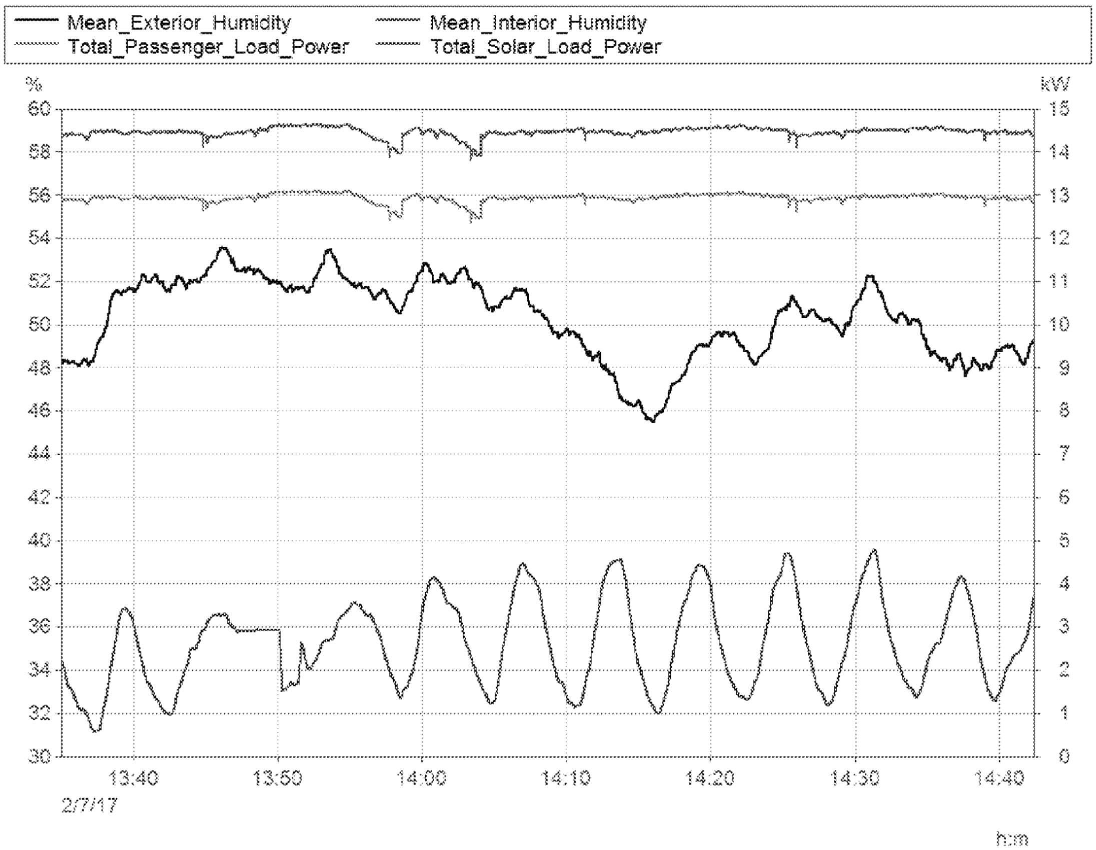


Figure 77 - Procedure E, Mean Humidities, Passenger and Solar Loads

With the Temperature Setpoint T_{ic} set to a minimum at 16°C at 13:35 such that the minimum achievable temperature was attained, the Cabin Heater Off and Booster set to Low speed, a steady state condition was achieved and data was recorded for one hour between 13:35 and 14:35 as shown in Figure 78. Over the one hour test duration, the Mean Interior Temperature T_{im} dropped by approximately 0.5°C from 22.5°C to 22.0°C.

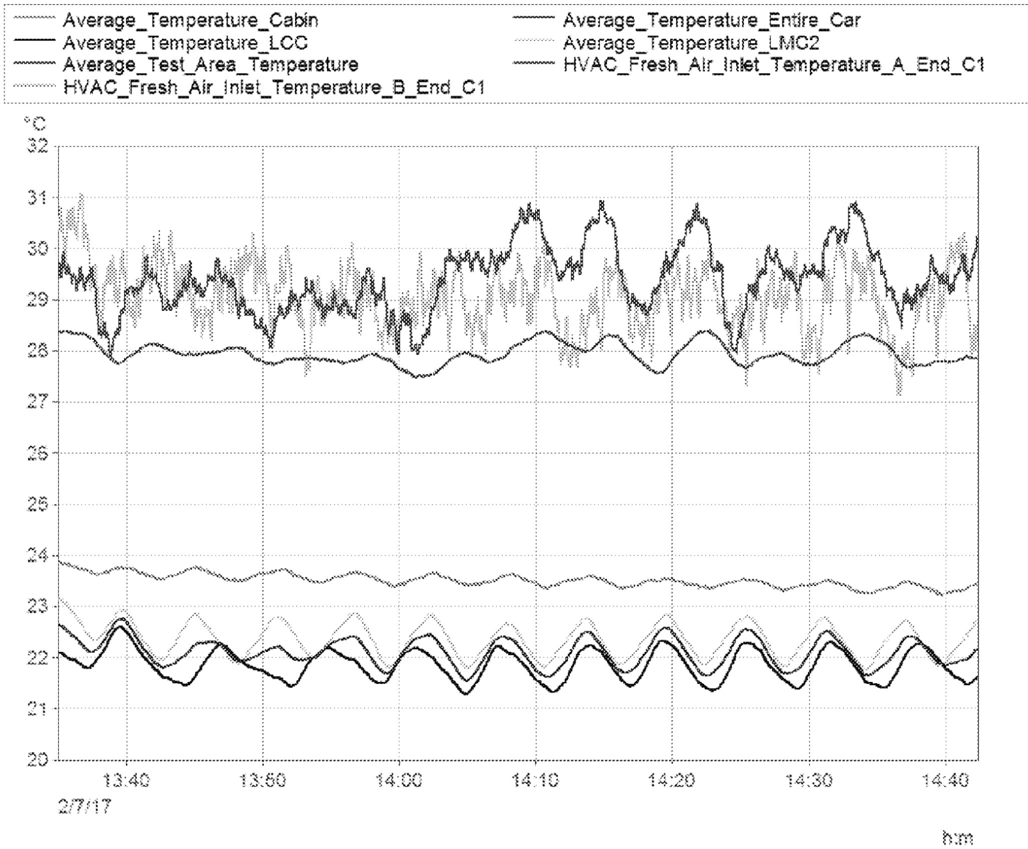


Figure 78 - Procedure E, Average Temperatures

5.2.5.6 Procedure F - Regulation in Heating Mode Without Passengers

Chamber temperature set points were set to achieve a temperature of -10°C, with no passenger loads and lights turned on at 11:00.

With the Temperature Setpoint T_{ic} set to 16°C, the Cabin Heater ON in High Speed and Booster set to Low speed, a steady state condition was achieved and data was recorded for a period of 30 minutes between 13:42 and 14:12 as shown in Figure 79. Over the 30 minute test duration, the Mean Interior Temperature T_{im} remained within ±2°C of the T_{ic} for approximately 15 minutes, while the Cabin Temperature remained within ±2°C tolerance of the set point for the majority of the test duration.

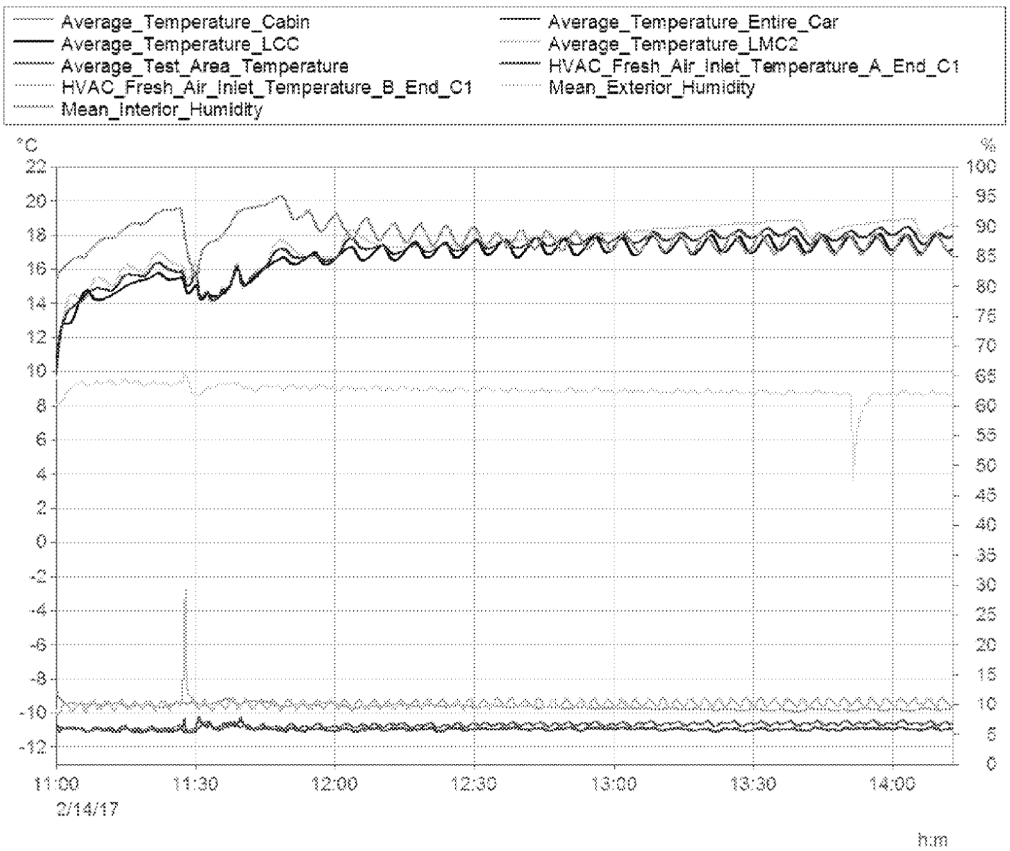


Figure 79 - Procedure F, Average Temperatures & Humidities

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 80. Looking globally at all 25 locations, the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 81.

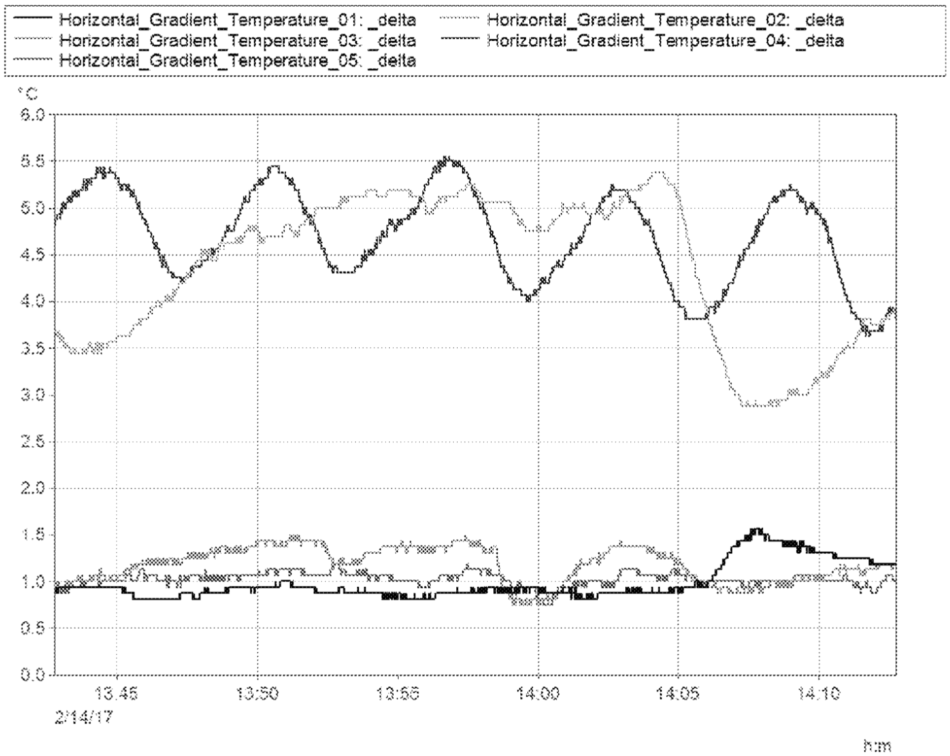


Figure 80 - Procedure F, Local Horizontal Gradients, Max Temperature Δ

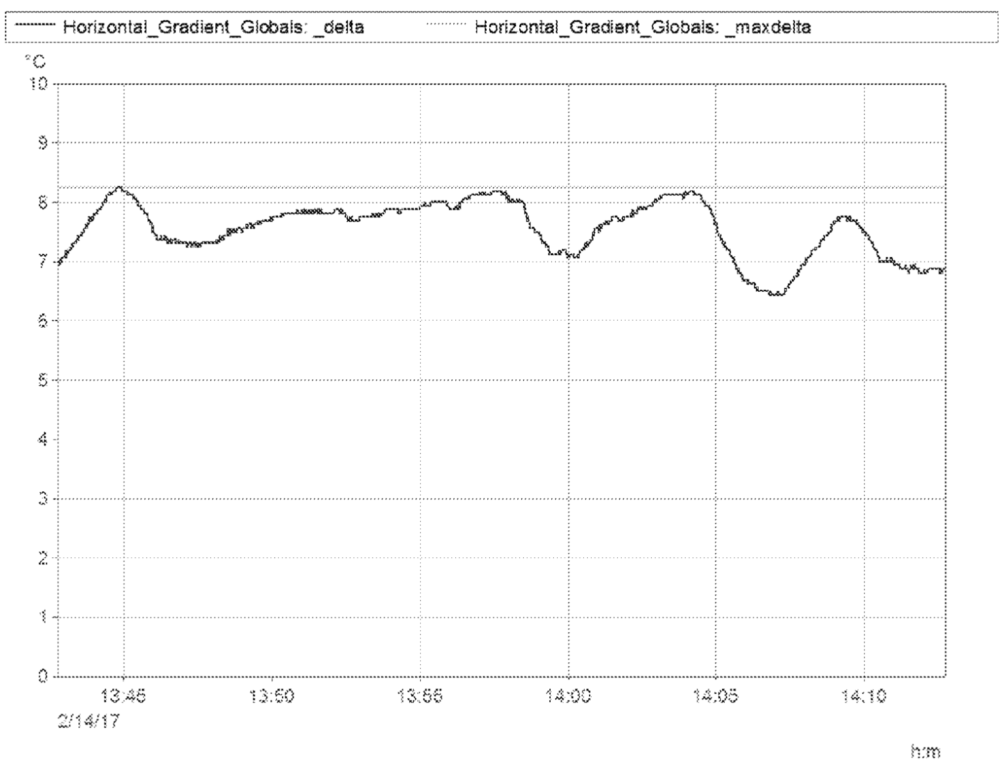


Figure 81 - Procedure F, Global Horizontal Gradients, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 82. Looking globally at all 33 locations, the temperature differential exceeded the 6°C specification for the majority of the duration of the test as shown in Figure 83.

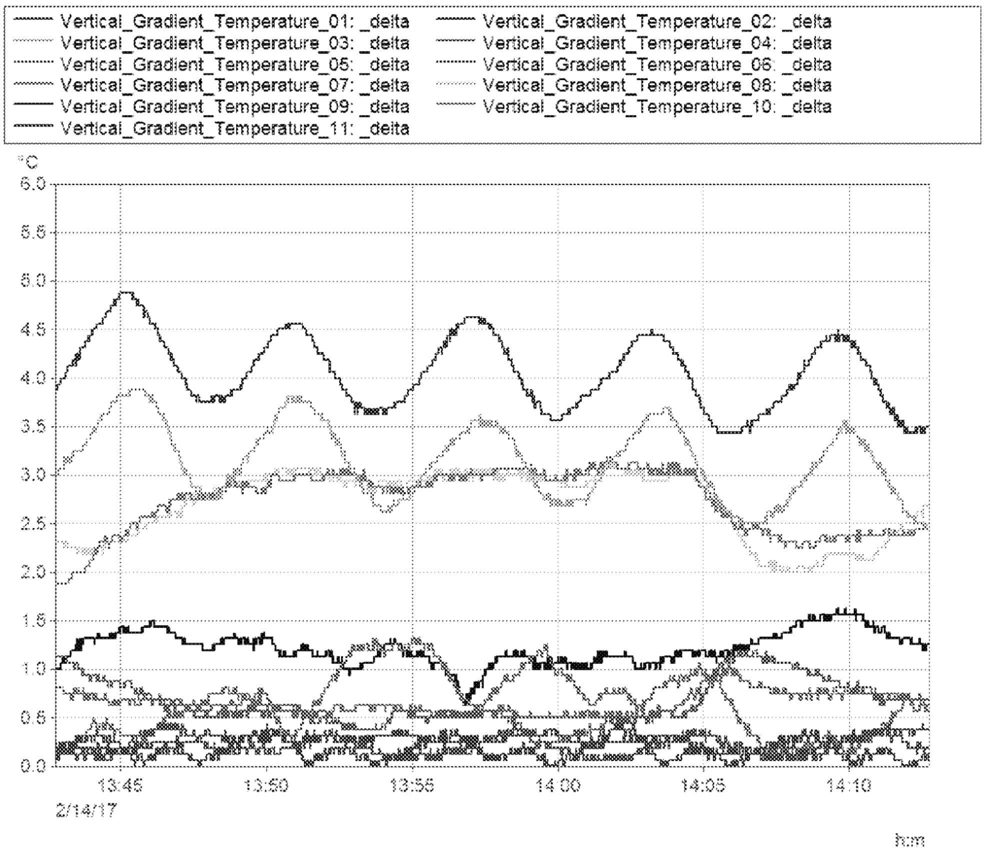


Figure 82 - Procedure F, Local Vertical Gradients, Max Temperature Δ

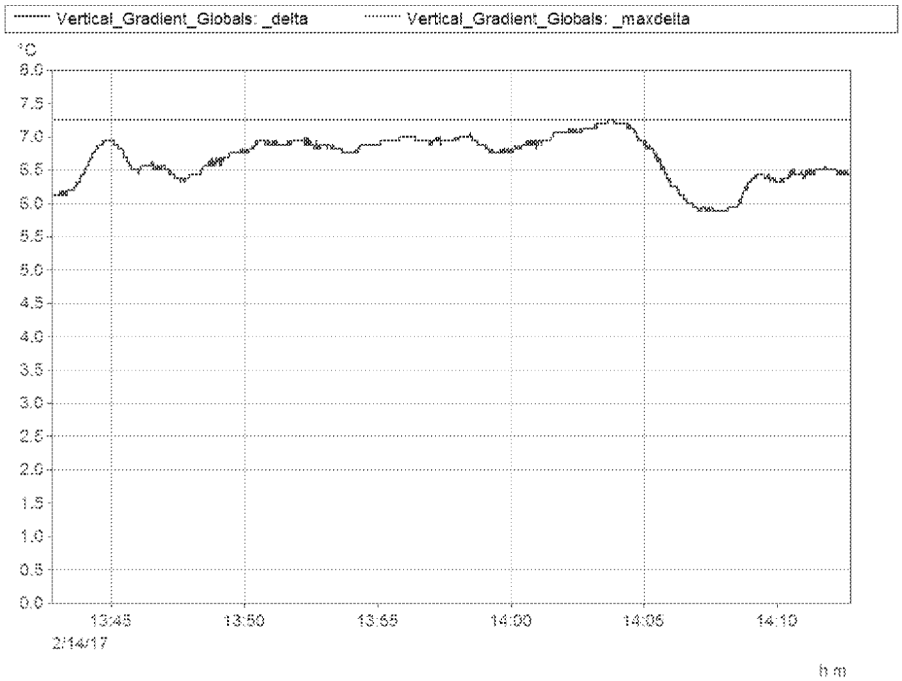


Figure 83 - Procedure F, Global Vertical Gradients, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 84 and Figure 85.

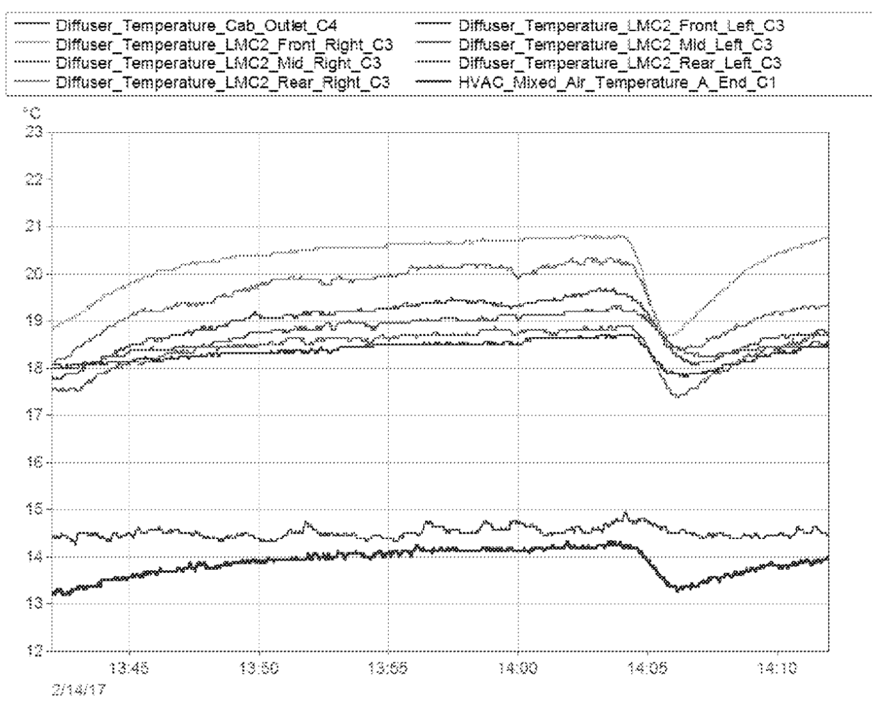


Figure 84 - Procedure F, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

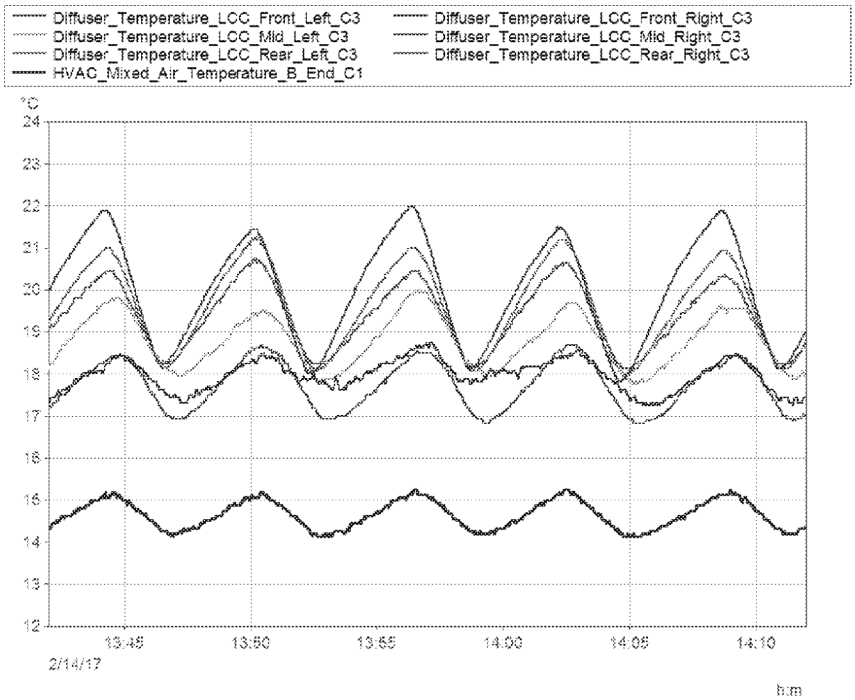


Figure 85 - Procedure F, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperature in the LCC car fluctuated between approximately 17°C and 30 °C while in the LMC2 car ranged from approximately 20°C to 30°C, remaining below 45°C for the duration of the 30 minute test as shown in Figure 86.

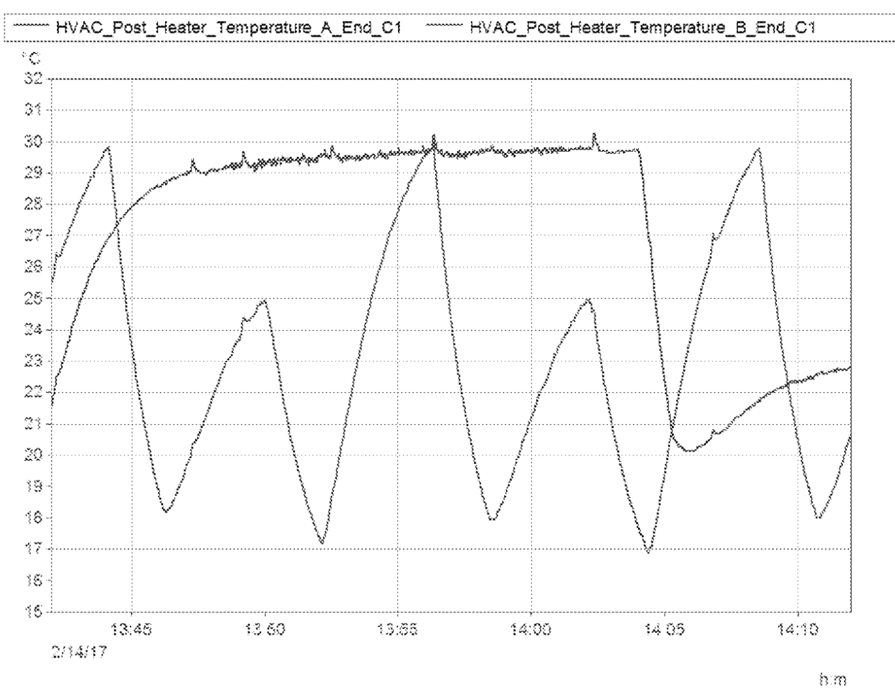


Figure 86 - Procedure F, HVAC Supply Air Temperatures, Heater Exit

Surface Temperatures of the walls, ceilings and floors measured at all 20 locations (five thermocouples at each of four cross sectional locations) all were in excess of 3°C for the duration of the test as shown in Figure 87.

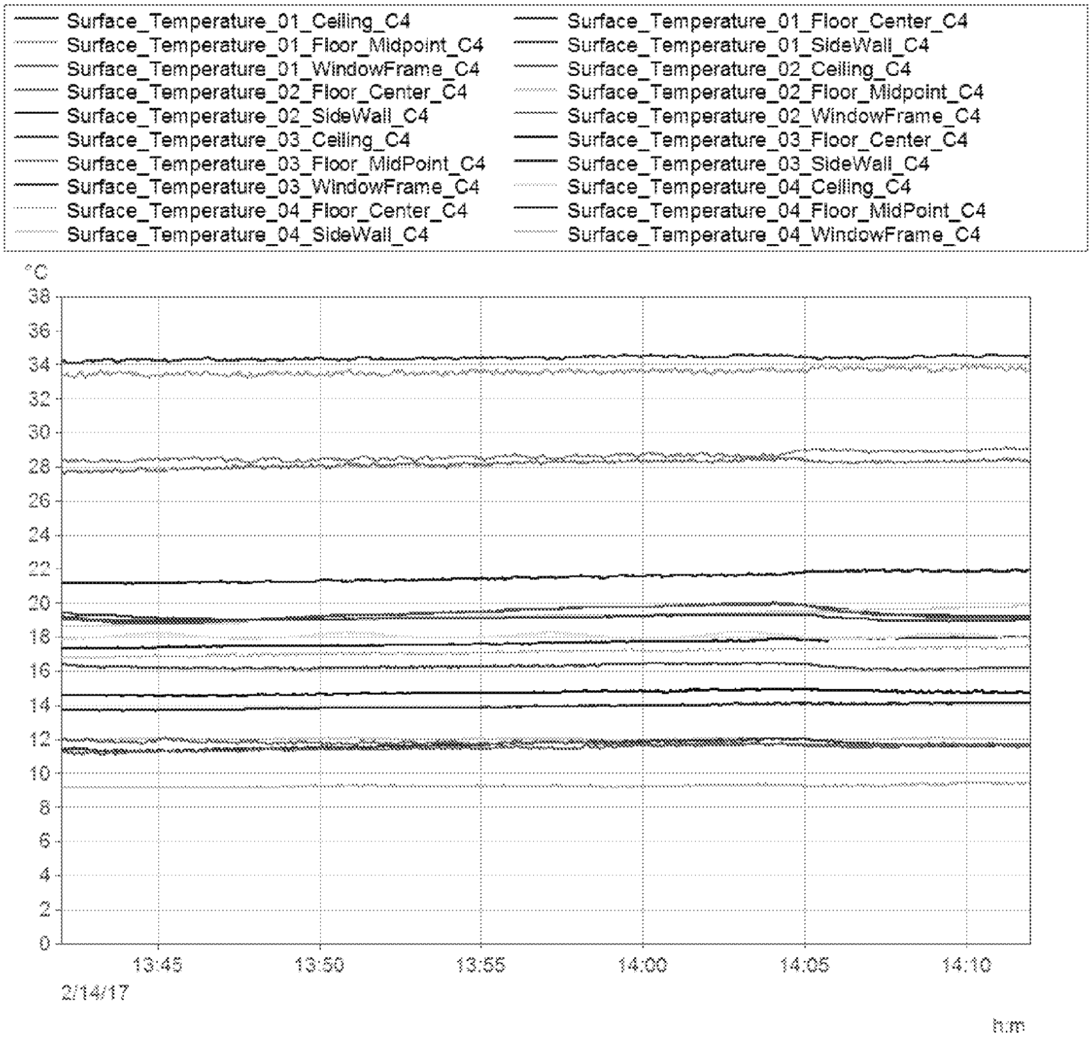


Figure 87 - Procedure F, Surface Temperatures, Wall, Ceiling and Floor Locations

Surface Temperatures of the walls measured at all 4 locations (one thermocouple at each of four cross sectional locations) were within 13°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 88.

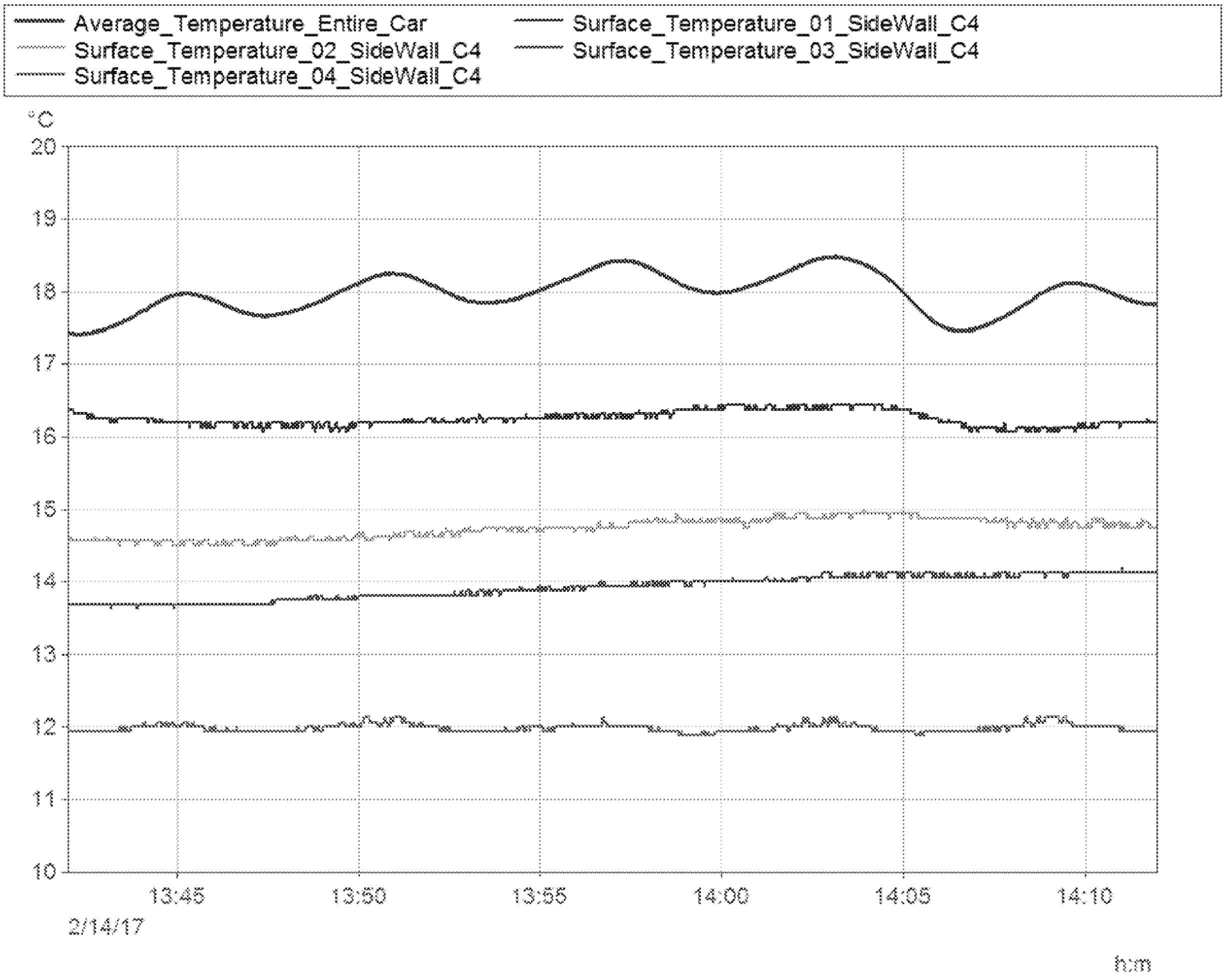


Figure 88 - Procedure F Surface Temperatures, Wall Locations versus Mean Interior Temperature

Of the 12 locations measuring Surface Temperatures of the ceilings and floors (three thermocouples at each of four cross sectional locations), two show a differential in excess of 12°C versus the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 89. These two locations are the floor measurements at the cross section located at the doors in the LCC car.

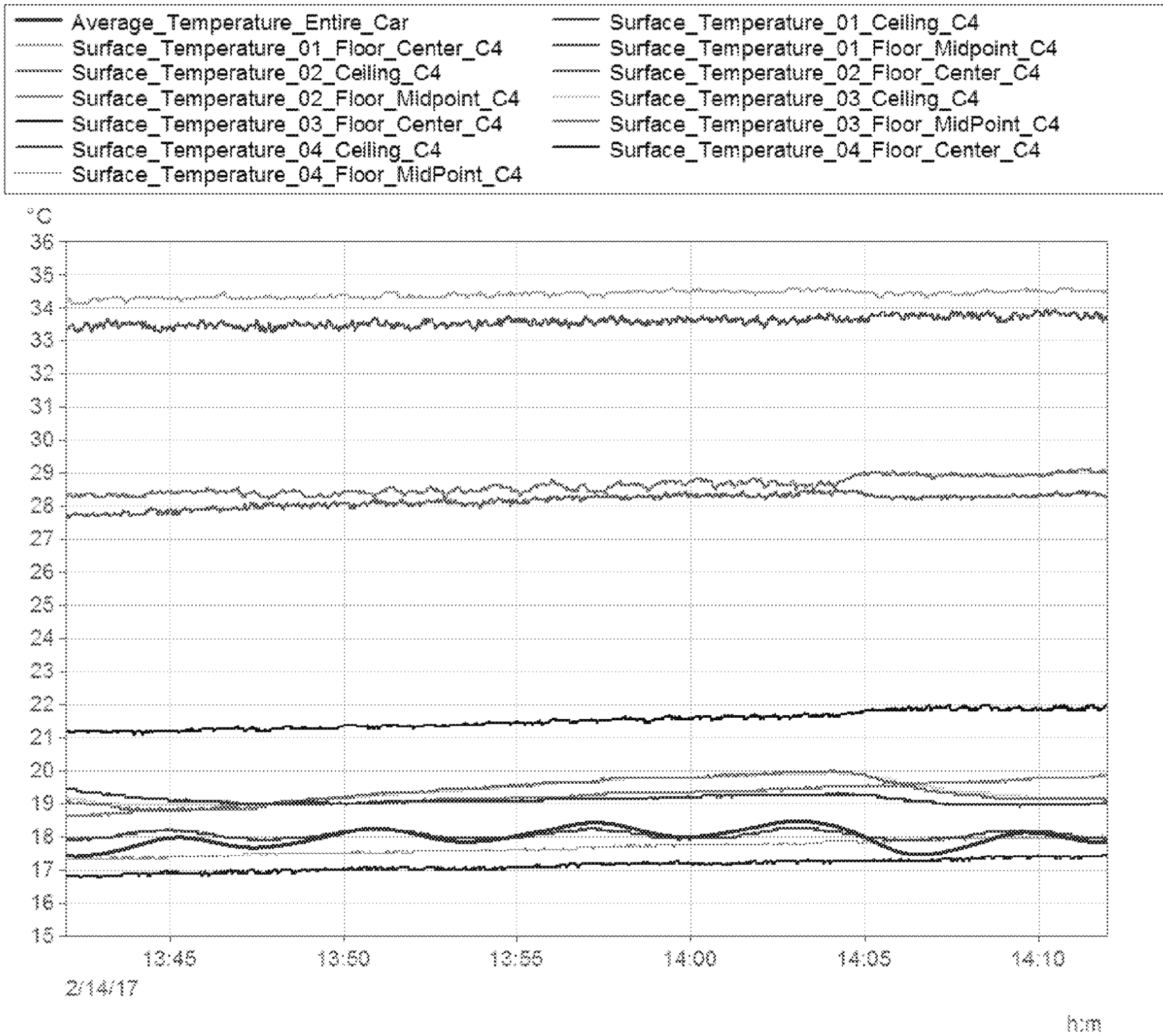


Figure 89 - Procedure F, Surface Temperatures, Ceiling and Floor Locations versus Mean Interior Temperature

Surface Temperatures of the window glass and frame locations as measured at all 8 locations (two thermocouples at each of four cross sectional locations) were within 15°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 90.

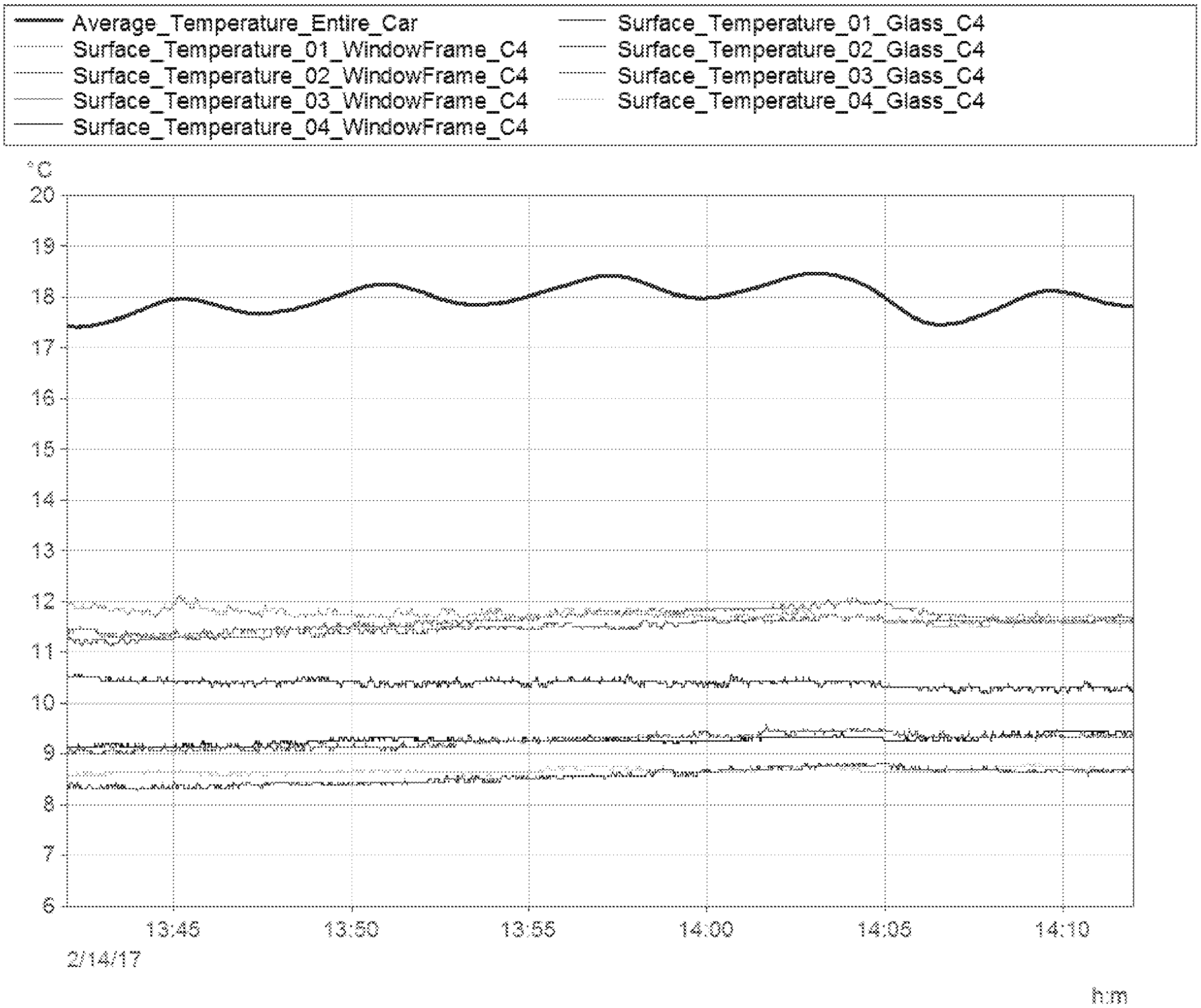


Figure 90 - Procedure F, Surface Temperatures, Window Locations versus Mean Interior Temperature

Measurements of the Cab Heater Grill Surface Temperature and Cab Diffuser Outler Temperature remained below 50°C and 35°C respectively for the duration of the 30 minute test as shown in Figure 91.

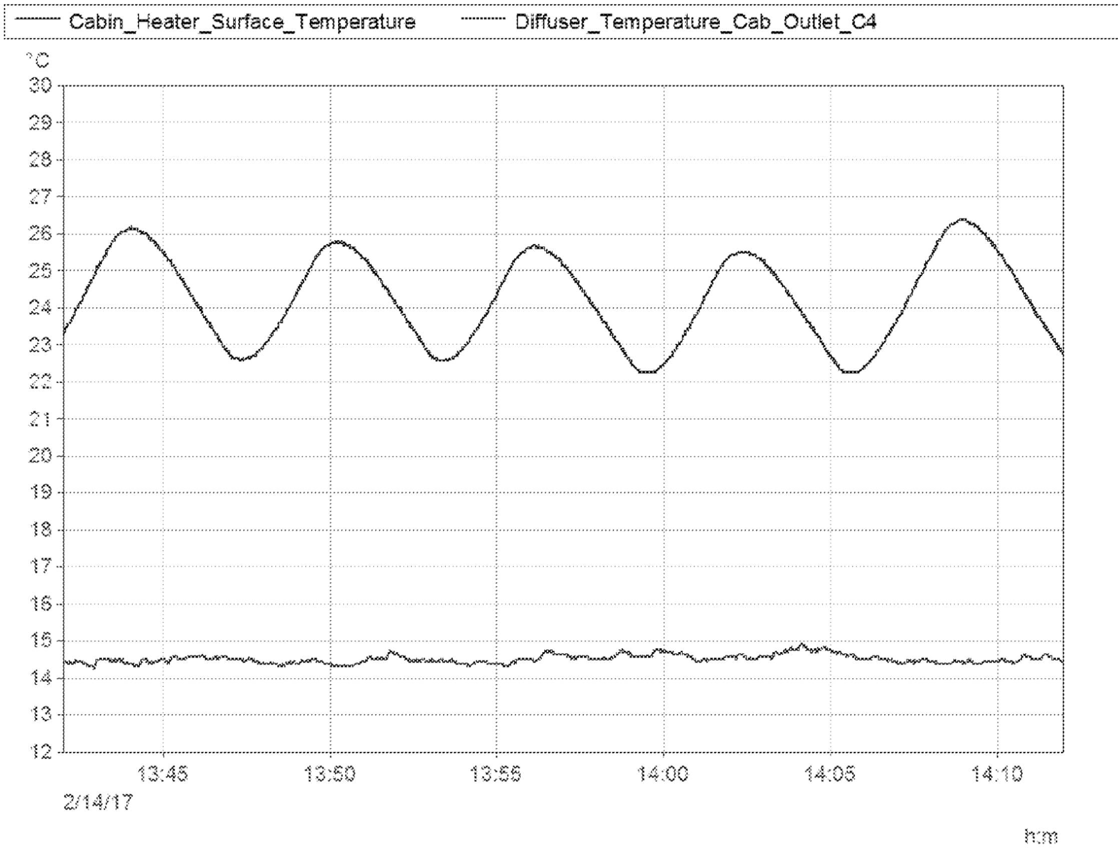


Figure 91 - Procedure F, Cab Grill Heater Surface and Diffuser Outlet Temperatures

5.2.5.7 Procedure G - Performance in Heating Mode

Procedure G testing was performed prior to the diffuser modifications which were made on February 4th. As this test was not deemed a priority by Alstom, testing was terminated prior to achieving a steady state condition

Chamber temperature set points were set to achieve a temperature of -20°C, with no passenger loads and lights turned on.

With the Temperature Setpoint T_{ic} set to a maximum at 40°C at 21:10 such that the maximum achievable temperature was attained, the Cabin Heater On High speed and Booster set to Low speed, data was recorded for two hours between 20:55 and 22:55 as shown in Figure 92. Over the approximately two hour test duration, the Mean Interior Temperature T_{im} rose by approximately 3°C from 18.0°C to 21.0°C and was clearly still positively sloping.

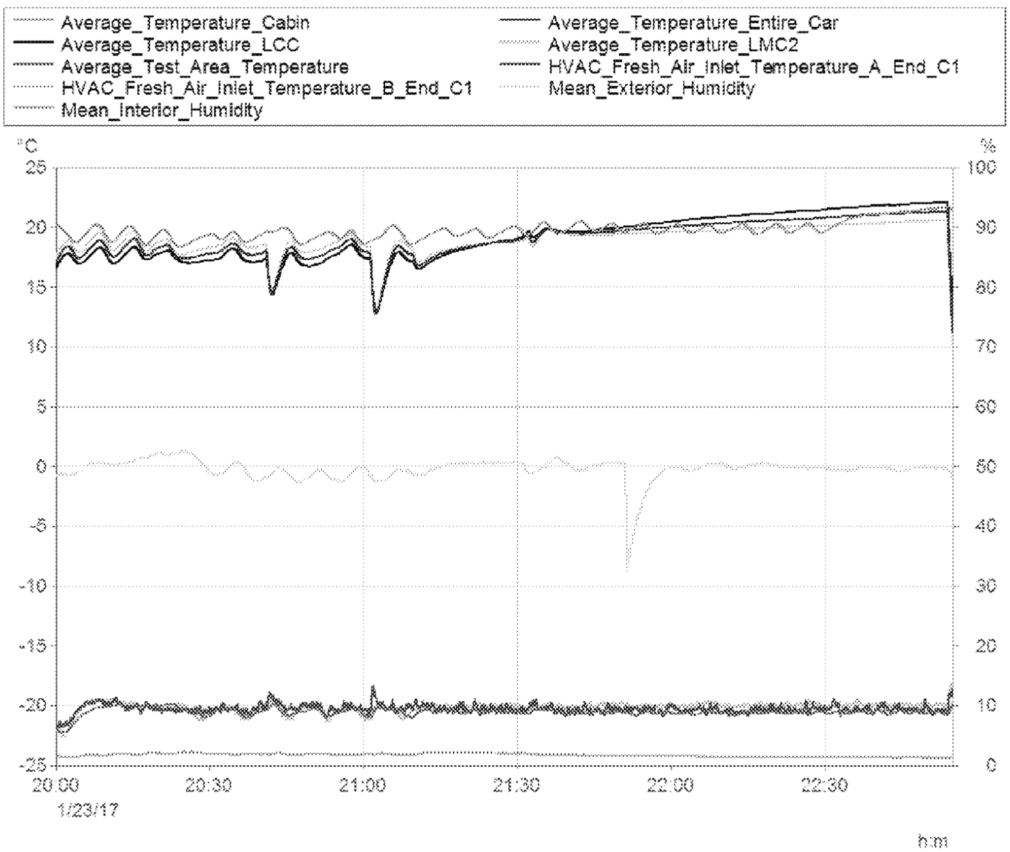


Figure 92 - Procedure G, Average Temperatures & Humidities

5.2.5.8 Procedure H - Regulation in Heating Mode Without Passengers

Chamber temperature set points were set to achieve a temperature of -22°C, with no passenger loads and lights turned on at 07:40.

With the Temperature Setpoint T_{ic} set to 16°C, the Cabin Heater ON in High Speed, Floor Heating On and Booster set to Low speed, a steady state condition was achieved and data was recorded for a period of 30 minutes between 15:03 and 15:33 as shown in Figure 93. Over the 30 minute test duration, the Mean Interior Temperature T_{im} remained within ±2°C of the T_{ic} while the Cabin Temperature remained >2°C in excess of the set point for the duration of the test.

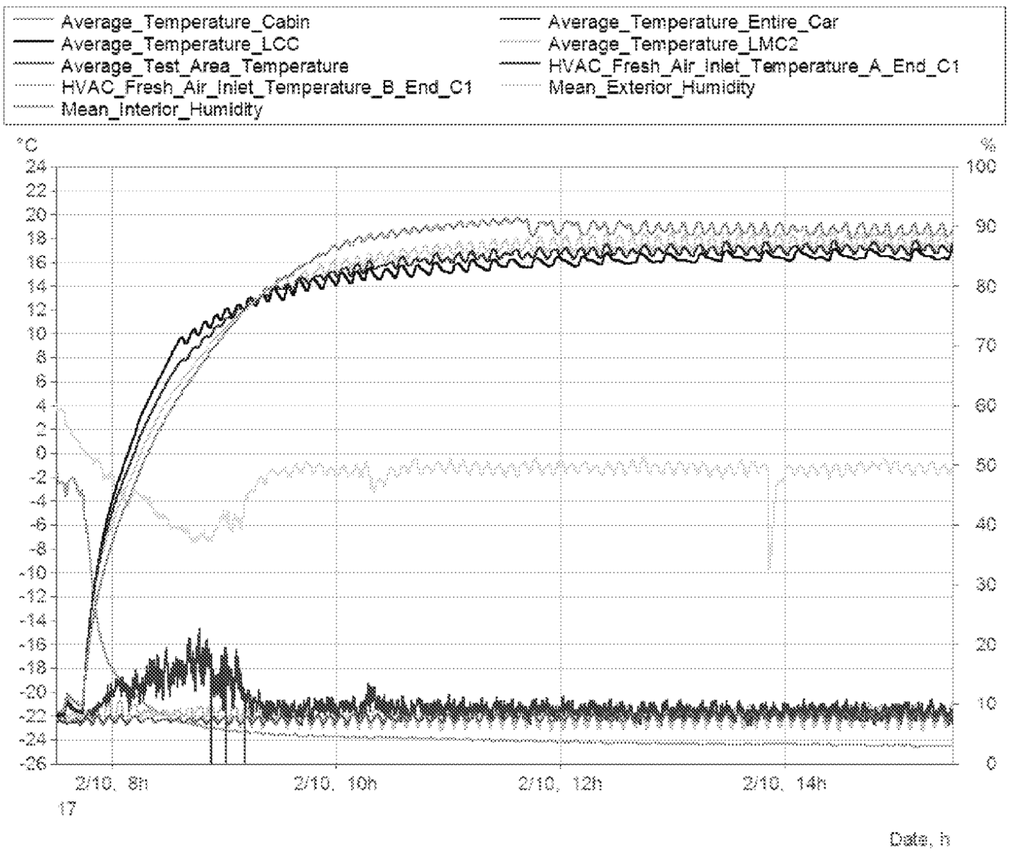


Figure 93 - Procedure H, Average Temperatures & Humidities

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at one location, HG2, exceeded the 6°C specification as shown in Figure 94. Looking globally at all 25 locations, the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 95.

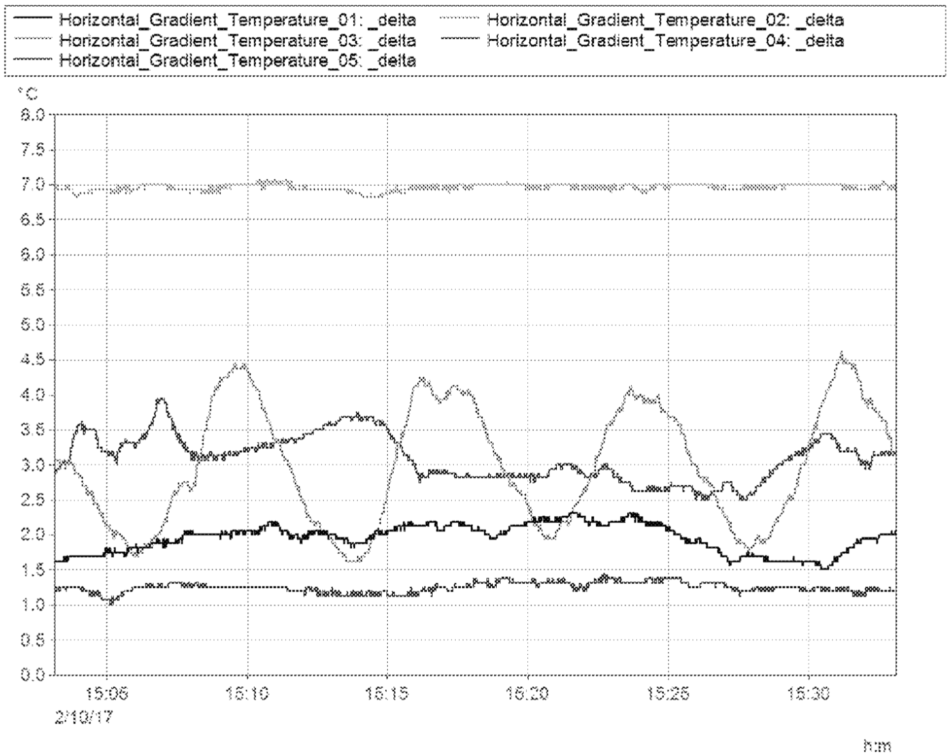


Figure 94 - Procedure H, Local Horizontal Gradients, Max Temperature Δ

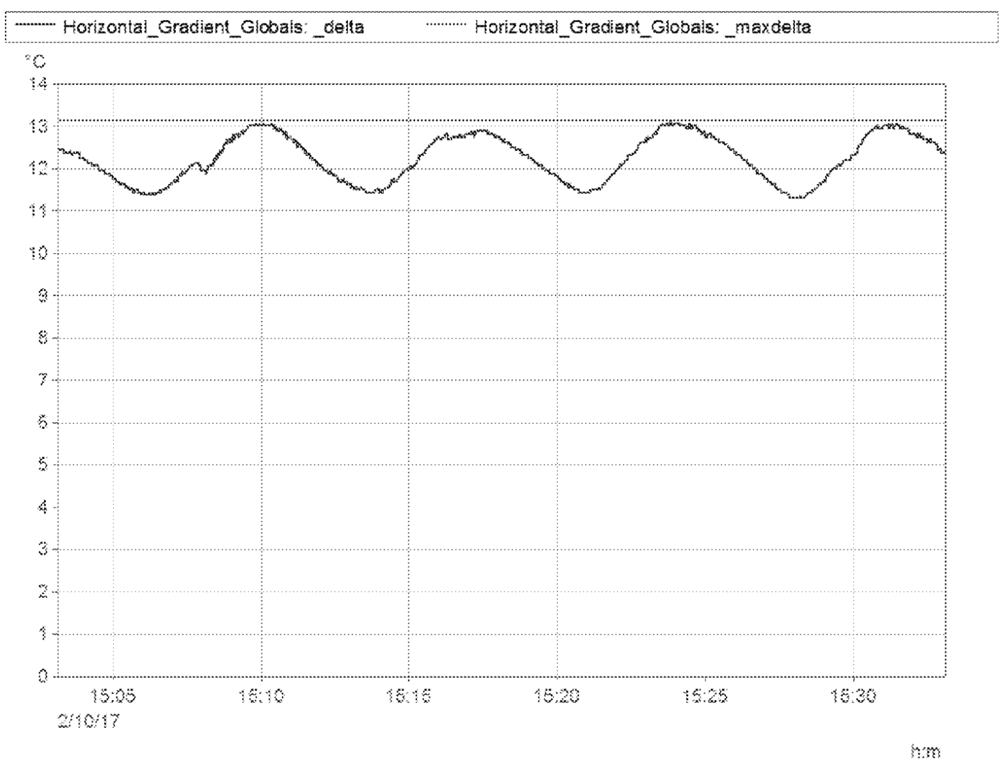


Figure 95 - Procedure H, Global Horizontal Gradients, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at six locations exceeded the 6°C specification as shown in Figure 96. Looking globally at all 33 locations, the temperature differential exceeded the 6°C specification for the duration of the test as shown in Figure 97.

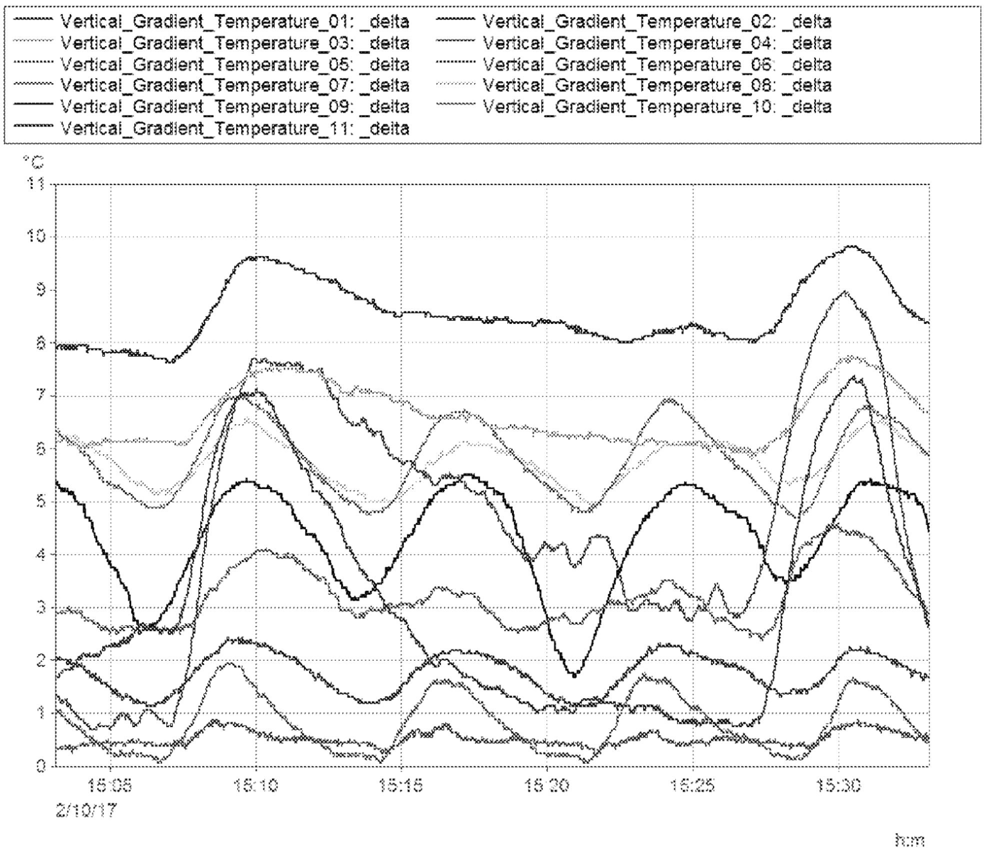


Figure 96 - Procedure H, Local Vertical Gradients, Max Temperature Δ

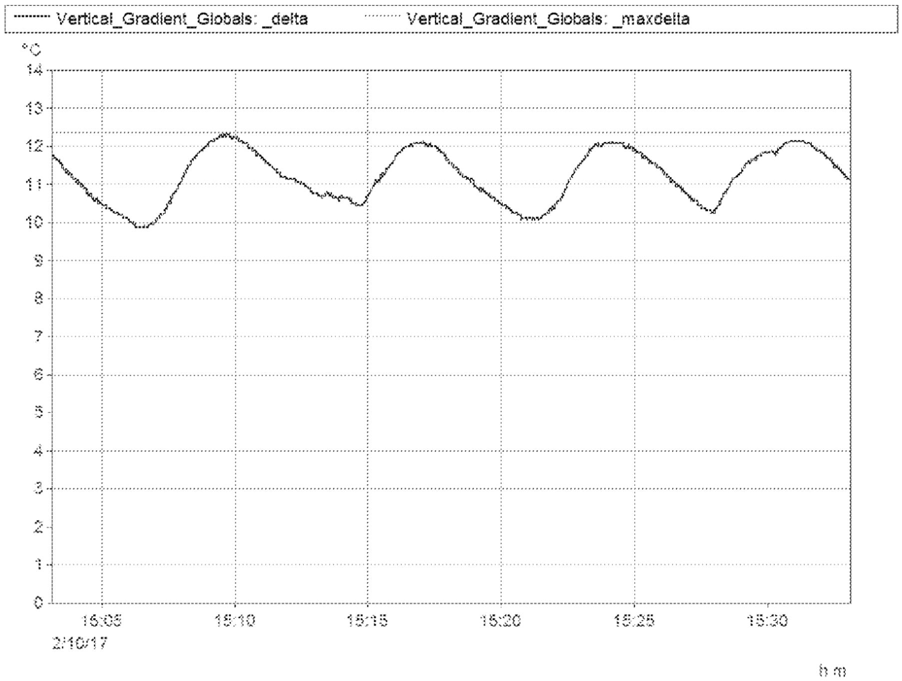


Figure 97 - Procedure H, Global Vertical Gradients, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 98 and Figure 99.

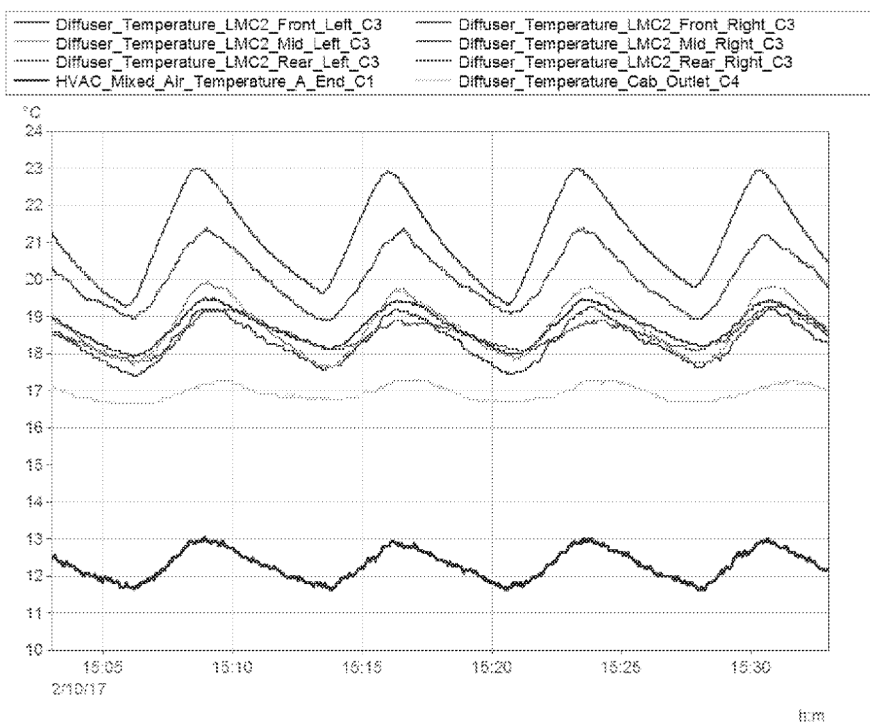


Figure 98 - Procedure H, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

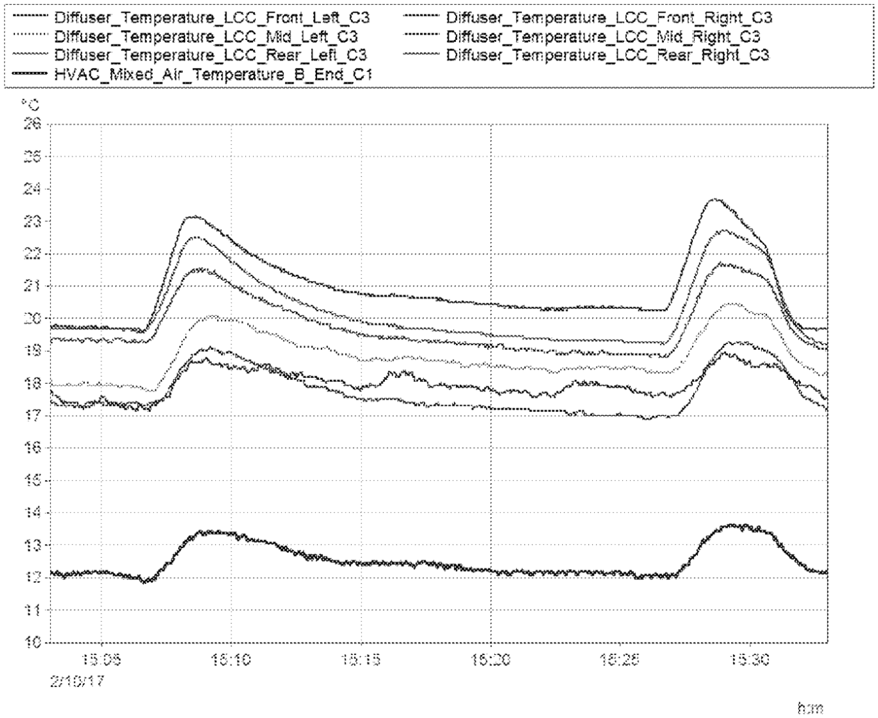


Figure 99 - Procedure H, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperature in the LCC ranged from approximately 21°C to 34°C while in the LMC2 car fluctuated between approximately 20°C to 35°C, remaining below 45°C for the duration of the 30 minute test as shown in Figure 100.

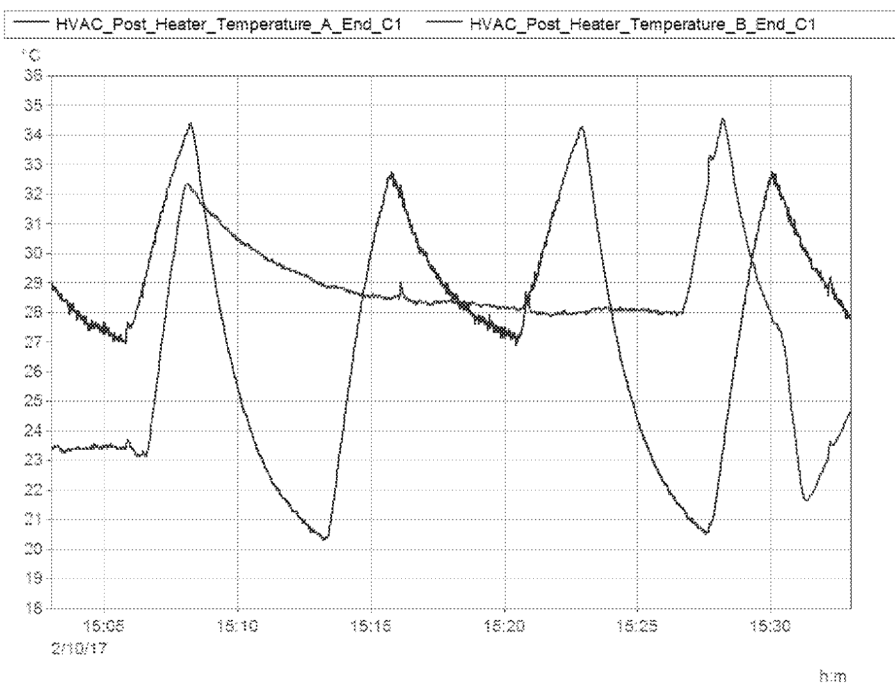


Figure 100 - Procedure H, HVAC Supply Air Temperatures, Heater Exit

Surface Temperatures of the walls, ceilings and floors measured at all 20 locations (five thermocouples at each of four cross sectional locations) all were in excess of 3°C for the duration of the test as shown in Figure 101.

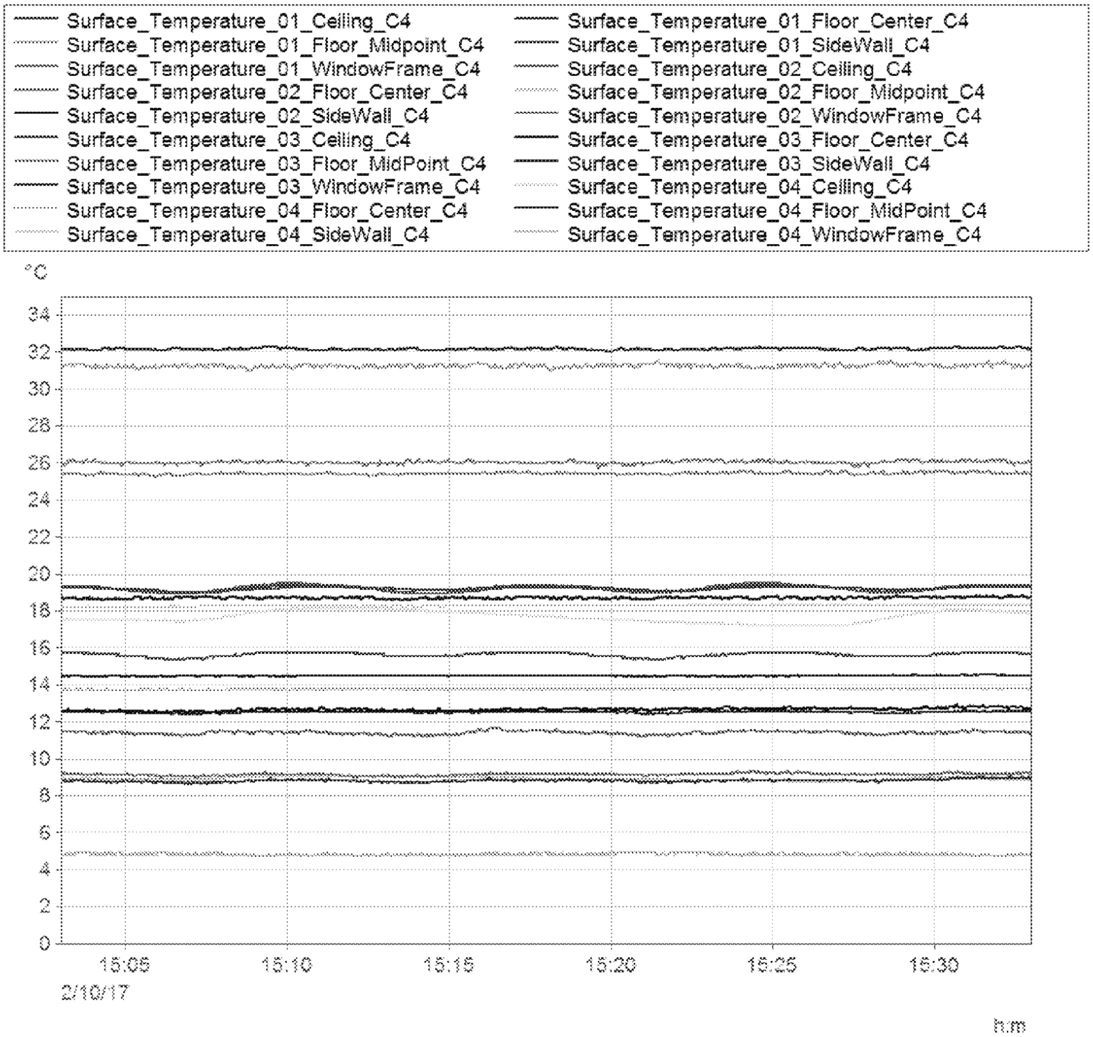


Figure 101 - Procedure H, Surface Temperatures, Wall, Ceiling and Floor Locations

Surface Temperatures of the walls measured at all 4 locations (one thermocouple at each of four cross sectional locations) were within 13°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 102.

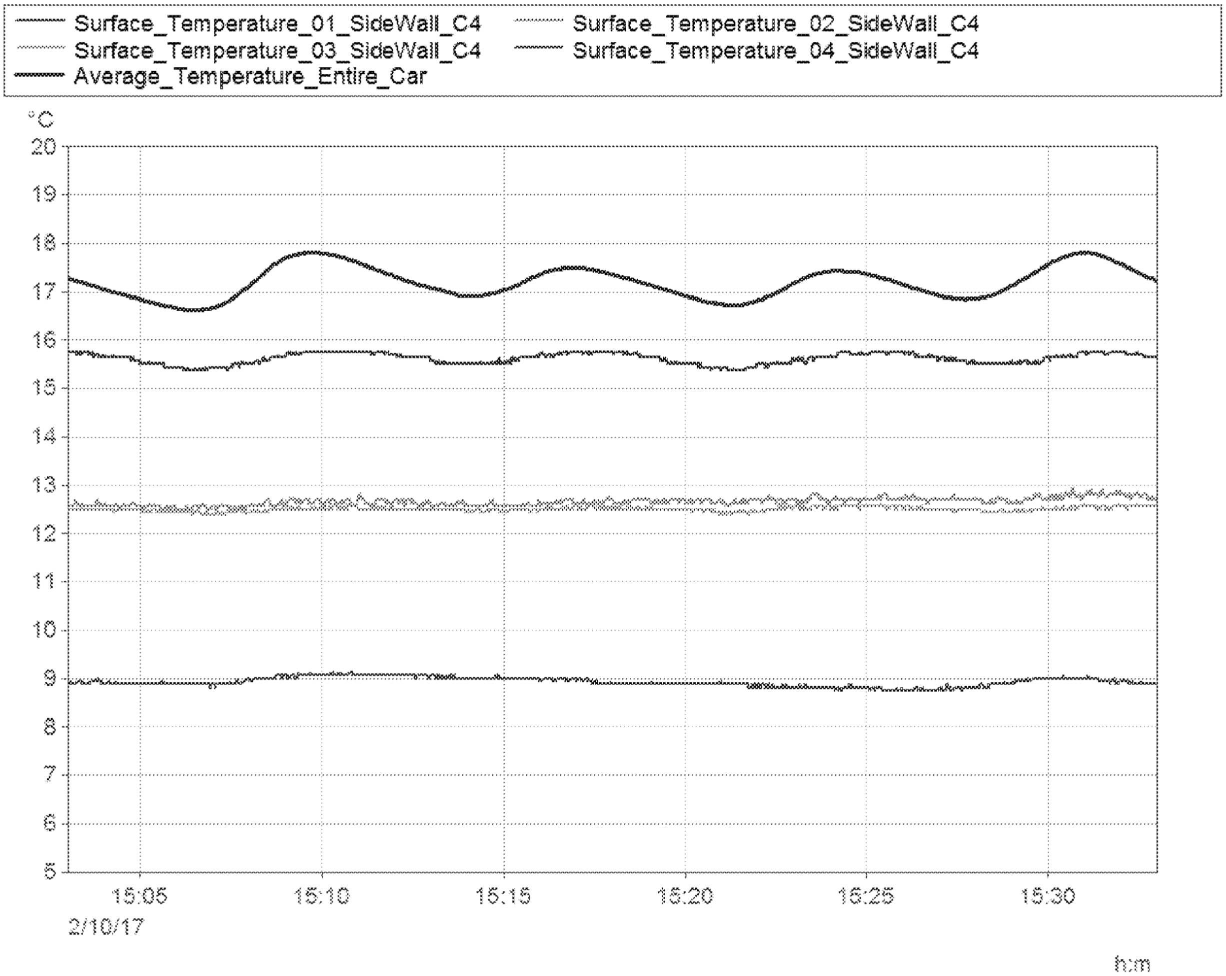


Figure 102 - Procedure H, Surface Temperatures, Wall Locations versus Mean Interior Temperature

Surface Temperatures of the ceilings and floors measured at all 12 locations (three thermocouples at each of four cross sectional locations), were within 12°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 103.

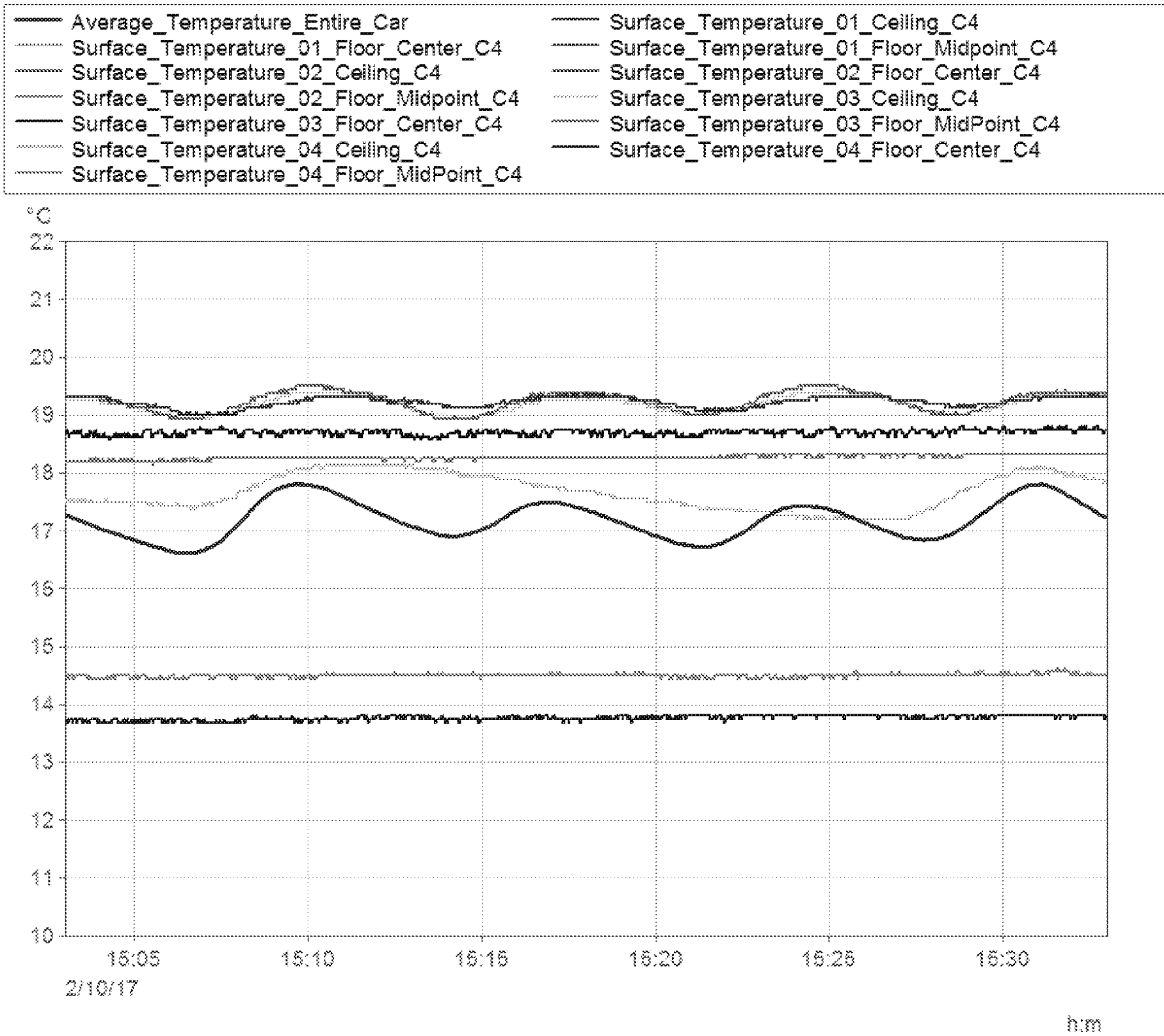


Figure 103 - Procedure H, Surface Temperatures, Ceiling and Floor Locations versus Mean Interior Temperature

Surface Temperatures of the window glass and frame locations as measured at all 8 locations (two thermocouples at each of four cross sectional locations) were within 15°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 104.

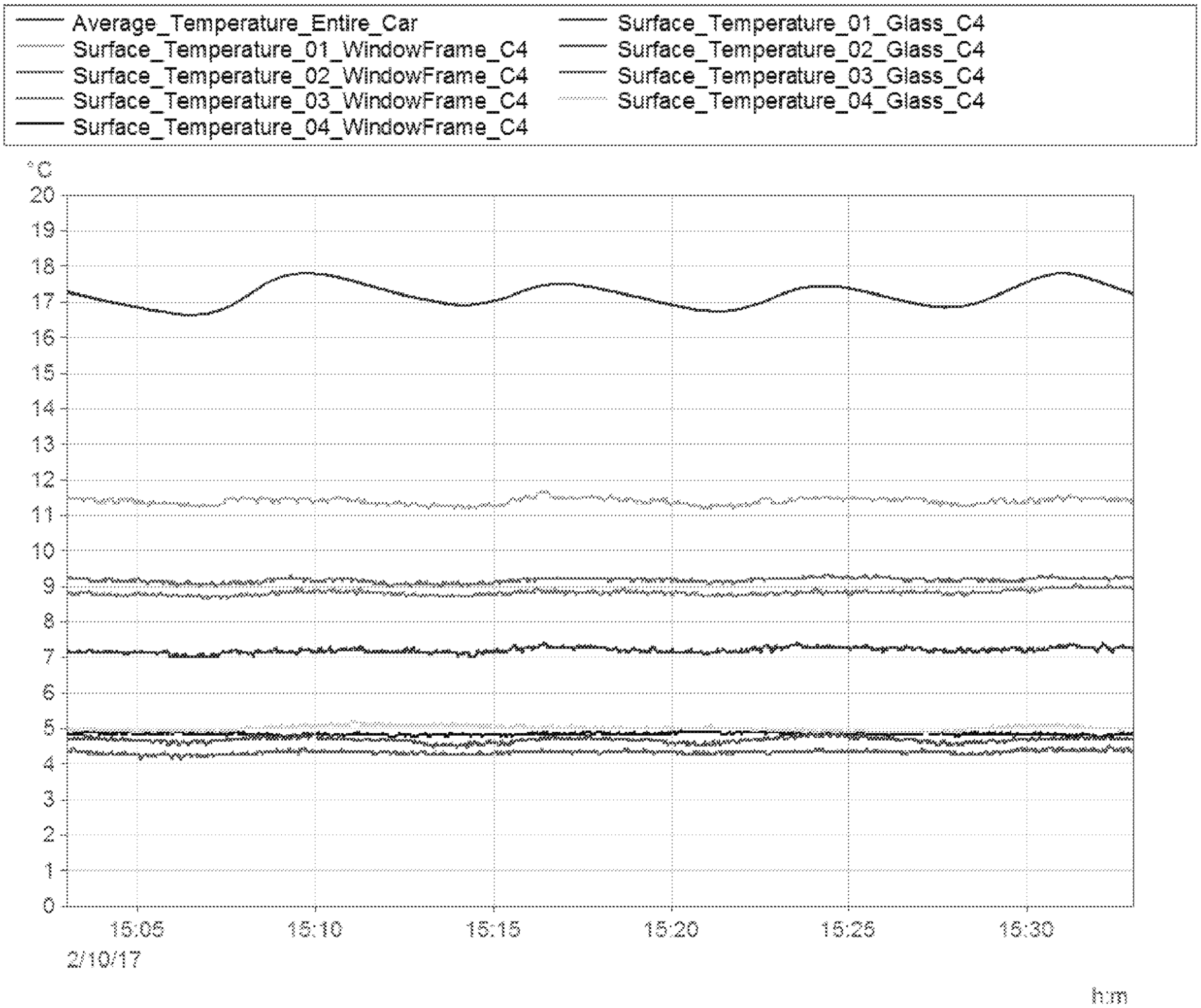


Figure 104 - Procedure H, Surface Temperatures, Window Locations versus Mean Interior Temperature

Measurements of the Cab Heater Grill Surface Temperature and Cab Diffuser Outler Temperature remained below 50°C and 35°C respectively for the duration of the 30 minute test as shown in Figure 105.

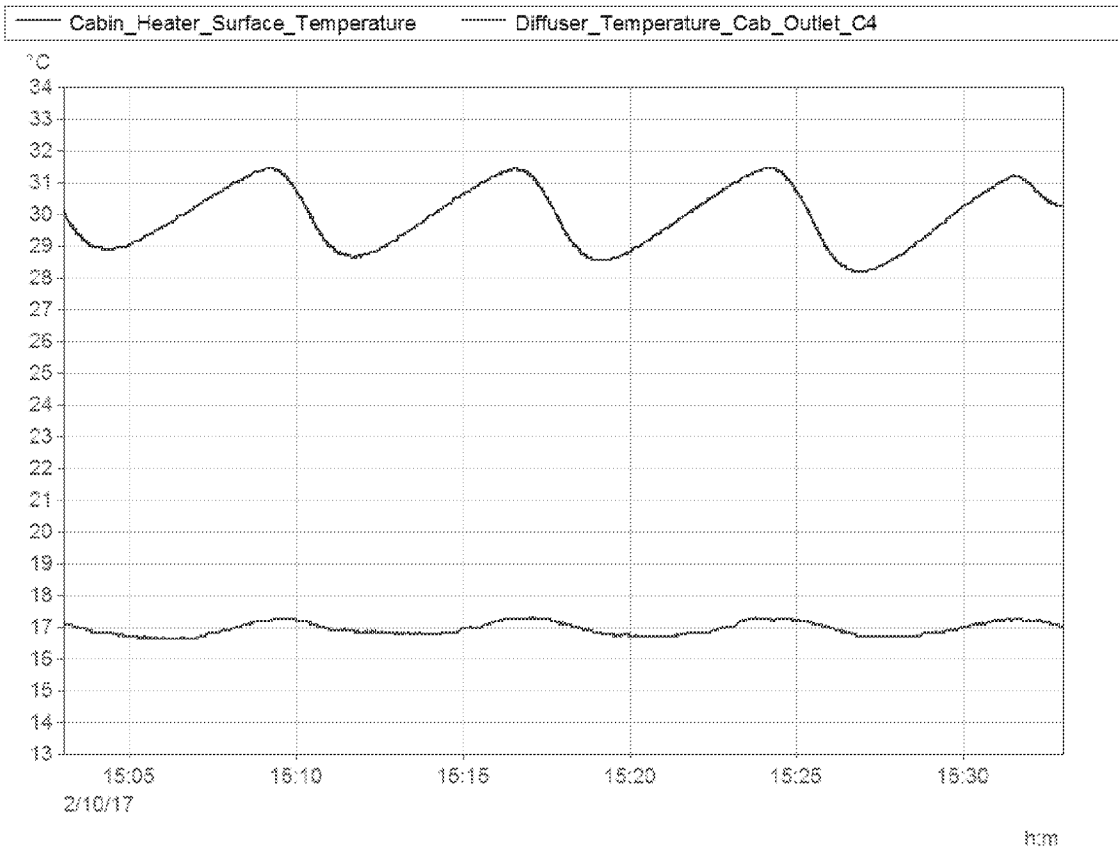


Figure 105 - Procedure H, Cab Grill Heater Surface and Diffuser Outlet Temperatures

5.2.5.9 Procedure I - Regulation in Heating Mode With Passengers

Chamber temperature set points were set to achieve a temperature of 0°C, with passenger loads applied of 13 kW (sensible) and 212 ml/min of steam (latent), and lights turned on at 15:00.

With the Temperature Setpoint T_{ic} set to 16°C, the Cabin Heater ON in High Speed, Floor Heating On and Booster set to Low speed, a steady state condition was achieved and data was recorded for a period of 30 minutes between 16:10 and 16:40 as shown in Figure 106. Over the 30 minute test duration, the Mean Interior Temperature T_{im} remained >2°C in excess of the T_{ic} for approximately 10 minutes, while the Cabin Temperature remained within ±2°C tolerance of the set point for the test duration.

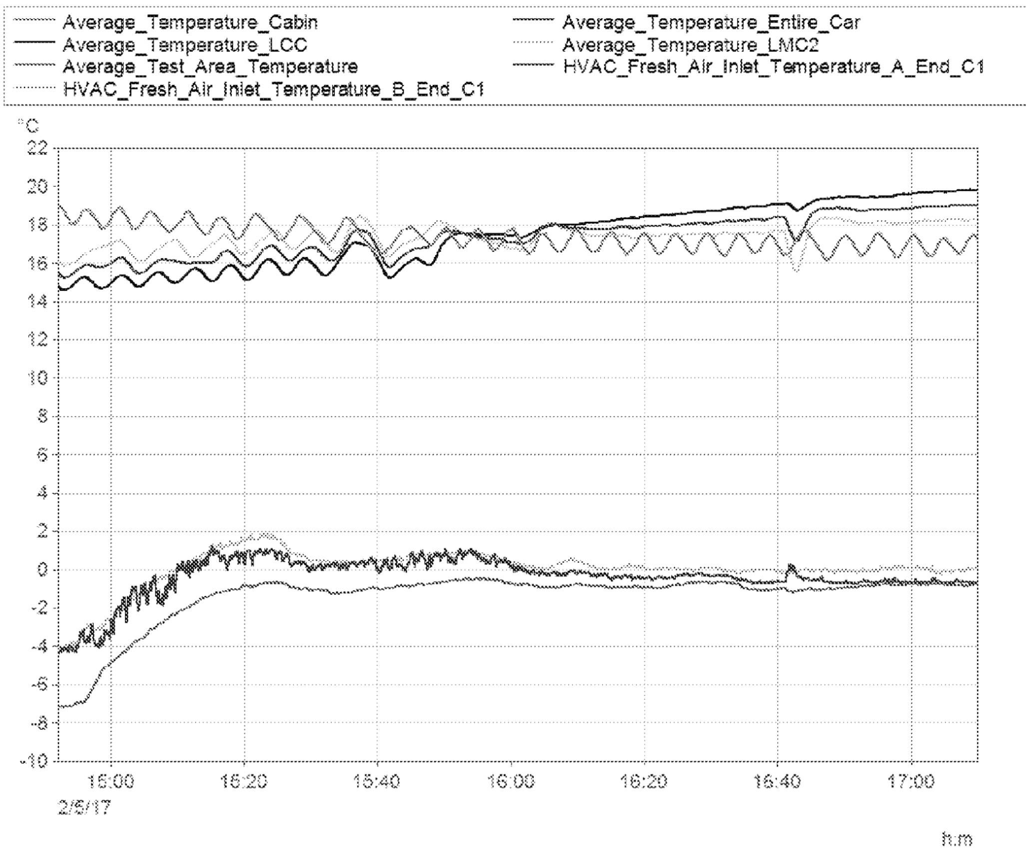


Figure 106 - Procedure I, Average Temperatures

Temperatures at all 25 Horizontal Gradient locations (five thermocouples at each of five cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the five cross sectional locations individually, the temperature differential at one location, HG04, exceeded the 6°C specification briefly as shown in Figure 107. Looking globally at all 25 locations, the temperature differential exceeded the 6°C specification intermittently during the test as shown in Figure 108.

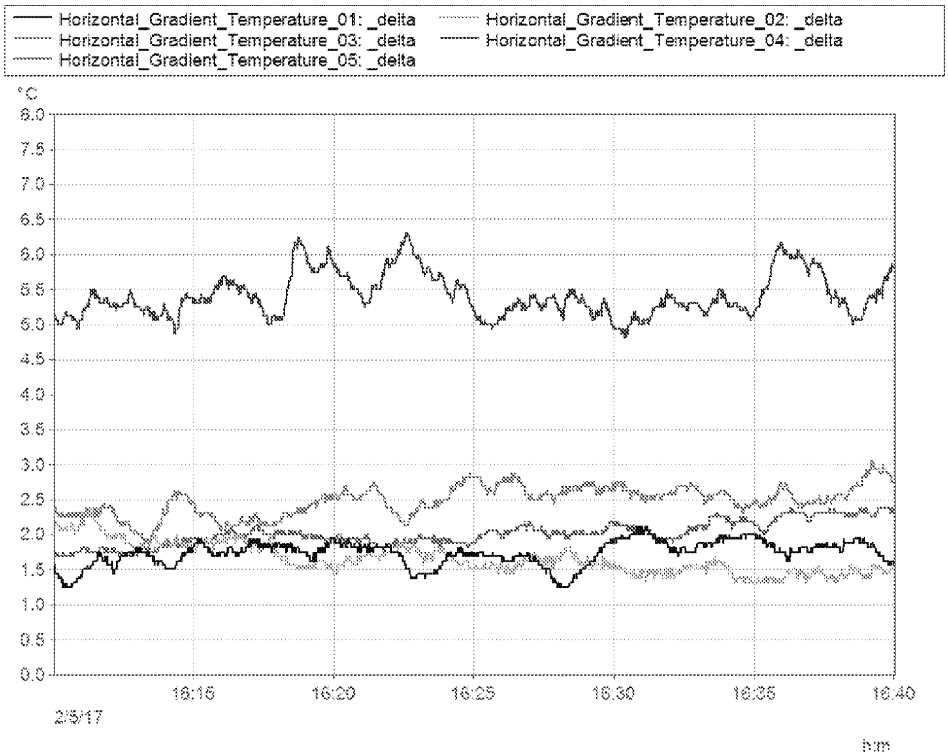


Figure 107 - Procedure I, Local Horizontal Gradients, Max Temperature Δ

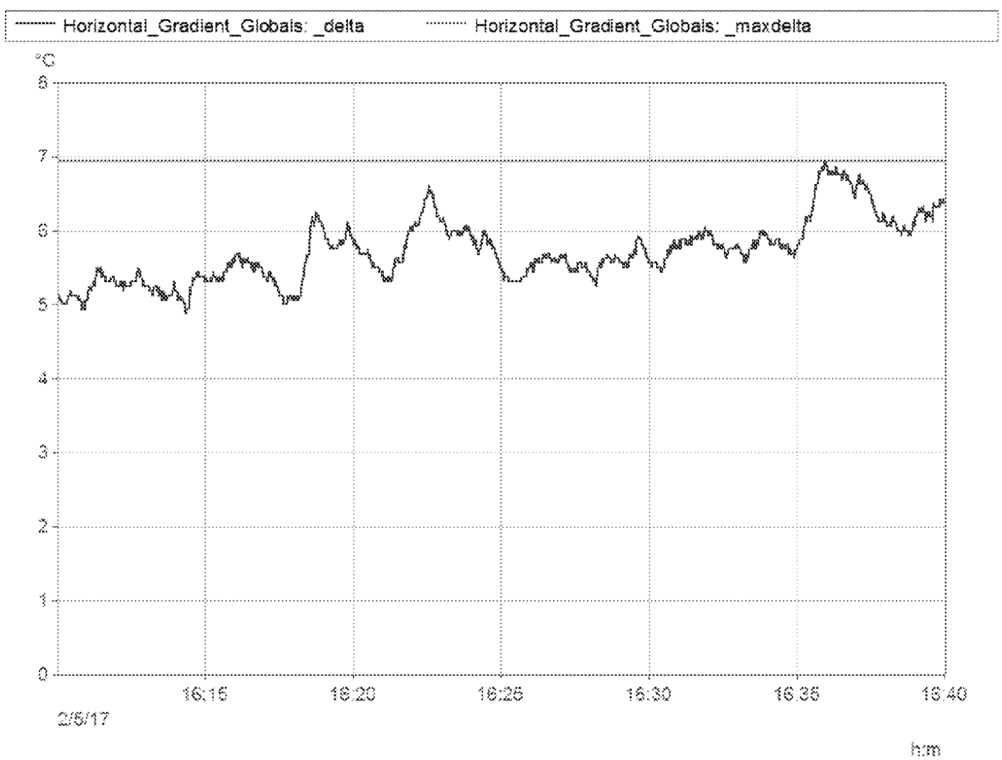


Figure 108 - Procedure I, Global Horizontal Gradients, Max Temperature Δ

Temperatures at all 33 Vertical Gradient locations (three thermocouples at each of eleven cross sectional locations) were compared on a local basis (within the cross section) and a global basis (against all other locations).

Based on each of the eleven cross sectional locations individually, the temperature differential at no locations exceeded the 6°C specification as shown in Figure 109. Looking globally at all 33 locations, the temperature differential exceeded the 6°C specification for the majority of the duration of the test as shown in Figure 110.

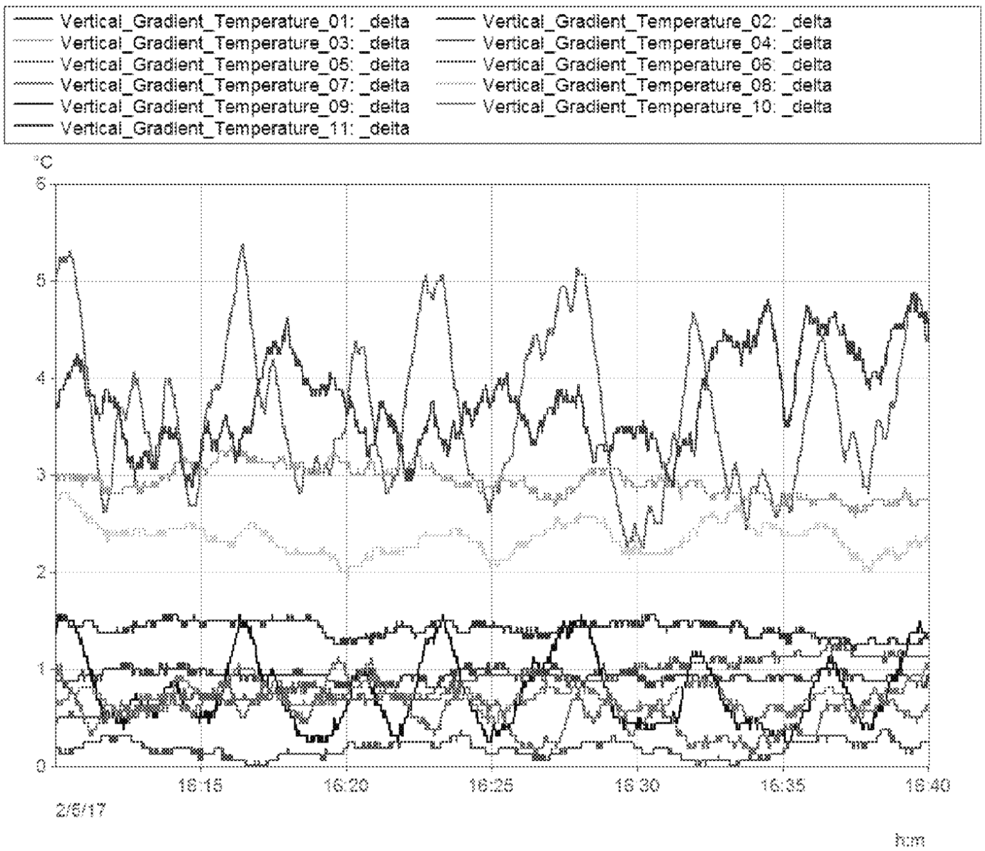


Figure 109 - Procedure I, Local Vertical Gradients, Max Temperature Δ

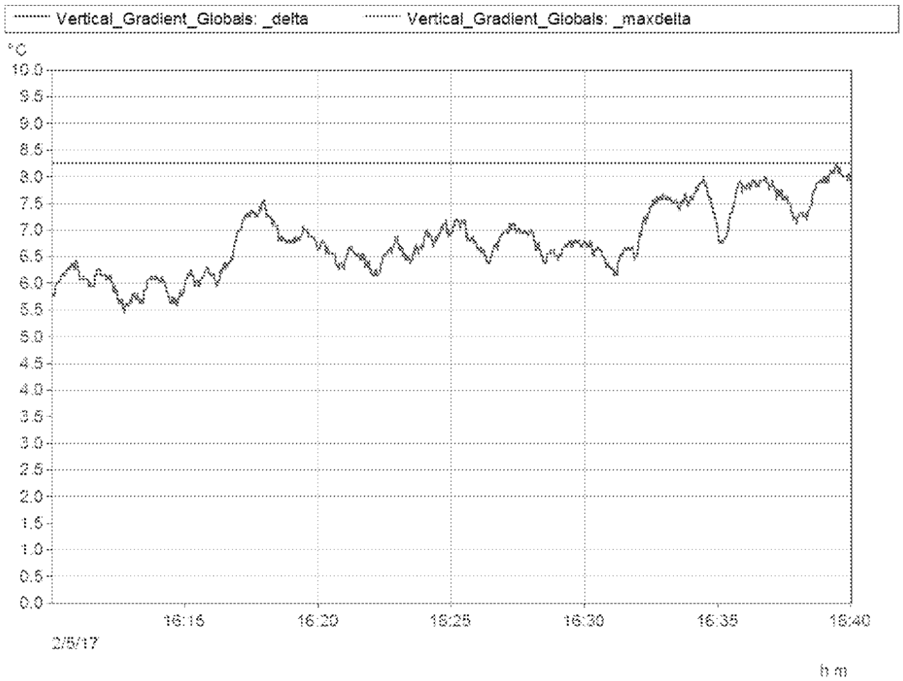


Figure 110 - Procedure I, Global Vertical Gradients, Max Temperature Δ

All Diffuser Temperatures in both the LMC2 and LCC cars were within 14°C of their respective HVAC mixed air inlet temperatures (thick red curve) as shown in Figure 111 and Figure 112.

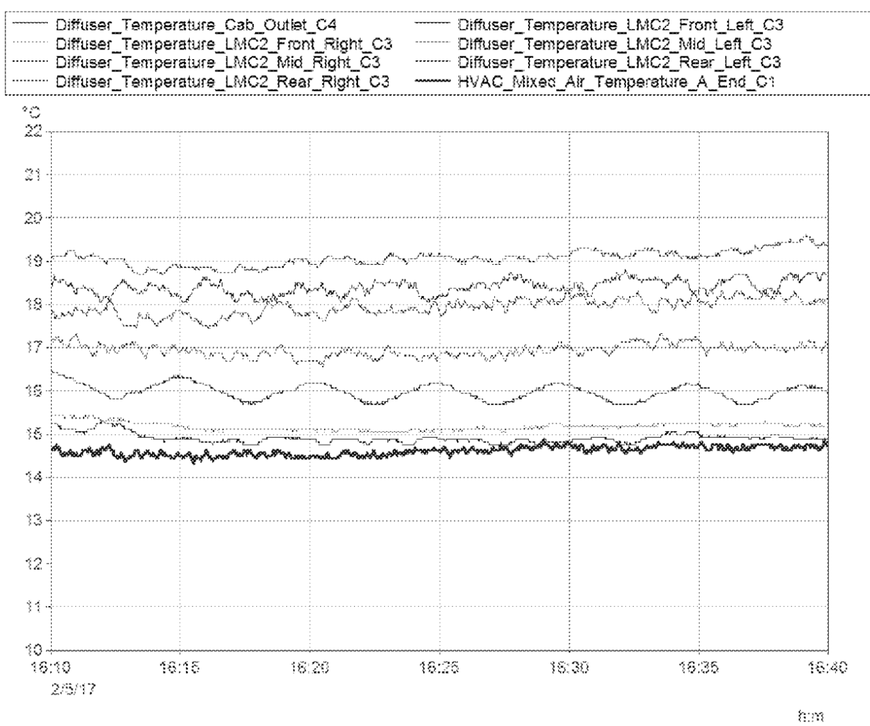


Figure 111 - Procedure I, Diffuser Temperatures versus LMC2 HVAC Inlet Air Temperature

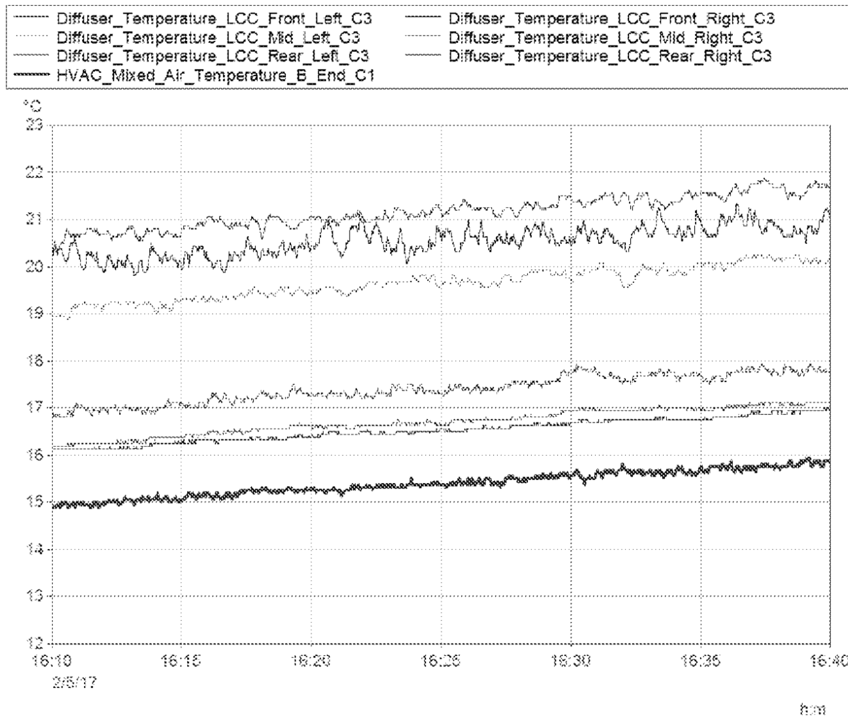


Figure 112 - Procedure I, Diffuser Temperatures versus LCC HVAC Inlet Air Temperature

Supply Air Temperature in the LCC and LMC2 cars was stable between approximately 14°C and 15°C, remaining below 45°C for the duration of the 30 minute test as shown in Figure 113.

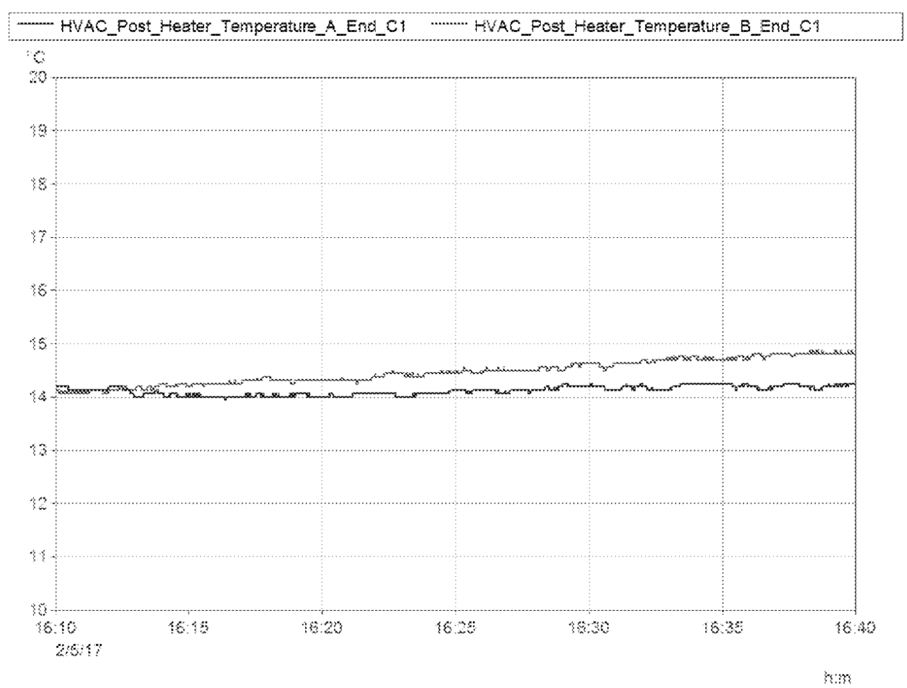


Figure 113 - Procedure I, HVAC Supply Air Temperatures, Heater Exit

Surface Temperatures of the walls, ceilings and floors measured at all 20 locations (five thermocouples at each of four cross sectional locations) all were in excess of 3°C for the duration of the test as shown in Figure 114.

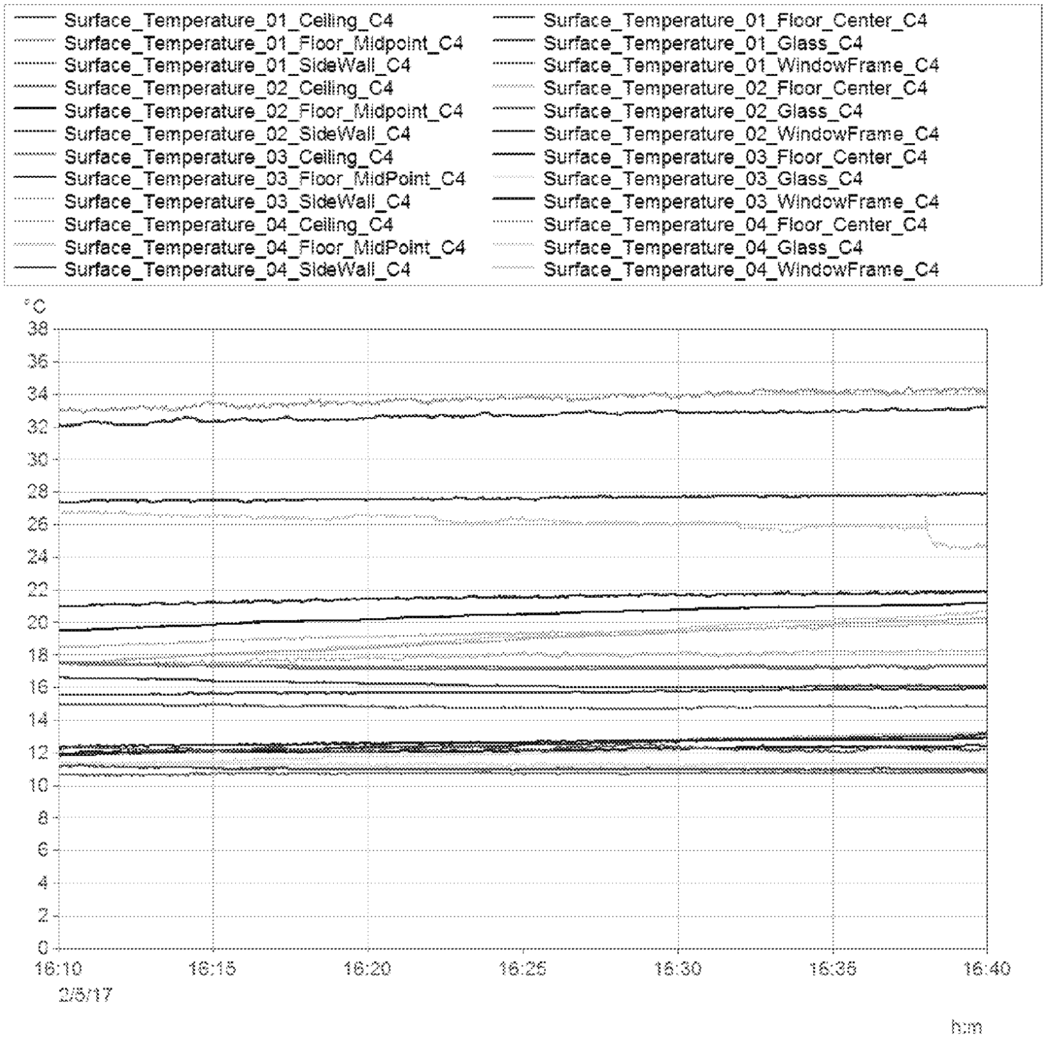


Figure 114 - Procedure I, Surface Temperatures, Wall, Ceiling and Floor Locations

Surface Temperatures of the walls measured at all 4 locations (one thermocouple at each of four cross sectional locations) were within 13°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 115.

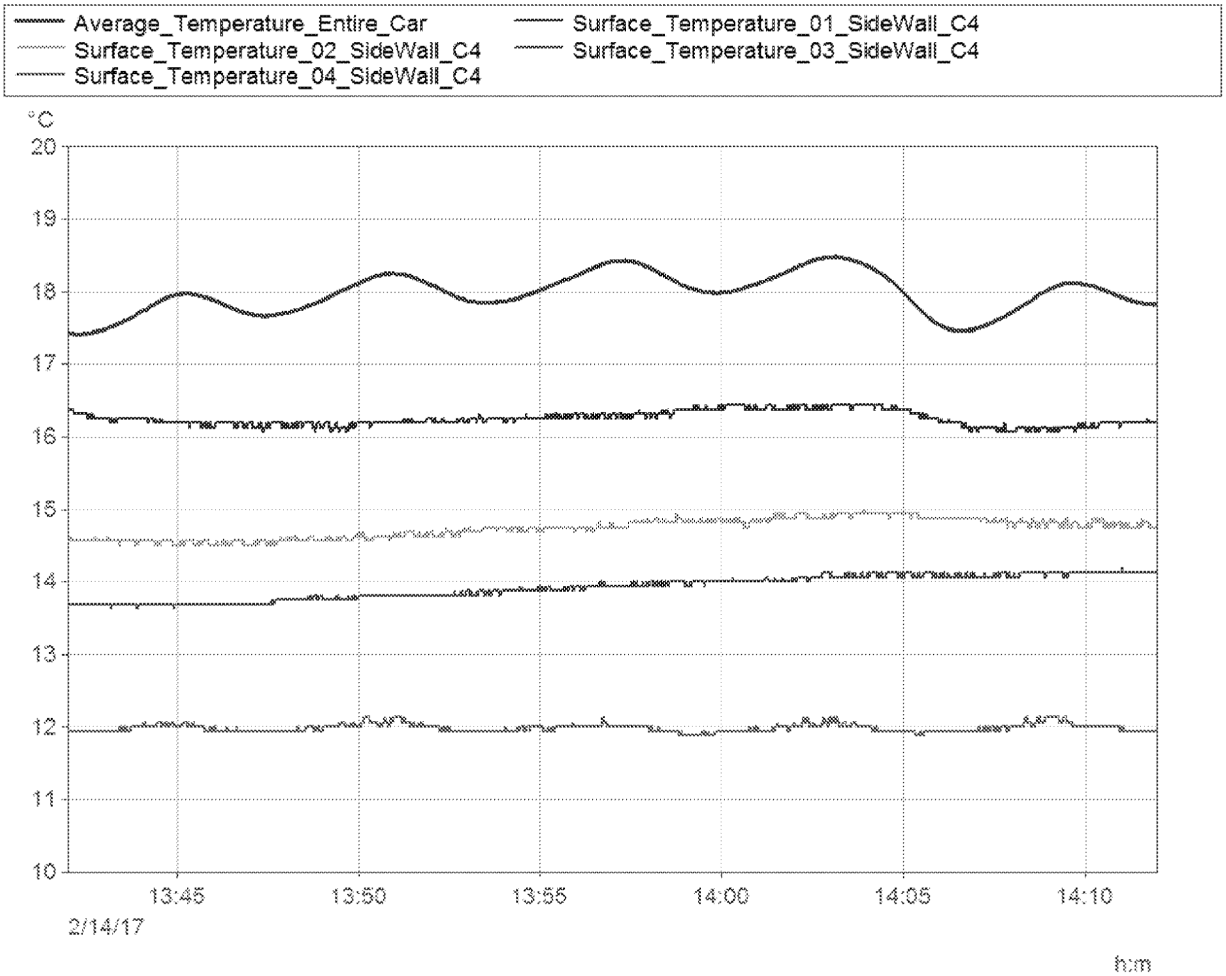


Figure 115 - Procedure I, Surface Temperatures, Wall Locations versus Mean Interior Temperature

Of the 12 locations measuring Surface Temperatures of the ceilings and floors (three thermocouples at each of four cross sectional locations), two show a differential in excess of 12°C versus the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 116. These two locations are the floor measurements at the cross section located at the doors in the LCC car.

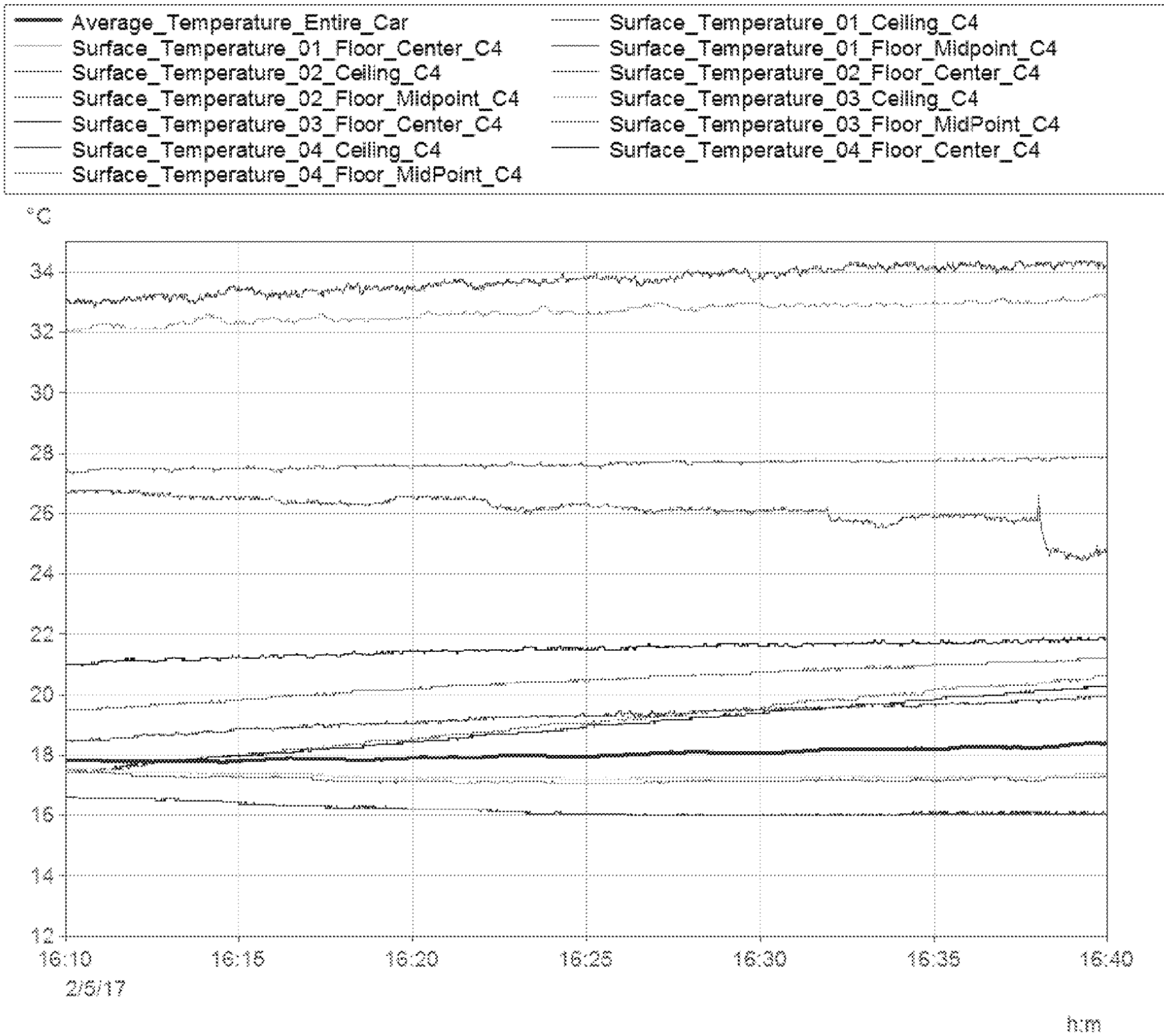


Figure 116 - Procedure I, Surface Temperatures, Ceiling and Floor Locations versus Mean Interior Temperature

Surface Temperatures of the window glass and frame locations as measured at all 8 locations (two thermocouples at each of four cross sectional locations) were within 15°C of the Mean Interior Temperature T_{im} (thick red curve) for the duration of the test as shown in Figure 117.

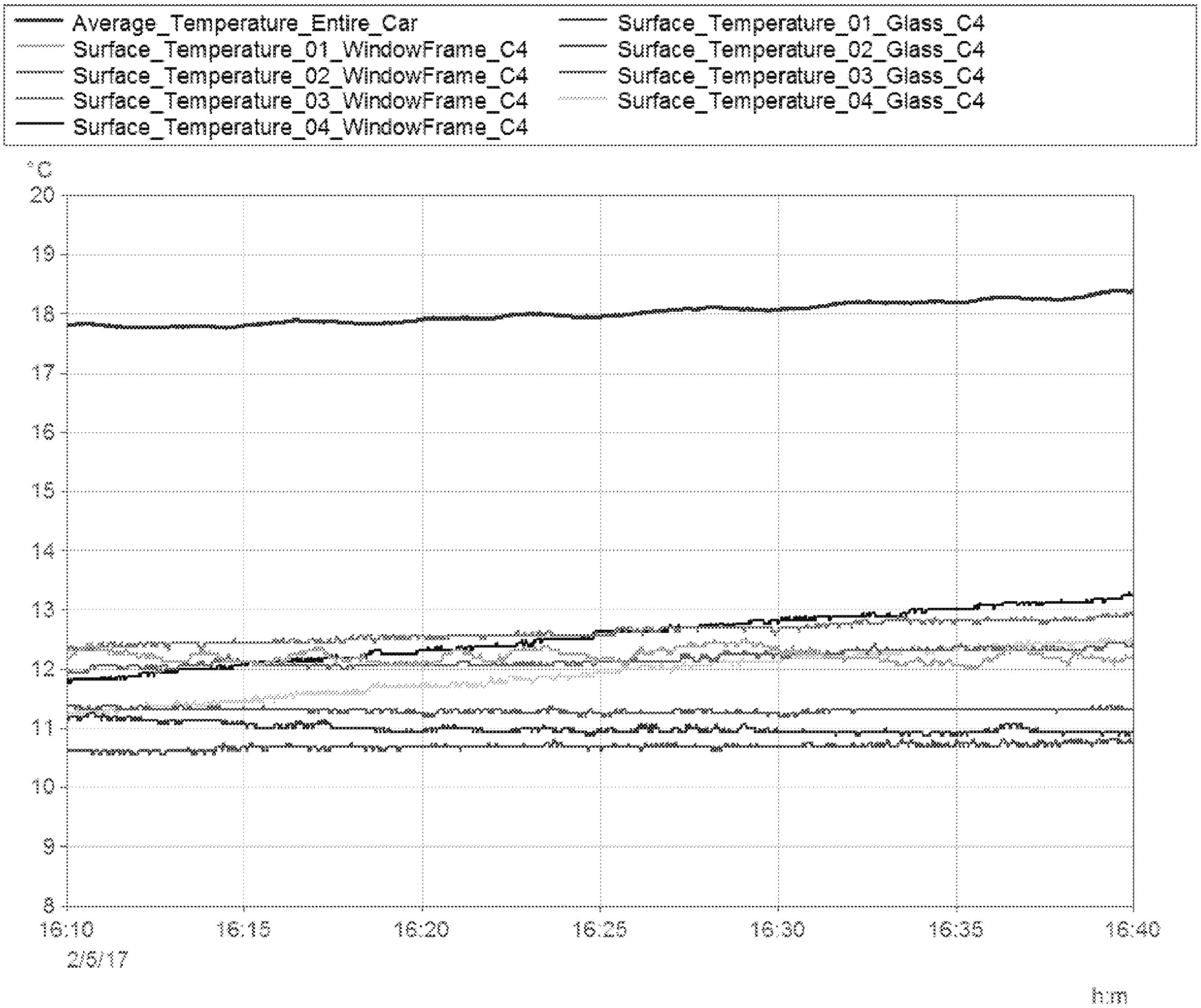


Figure 117 - Procedure I, Surface Temperatures, Window Locations versus Mean Interior Temperature

Measurements of the Cab Heater Grill Surface Temperature and Cab Diffuser Outlet Temperature remained below 50°C and 35°C respectively for the duration of the 30 minute test as shown in Figure 118.

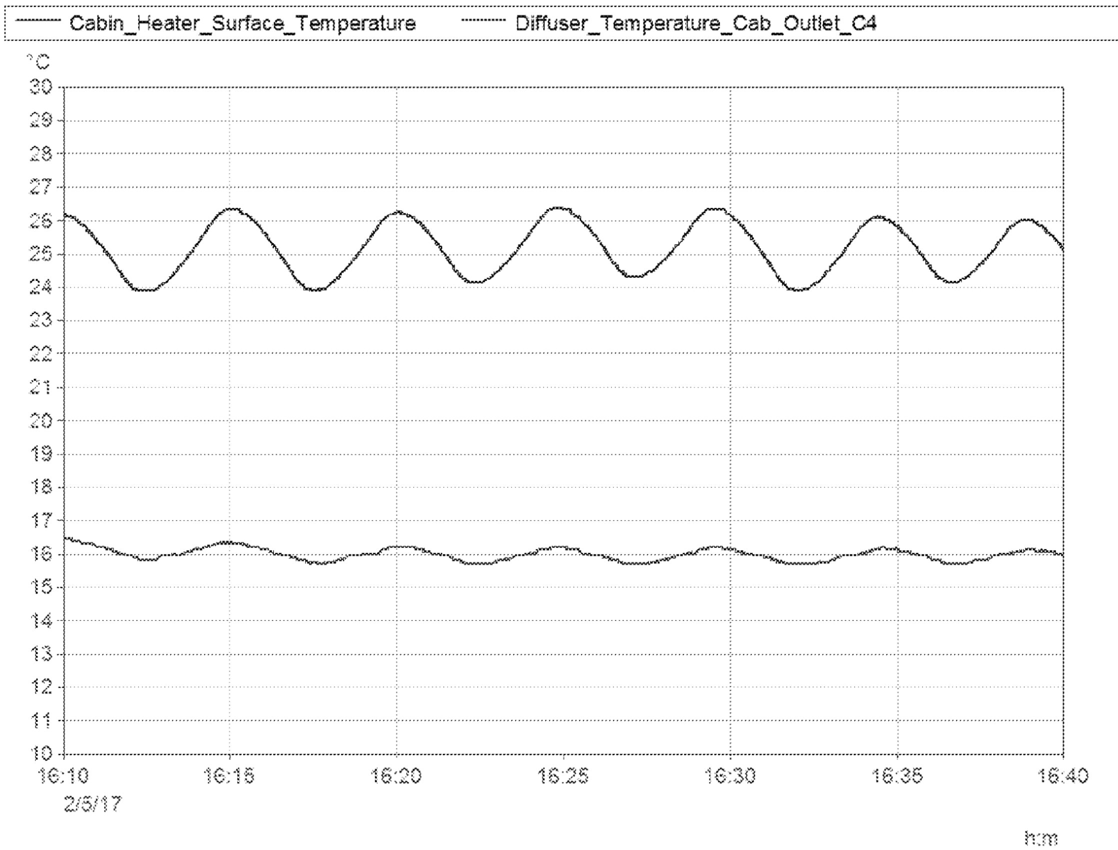


Figure 118 - Procedure I, Cab Grill Heater Surface and Diffuser Outlet Temperatures

5.2.5.10 Procedure J - Layover Heating Mode Test

Procedure J testing was performed prior to the diffuser modifications which were made on February 4th. The test was performed immediately subsequent to a Pre-Heating Test trial, accordingly temperatures approached a steady state condition of 4°C < T_{im} < 8°C from above the specified steady state range,

Chamber temperature set points were set to achieve a temperature of -22°C, with no passenger loads and lights turned on.

With the HVAC set in Layover Heating Mode, the fresh air dampers were closed and the Master Controller Key removed. Data was recorded for two hours between 15:00 and 17:00 as shown in Figure 119. Over the approximately two hour test duration, the Mean Interior Temperature T_{im} remained between 4°C and 8°C.

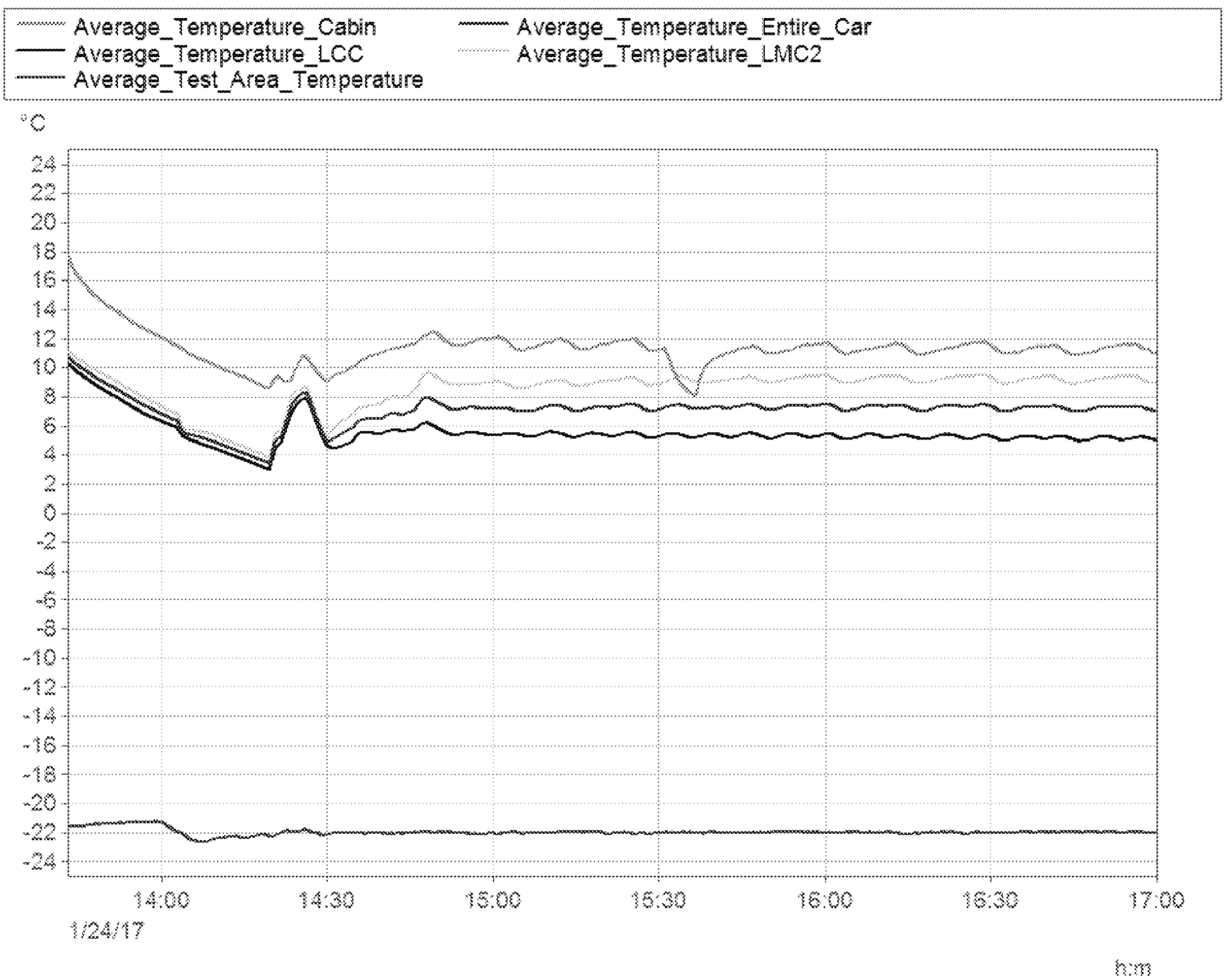


Figure 119 - Procedure J, Average Temperatures

5.2.6 ***Tests with Doors Open/Closed in the Saloon***

5.2.6.1 Purpose

The purpose of the Doors Opening & Closing Tests is to record the time required for the T_{im} to return to within a target range ±1.5°C of the T_{ic} (Temperature Setpoint). One design setpoint in Cooling and two in Heating were tested, with a total of six test configurations as per Table 7

5.2.6.2 Results

Subsequent to the chamber achieving steady state conditions at T_{em} and relative humidity levels as shown in Table 7, the HVAC was switched to 45 Hz and the specified doors opened as indicated in Table 7 for 30 seconds. After the 30 seconds elapsed, the doors were closed, the HVAC switched to 60 Hz and the T_{im} recorded to determine the length of time required for T_{im} to achieve T_{ic} ± 1.5°C, as summarized in Table 7.

Table 7: Doors Open/Closed Test Configurations

Test Sequence	Doors Opened	Floor Heater	Temperatures (°C)		Humidity % RH	T (s) T_{im} ± 1.5°C = T_{ic}
			Int (T_{ic})	Ext (T_{em})		
1	All doors on one side, full passenger and solar load	OFF	22.6	28.9	48	**T_{im} ± 1.5°C = T_{ic}** throughout test
2	All doors on one side	ON	17.2	-20	NA	152
3	All doors on one side	ON	17.2	-22	NA	166
4	Half doors on one side, full passenger and solar load	OFF	22.6	28.9	48	**T_{im} ± 1.5°C = T_{ic}** throughout test
5	Half doors on one side	ON	17.2	-20	NA	147
6	Half doors on one side	ON	17.2	-22	NA	158

The two test sequences at -22°C were performed followed by -20°C as shown in Figure 120, with door opening and closing times detailed in Table 8. Times for T_{im} to recover within 1.5°C of T_{ic} (17.2°C calculated as the average of the stabilized T_{im} prior to the start of testing) for both of the test sequences at -22°C and both test sequences at -20°C exceeded 2 minutes.

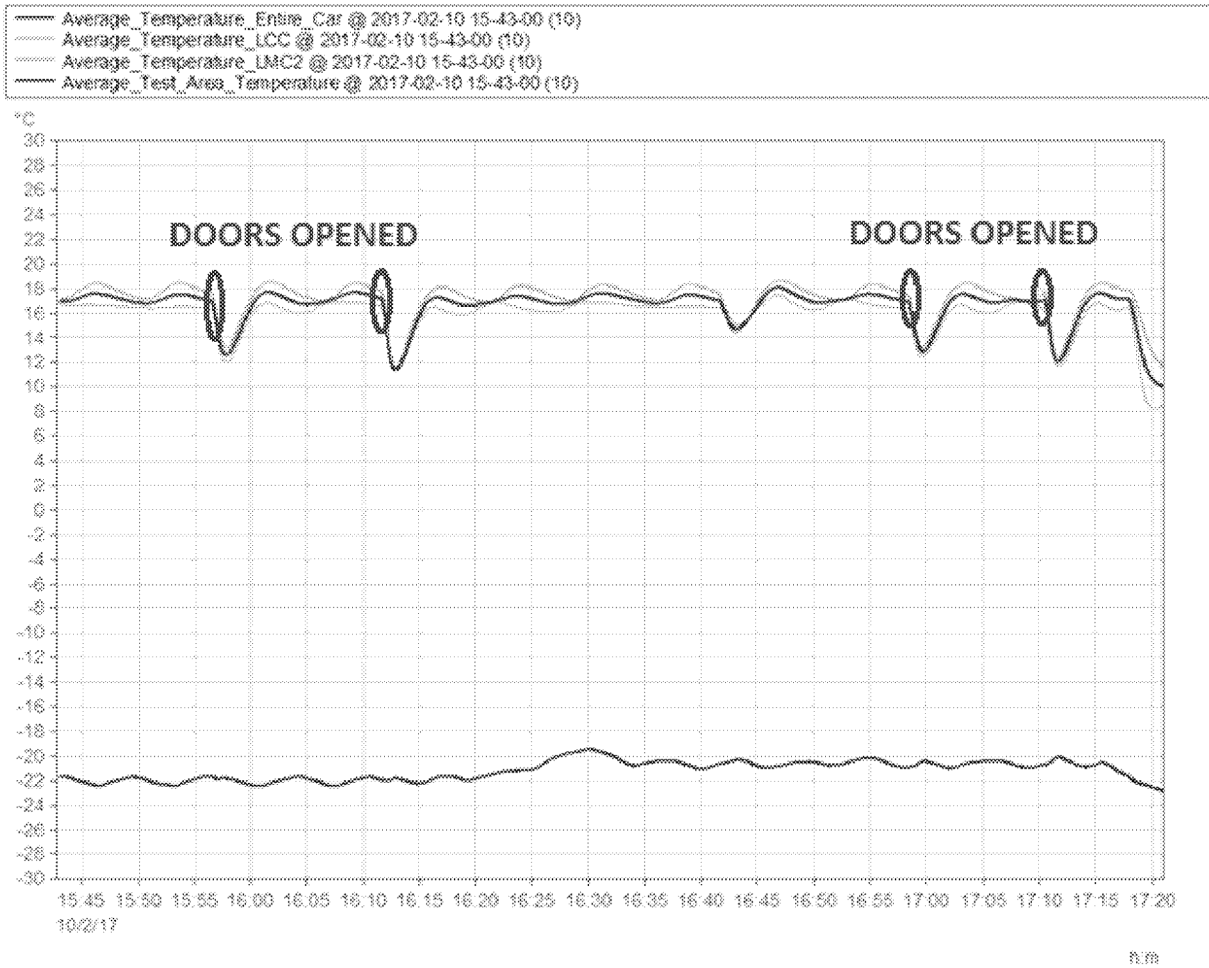


Figure 120 - Doors Opening & Closing @ -22°C and -20°C

Table 8: Doors Opening & Closing @ -22°C and -20°

Test Sequence	Doors Opened	Doors Opened	Doors Closed	$T_{im} \pm 1.5°C = T_{ic}$ Achieved
6	Half doors on one side	15:56:31	15:57:01	15:59:39
3	All doors on one side	16:11:41	16:12:11	16:14:57
5	Half doors on one side	16:58:24	16:58:54	17:01:21
2	All doors on one side	17:10:30	17:11:00	17:13:32

The two test sequences at 28.9°C were performed as shown in Figure 121, with door opening and closing times detailed in Table 9. T_{im} remained within 1.5°C of T_{ic} (22.6°C calculated as the average of the stabilized T_{im}) for the duration of the 2m 30s door cycling test.

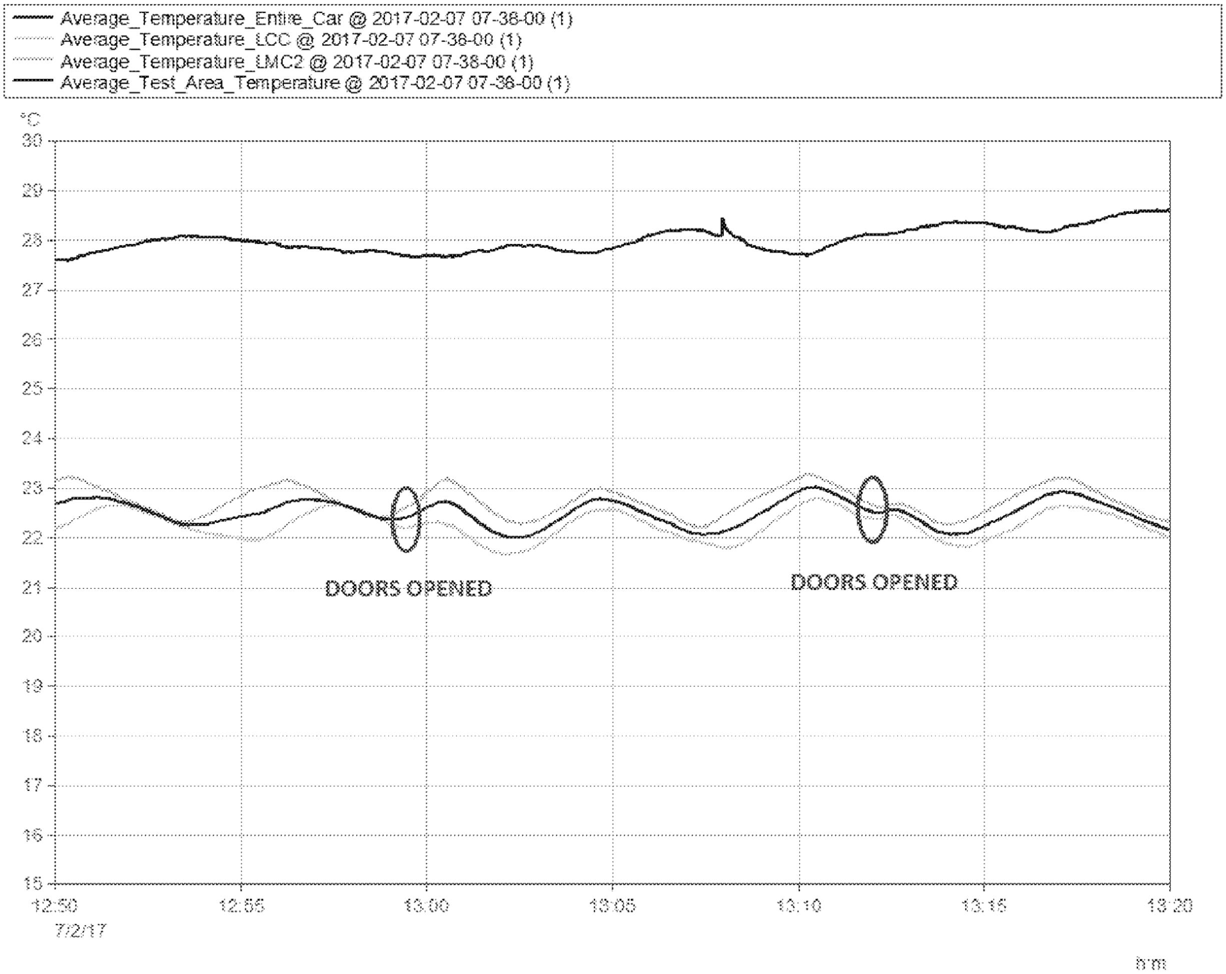


Figure 121 - Doors Opening & Closing @ 28.9°C

Table 9: Doors Opening & Closing @ 28.9°C

Test Sequence	Doors Opened	Doors Opened	Doors Closed	T_{im} ± 1.5°C = T_{ic} Achieved
4	Half doors on one side, full passenger and solar load	12:59:13	12:59:43	**T_{im} ± 1.5°C = T_{ic}** throughout test
1	All doors on one side, full passenger and solar load	13:11:46	13:12:16	**T_{im} ± 1.5°C = T_{ic}** throughout test

5.2.7 ***Insulation Validation (K Factor Measurement)***

5.2.7.1 Purpose

To validate the thermal performance of the rail car including the cabin car.

5.2.7.2 Results

Externally powered resistive heaters were installed in the LCC and LMC2 cars (with a combined area of 249.49 m^2) as per Figure 122. All fresh air and exhaust air openings were sealed and four fans installed to promote uniform thermal gradients within the rail cars.

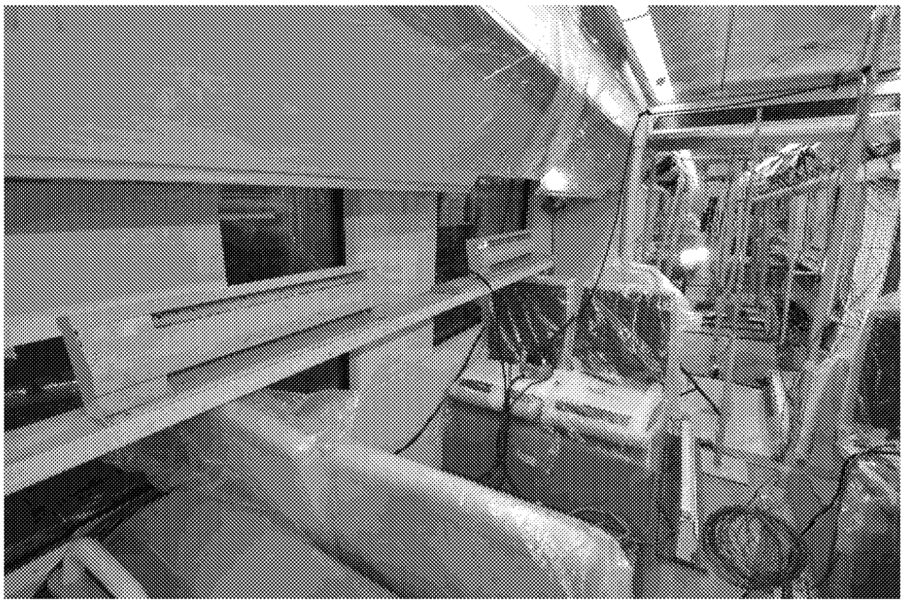


Figure 122 - Resistive Heaters Equally Spaced Throughout LMC2/LCC

A steady state internal temperature (T_{im}) of 22.3°C (25°C ±5°C allowable) and external temperature (T_{em}) of -20.4°C were achieved, with a temperature differential of 42.7°C resulting from power application of 26.2 kW as per Figure 123.

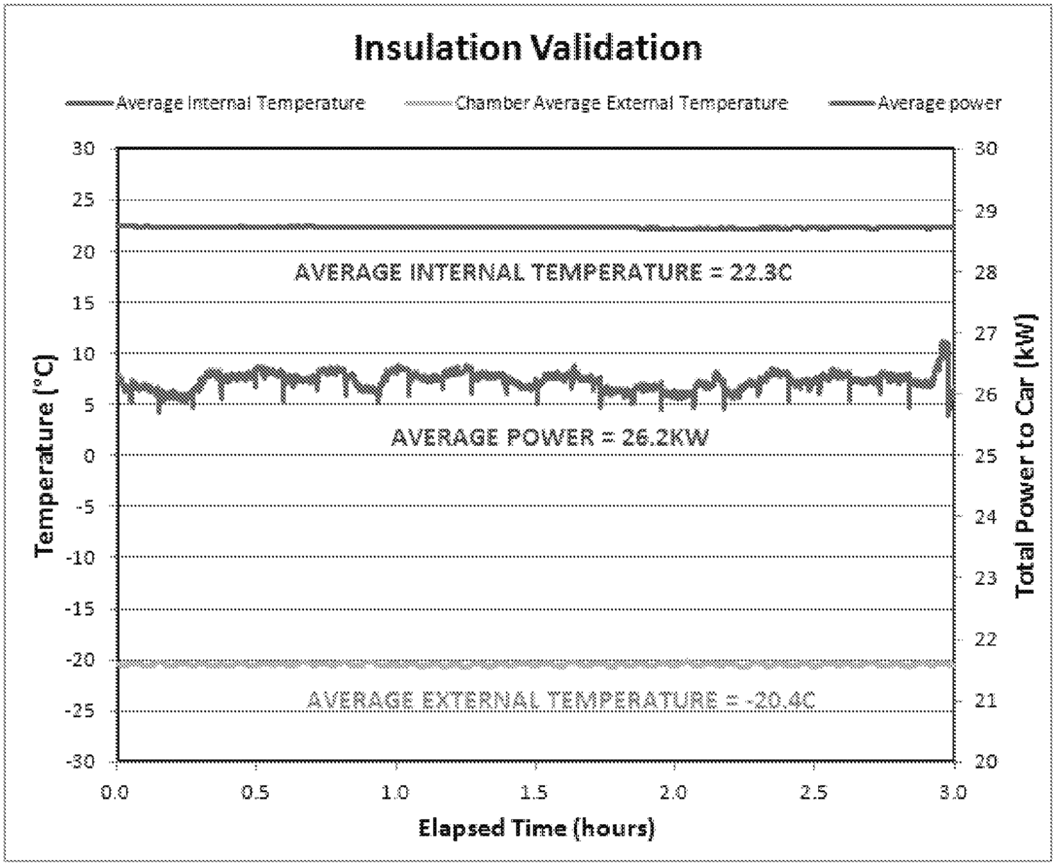


Figure 123 - Internal, External Temperatures & Power Consumption

After three hours of stabilization with the variation in temperature differential per 30 minute segment as shown per Table 10, calculations were performed using the following formulas and the data from the last hour of stabilization to determine the K Factor.

Table 10: Temperature Variation per 30 Minute Segments

Time Segment (min)	Standard Deviation (°C)
0 - 30	0.11
30 - 60	0.10
60 - 90	0.11
90 - 120	0.12
120 - 150	0.14
150 - 180	0.12

$$K = \frac{\left(\frac{P}{Tim - Tem}\right)}{Area} \qquad Units = \frac{W/°C}{m^2}$$

$$K = \frac{\left(\frac{26000}{22.3 - (-20.4)}\right)}{249.49} = 2.46\ \frac{W/°C}{m^2}$$

With the LMC and LCC cars connected it was not possible to isolate the amount of power being dispersed in each car. Accordingly, a K Factor for the combined car was calculated as 2.46 (W/°C)/m^2, a value which is below the expected 2.5 (W/°C)/m^2 for the LMC2 and Cabin Car and exceeds the expected 2.22 (W/°C)/m for the LCC Car. Temperature variation exceeded the specified 0.1°C for each of six the 30 minute segments with a range of 0.10 to 0.14°C.

5.3 Auxiliary Power System Tests

5.3.1 *Test in Winter Conditions, -38°C*

5.3.1.1 Purpose

The purpose of the APS Test in Winter Conditions is to evaluate the power capacity of the APS in winter conditions.

5.3.1.2 Results

Chamber temperature set points were set to achieve a temperature of -38°C, with the APS internal temperature monitored throughout the duration of the test as shown in Figure 124.

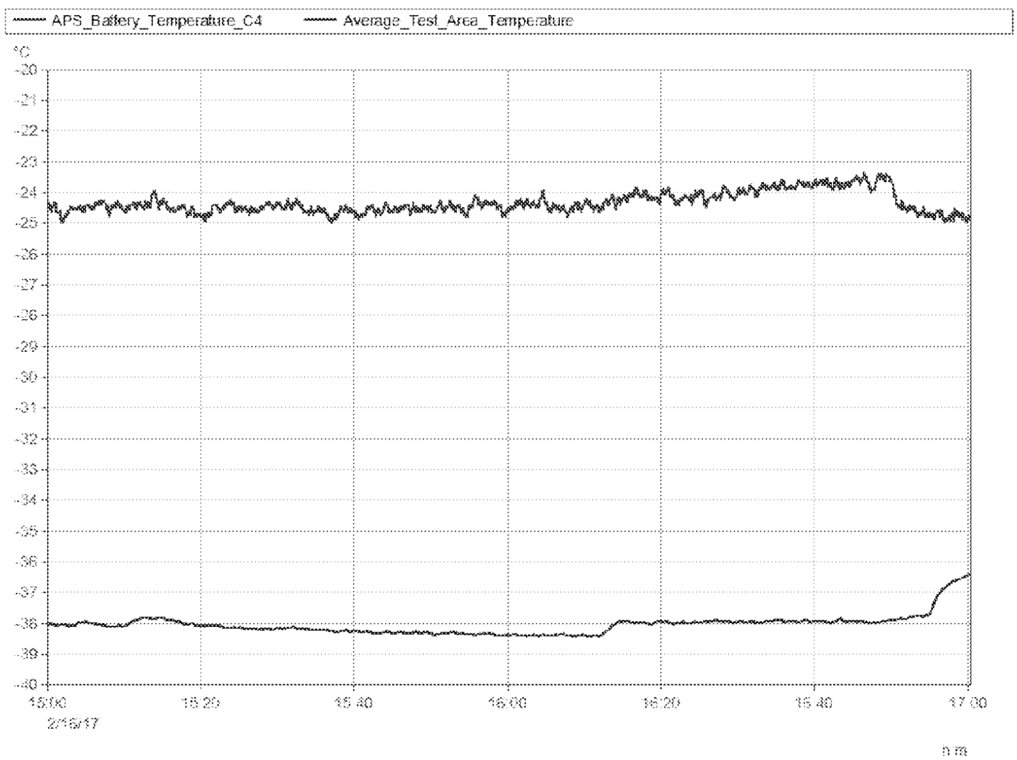


Figure 124 - Chamber & APS Temperatures, Test in Winter Conditions

By drawing approximately 100A (2.0kW) combined for 40 minutes as per Figure 125 using a load bank and minimal train loads followed by a step reduction in load bank current (50A to 40A at 15:58, 25A at 16:03 and 5A at 16:10) and train load current (50A to 30A at 15:52, 5A at 16:02 and 5A at 16:10, shown as a negative value), the battery was discharged to 19V as per Figure 126.

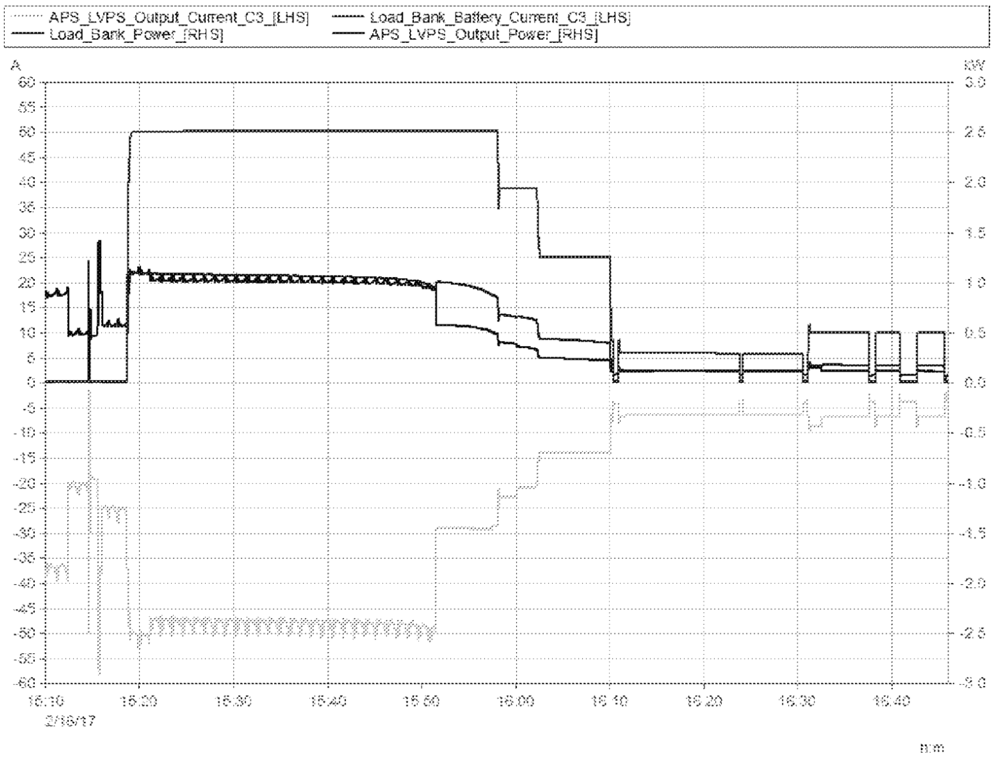


Figure 125 - Battery Discharge, 2.0 kW @ 100A Combined Draw

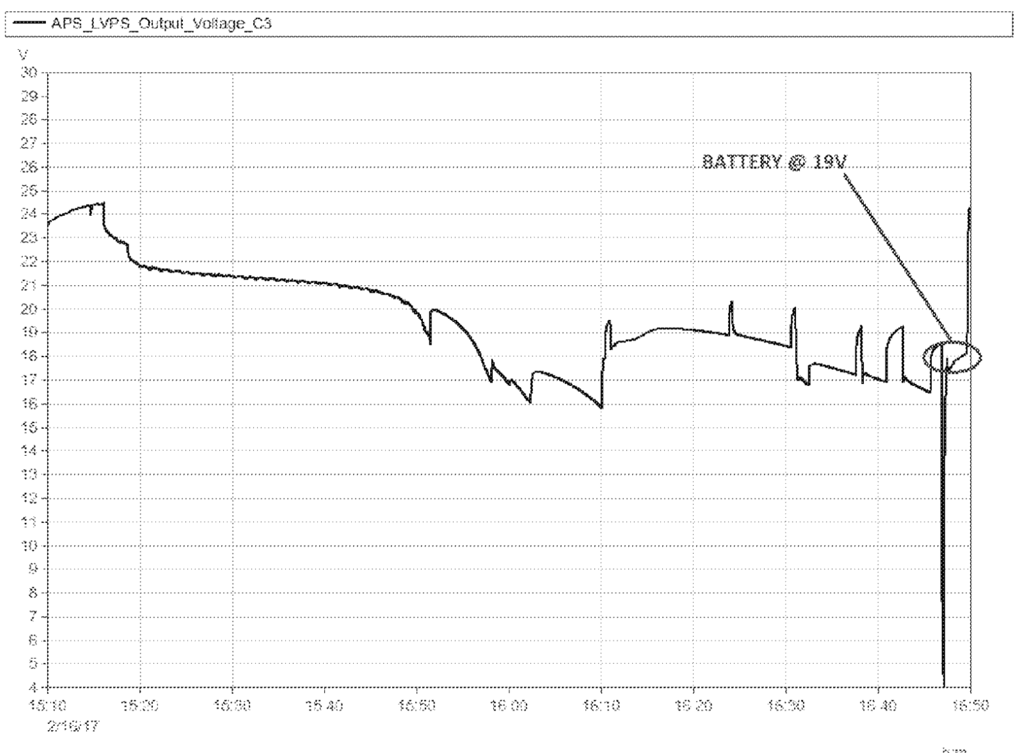


Figure 126 - Battery Discharged to 19V, Test in Winter Conditions

After trial and error it was determined that a variable lag exists between the toggling of the HVAC compressor breaker switches and the restart of the compressors. Accordingly the procedure was revised such that the compressors were forced to restart as the first step in the sequence so that the application of the loads would overlap to the extent possible.

With the train energized for 5 minutes and approximately 50kW of power drawn on the 440V circuit (APS_AC1_Real_Power), at 16:55 as shown in Figure 127 at t=0s the doors were opened and the compressor breaker switchers toggled to force the HVAC to start. At t=45s simultaneously the hydraulic brakes were simulated using a load bank (1.8kW Load Bank Power at 24V) and the track brakes applied drawing power on the 24V circuit (3kW APS_LVSP_Output_Power). At t=165s the track brakes and simulated hydraulic brakes were released. As can be seen from Figure 127, the compressor restart coincided with the application of hydraulic and track brake loads, with the 440V HVAC load having reached a peak within the 120s.

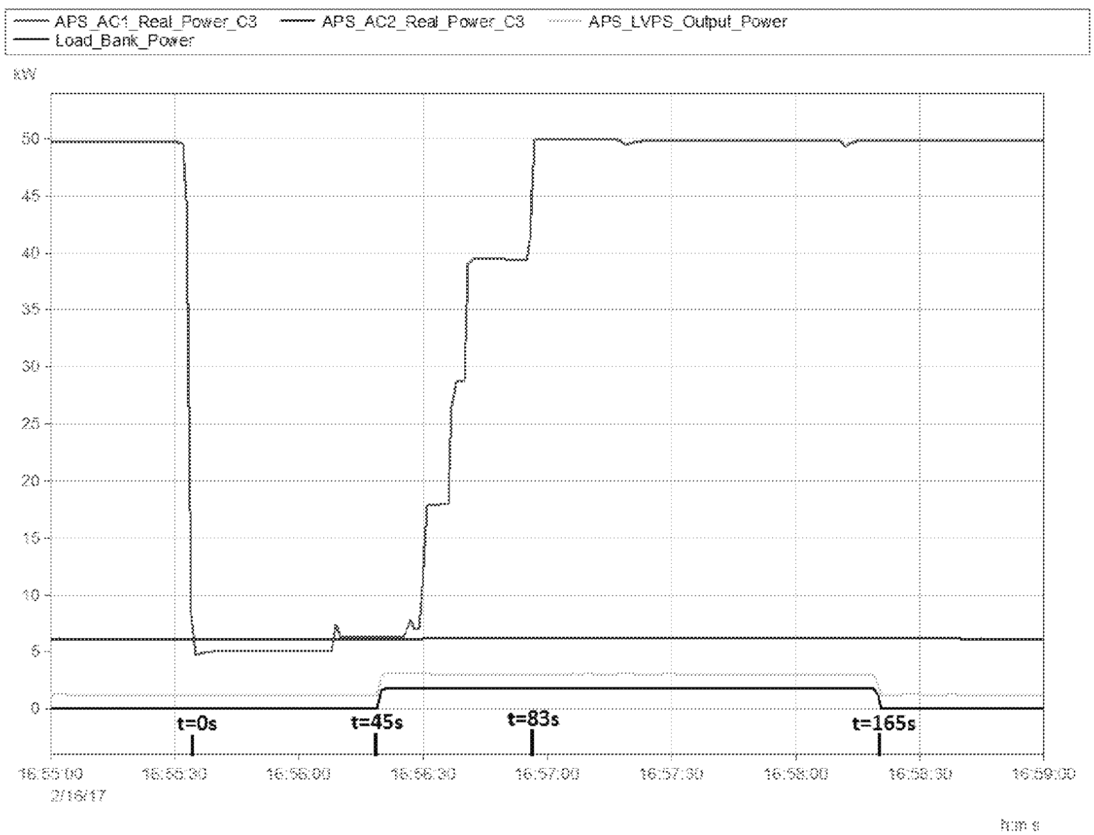


Figure 127 - APS Test in Winter Conditions

Throughout the duration of the test from t=0s to t=165s, power consumption was 6.1 kW on the 120V circuit (APS_AC2_Real_Power), approximately 4.8 kW on the 24V circuit (APS_LVSP_Output_Power) and peaked at 50 kW on the 440V circuit (APS_AC1_Real_Power) at t=83s.

APS circuits were monitored and data recorded for voltage, current, power and frequency (where applicable).

5.3.2 *Test in Summer Conditions, 38°C*

5.3.2.1 Purpose

The purpose of the APS Test in Summer Conditions was to evaluate the power capacity of the APS in summer conditions.

5.3.2.2 Results

Chamber temperature set points were set to achieve a temperature of 38°C, with the APS internal temperature monitored throughout the duration of the test as shown in Figure 128.

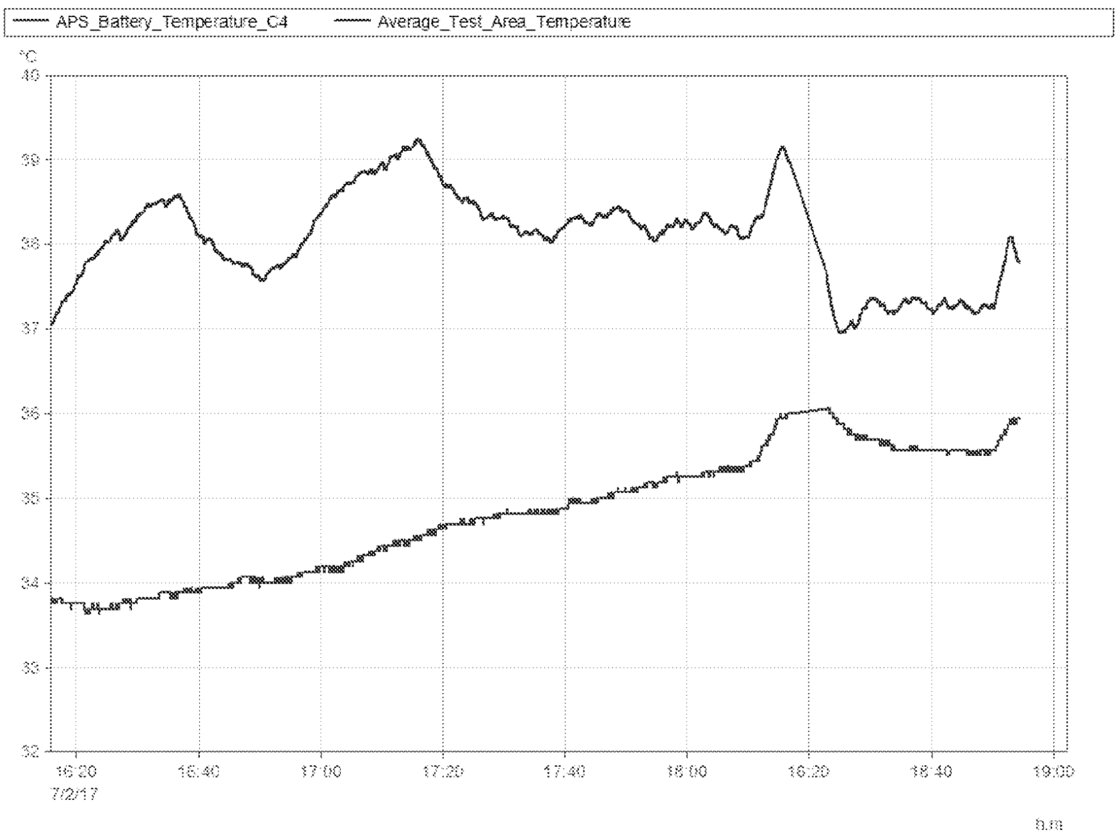


Figure 128 - Chamber & APS Temperatures, Test in Summer Conditions

By drawing approximately 70A (1.5kW) combined for three hours as per Figure 129 using a load bank and minimal train loads with a step increase in load bank current (25A to 50A at 16:07) and step reduction in train load current (35A to 25A at 16:07, train current and power shown as negative values), the battery was discharged to 19V as per Figure 130.

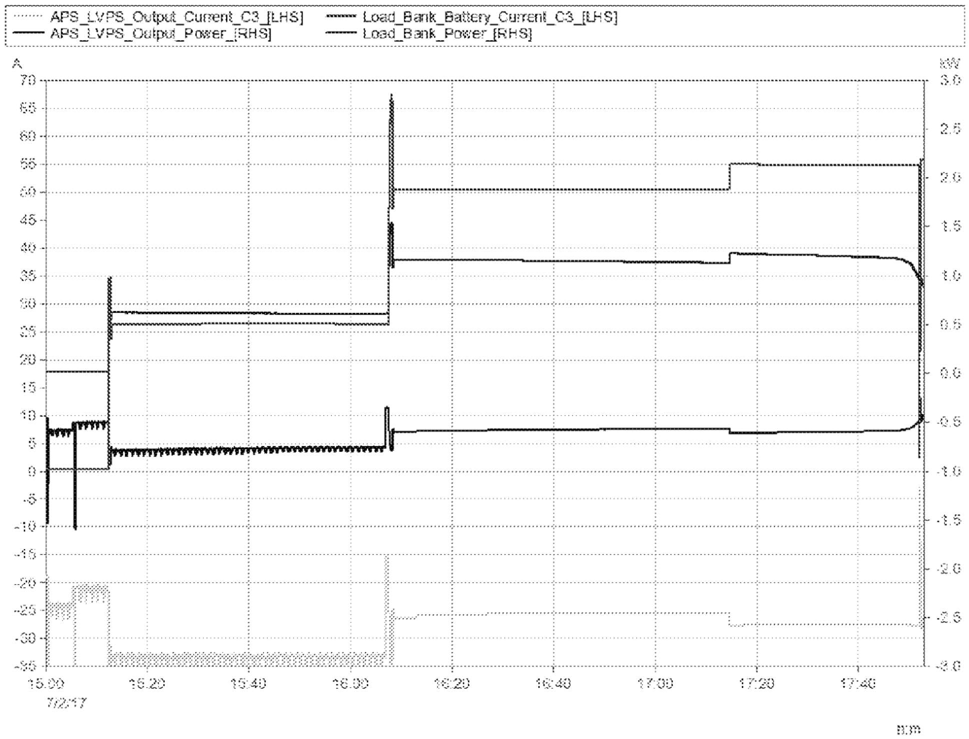


Figure 129 - Battery Discharge, 1.5 kW @ 70A Combined Draw

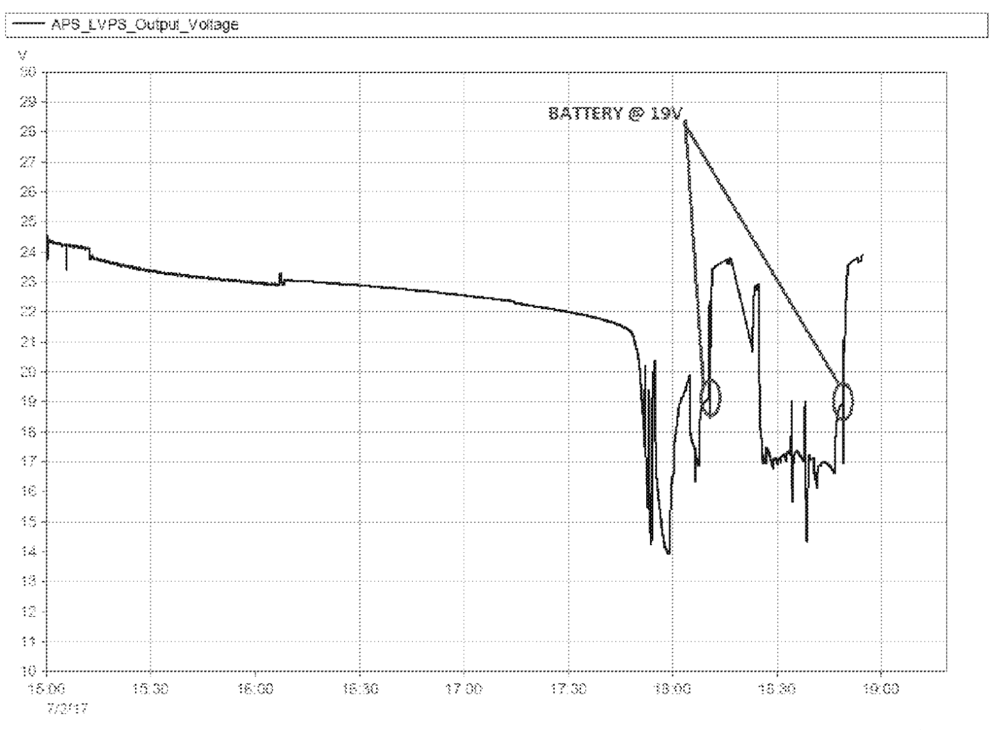


Figure 130 - Battery Discharged to 19V, Two Test Instances

A first attempt to perform the APS Test was made at 18:15 as shown in Figure 131. With the train energized for 5 minutes and approximately 31kW of power drawn on the 440V circuit (APS_AC1_Real_Power), at t=0s the doors were opened and the compressor breaker switchers toggled to force the HVAC to start. At t=15s simultaneously the hydraulic brakes were simulated using a load bank (1.5kW Load Bank Power at 24V) and the track brakes applied drawing power on the 24V circuit (2kW APS_LVSP_Output_Power). At t=30s the track brakes and simulated hydraulic brakes were released, however as can be seen from Figure 131 a lag in the compressor restart meant the 24V loads did not overlap with the 440V HVAC load and it was deemed that a retest was required.

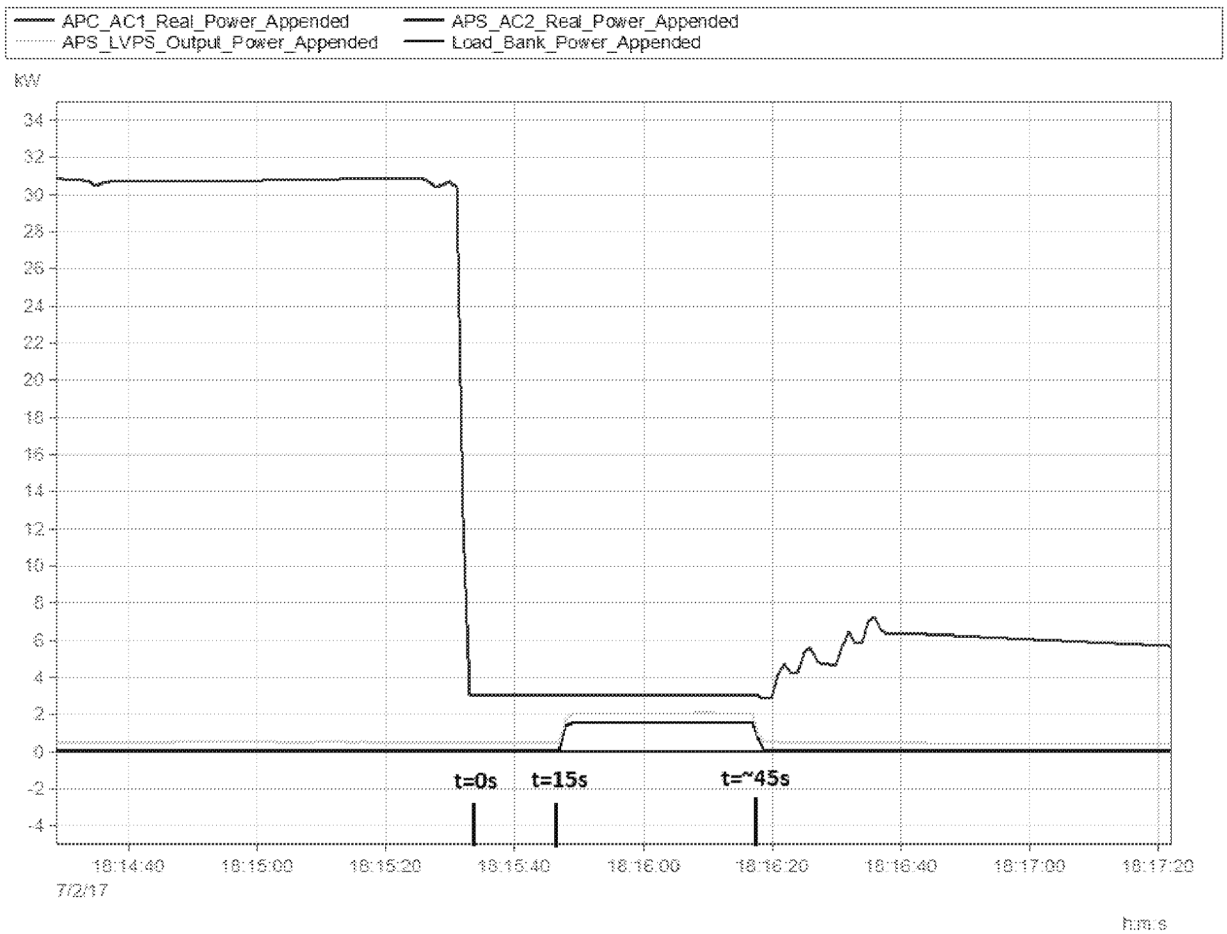


Figure 131 - APS Test in Summer Conditions, First Attempt

After trial and error it was determined that a variable lag exists between the toggling of the HVAC compressor breaker switches and the restart of the compressors. Accordingly the procedure was revised such that the compressors were forced to restart as the first step in the sequence so that the application of the loads would overlap to the extent possible.

Subsequently the battery was discharged to 19V and a second attempt to perform the APS Test was made at 18:52 as shown in Figure 132. With the train energized for 5 minutes and approximately 40kW of power drawn on the 440V circuit (APS_AC1_Real_Power), at t=0s the doors were opened and the compressor breaker switchers toggled to force the HVAC to start. At t=30s simultaneously the hydraulic brakes were simulated using a load bank (1.5kW Load Bank

Power at 24V) and the track brakes applied drawing power on the 24V circuit (2kW APS_LVSP_Output_Power). At t=90s the track brakes and simulated hydraulic brakes were released. As can be seen from Figure 132 the compressor restart coincided with the application of hydraulic and track brake loads, however the 440V HVAC load had not reached a peak within the 60s.

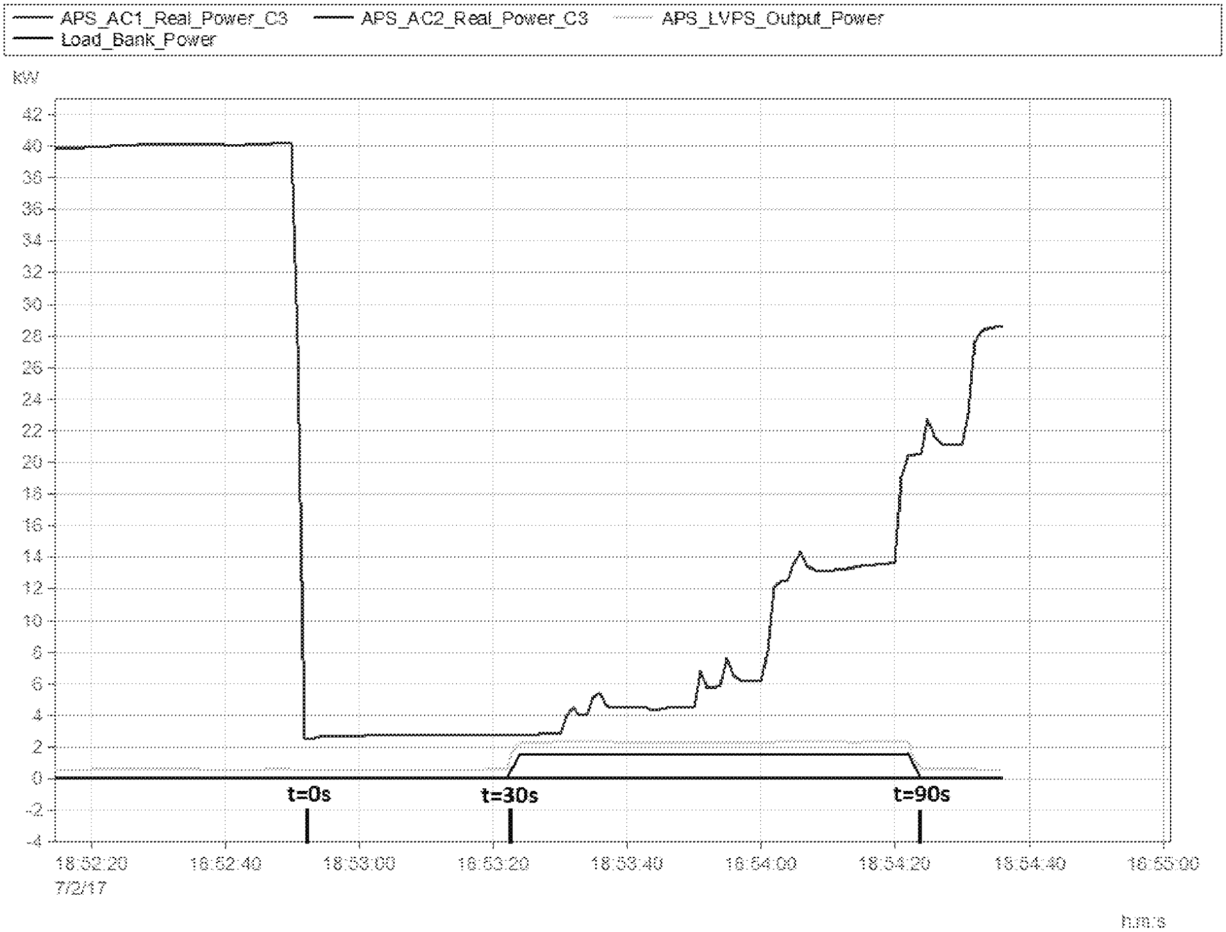


Figure 132 - APS Test in Summer Conditions, Second Attempt

Throughout the duration of the test from t=30s to t=90s, power consumption was 0 kW on the 120V circuit (APS_AC2_Real_Power), approximately 3.5 kW on the 24V circuit (APS_LVSP_Output_Power) and peaked at 14 kW on the 440V circuit (APS_AC1_Real_Power) at t=90s though it had not stabilized when the test was completed and data recording stopped to analyze the data.

APS circuits were monitored and data recorded for voltage, current, power and frequency (where applicable).

5.4 Windshield Wiper Test - Effectiveness of Wiping in Cold Conditions

Windshield Wiper testing was performed Feb 1st as per the original test plan with 3mm of ice accumulated on the windshield. Alstom instructed the Windshield Wiper test be repeated on February 14th with 2.5mm of ice accumulated on the windshield with the car in layover mode.at approximately 5°C interior temperature.

For the purposes of the windshield wiper test, the windshield zones for assessment, defined as Visibility Area and Wiper's Area, were as per Figure 133 and Figure 134 and the performance criteria were as per Figure 135.

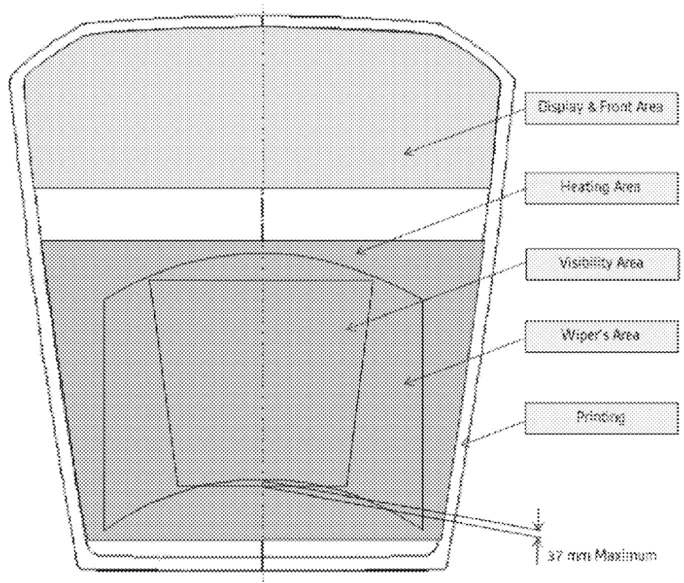


Figure 133 - Windshield Zones

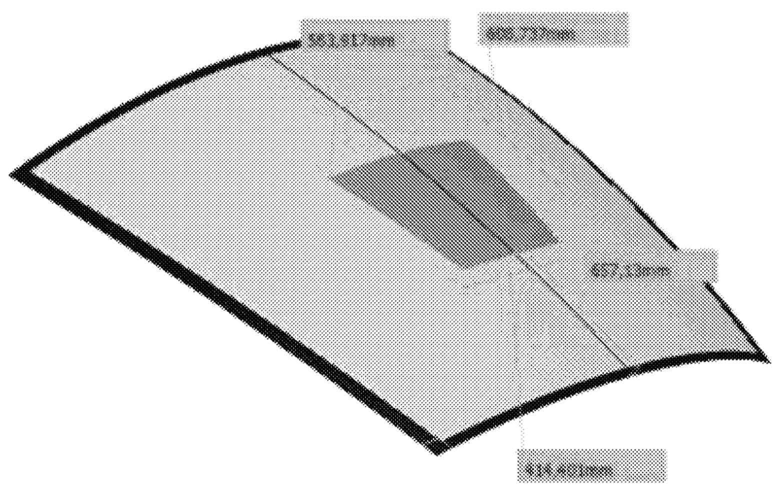


Figure 134 - Visibility Area Dimensions

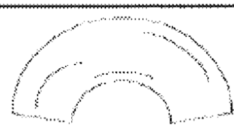
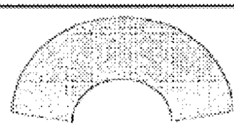
WIPING DEFECTS	NOTE	DEFECTS DEFINITION
	10	No mark in the Visibility Area
	9	1 very thin non persistent streak remains in the Visibility Area
	8	1 very thin persistent streak remains in the Visibility Area
	7	2-3 very thin persistent streaks remain in the Visibility Area
	6	4 thin persistent streaks of 1mm maxi remain in the Visibility Area
	5	6 thin persistent streaks of 1mm maxi remain in the Visibility Area
	4-3-2-1	Notation from 4 to 1 according to the generalisation of streaks
	0	Muddy
	0	Missing parts
	0	Stick-slip motion

Figure 135 - Wiping Defects

5.4.1 Purpose

The purpose of the Effectiveness of Wiping in Cold Conditions Test was to demonstrate that the windshield wipers are effective in maintaining a clear state of visibility under cold and defrosted conditions. The Demisting Test was incorporated within this procedure,

5.4.2 Results

Chamber temperature set points were set to achieve a temperature between -5°C < t < 0°C which was maintained as shown in Figure 136 for the duration of testing between 09:00 and 15:00.

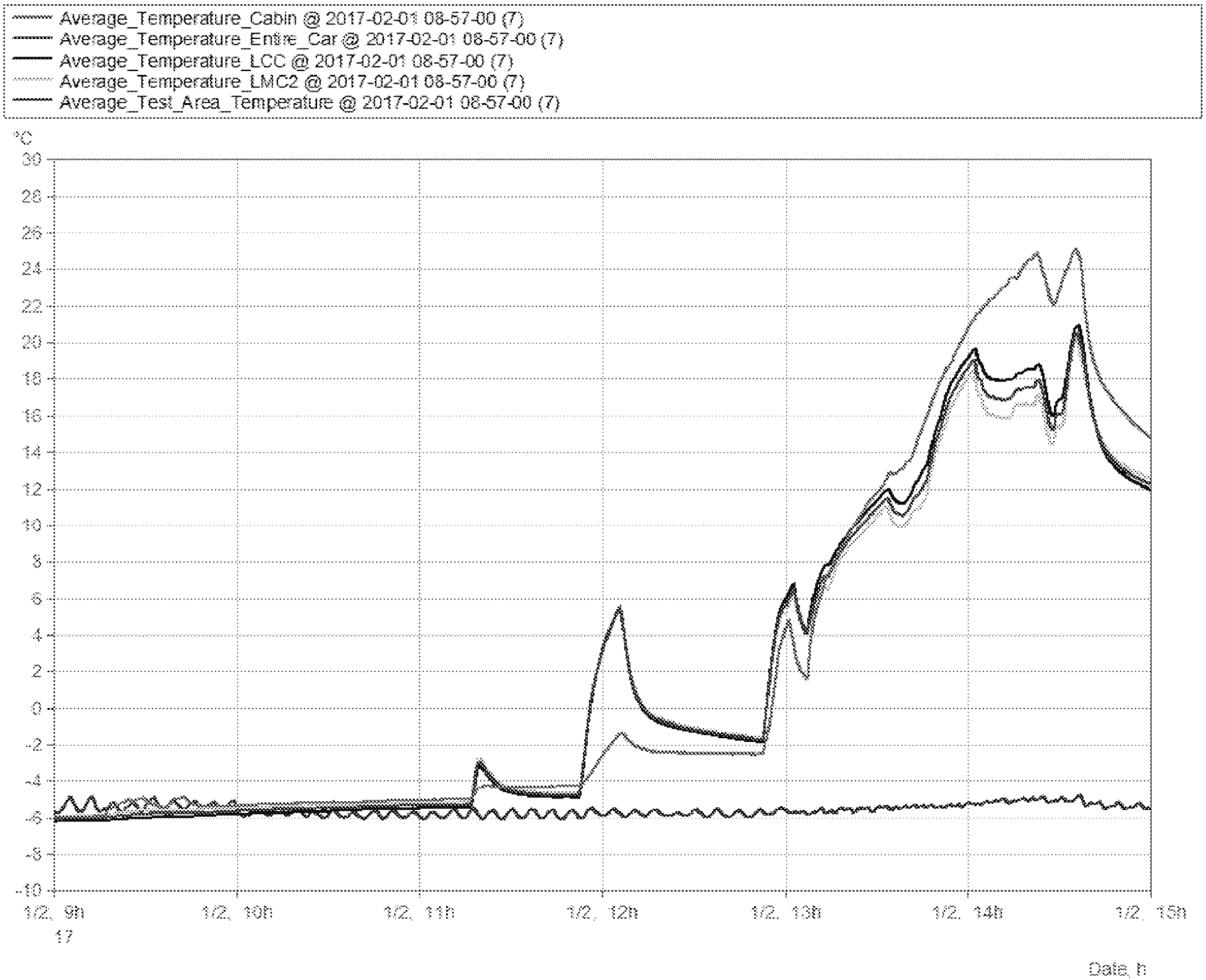


Figure 136 - Feb 1st Windshield Wiper Test, Average Temperatures

Water was directed at the windshield of the Long Motor Car (LMC2) in accordance with MIL–STD-810G, Test Methods 521.3, Icing/Freezing Rain, Procedure 4.5.2. After accumulation of 3mm ice thickness the application of water was terminated at 11:45. Measurements of 3.16mm and 2.89mm of ice thickness were taken at two locations (6.16mm and 5.89mm less a 3mm thick plastic reference) to verify the application as shown in Figure 137.

Figure 137 - Ice Accumulation of ~3mm as Measured

After application the ice was allowed to harden for one hour until 13:08, after which the cab heater and windscreen defrosting were turned on, layover mode activated for the car and the time elapsed to defrost the driver view monitored.

When 45 minutes had elapsed at 13:53, the windshield wiper was activated for two wipes to demonstrate it was not stuck to the windscreen, again at 13:56 for a single wipe, and at 14:10 for two wipes totalling five wipes.

Subsequently at 14:14 the wipers were activated for ten wipes and at 14:28 for 17 wipes. The series of figures below show the evolution of the wiping and defrost.

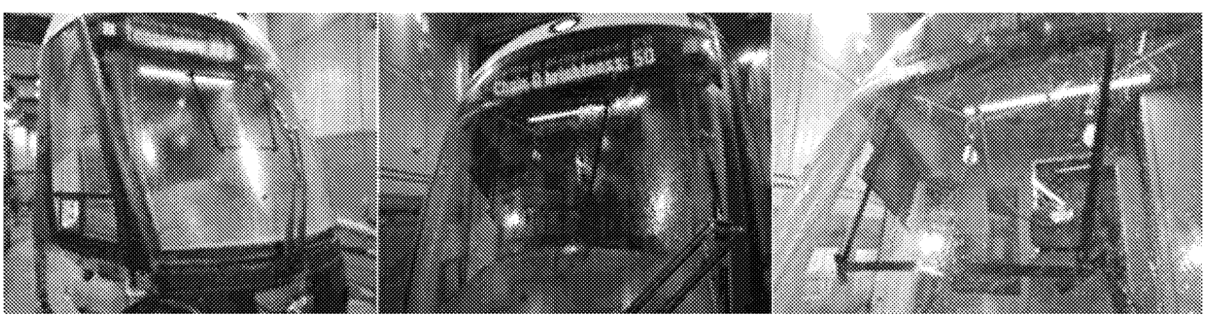


Figure 138 - Wipe at 13:53 / 14:17 After 32 wipes / 14:28

Assessing the wiper defects with respect to Figure 135, a note of 0 (zero) is assigned based on the fact that the blade was missing portions of the visibility area due to either a frozen blade or ice persisting on the windshield after the 32 wipes.

Following the defrost test, mist was applied to the interior of the windshield using a kettle from 15:23 to 15:36 until condensation could be seen forming as shown in Figure 139.

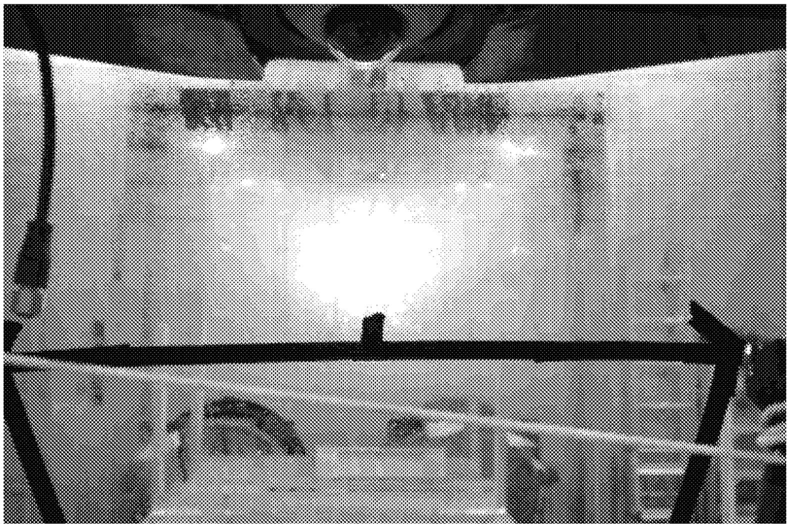


Figure 139 - Application of Mist

Subsequently the defrost was activated and Figure 140 and Figure 141 below show the evolution of the demist for the following 15 mins until 15:51 when demisting was complete.

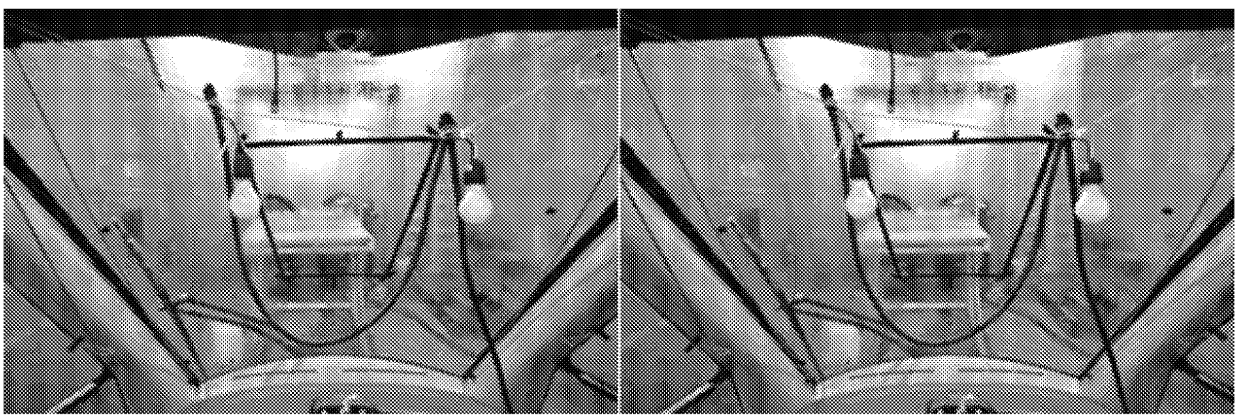


Figure 140 - Demisting @ 2 mins and 5 mins

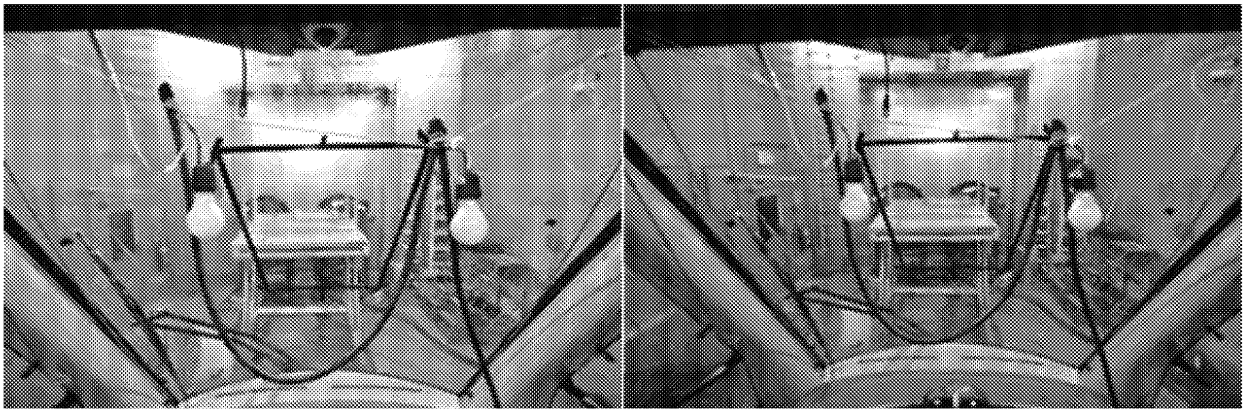


Figure 141 - Demisting @ 8 mins and 15 mins

On February 14th, the Windshield Wiper effectiveness test was repeated, with 2.5mm of ice accumulated on the windshield with the car in layover mode reaching approximately 5°C interior temperature during the application of ice.

Chamber temperature set points were set to achieve a temperature of -10°C which was maintained as shown in Figure 142 for the duration of testing between 07:45 and 11:00.

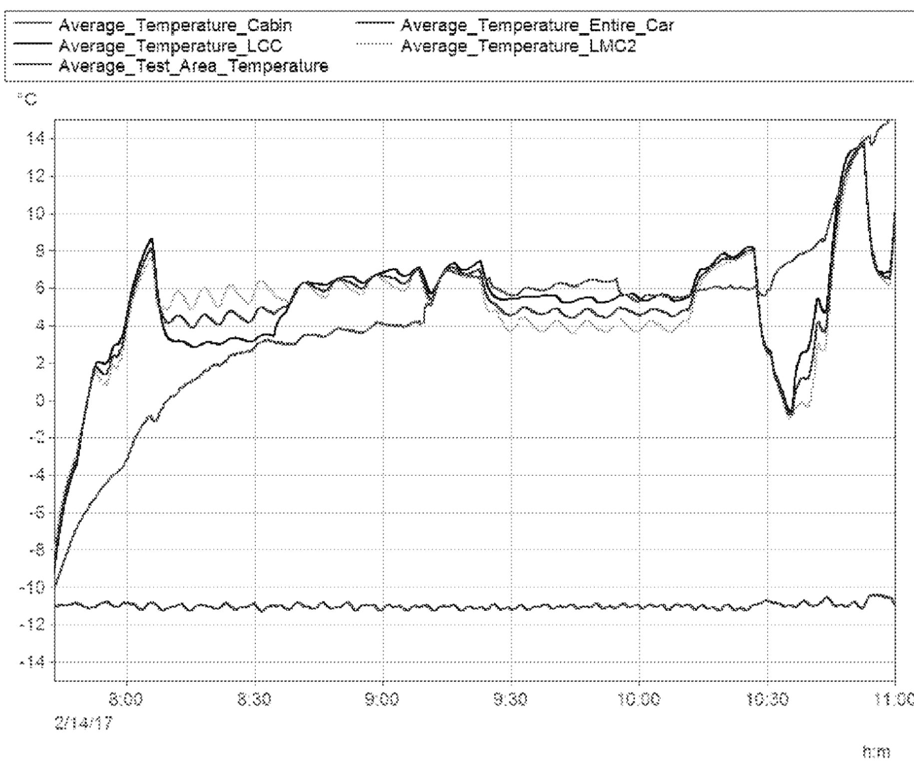


Figure 142 - Feb 14th Windshield Wiper Test, Average Temperatures

Water was directed at the windshield of the Long Motor Car (LMC2) in accordance with MIL–STD-810G, Test Methods 521.3, Icing/Freezing Rain, Procedure 4.5.2 starting at 07:15. After accumulation of 2.5mm ice thickness the application of water was terminated at 08:50. A measurement of 3.1mm was taken to verify the application as shown in Figure 143.

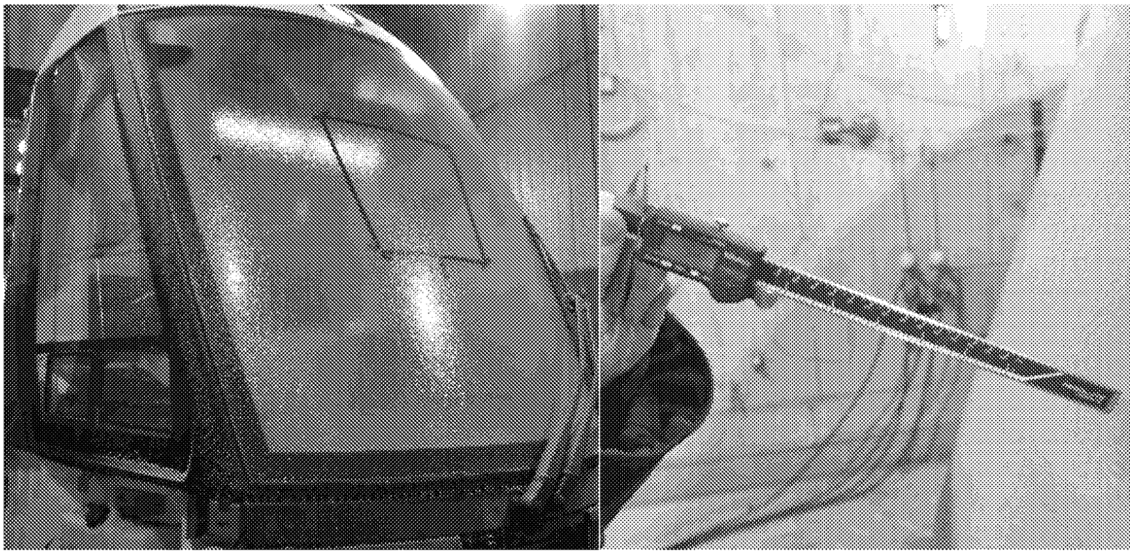


Figure 143 - Ice Accumulation of ~3.1mm as Measured

After application the ice was allowed to harden for 30 minutes until 09:30, after which the windscreen defrosting was turned on and the time elapsed to defrost the driver view monitored.

When 20 minutes had elapsed at 09:50, an unsuccessful attempt was made to activate the windshield wiper, which was stuck to the windscreen. A second attempt was made at 10:00 with the wiper breaking free from the ice.

Subsequently the wipers were activated for five separate wipe attempts until 11:00. The series of figures below show the evolution of the wiping and defrost.

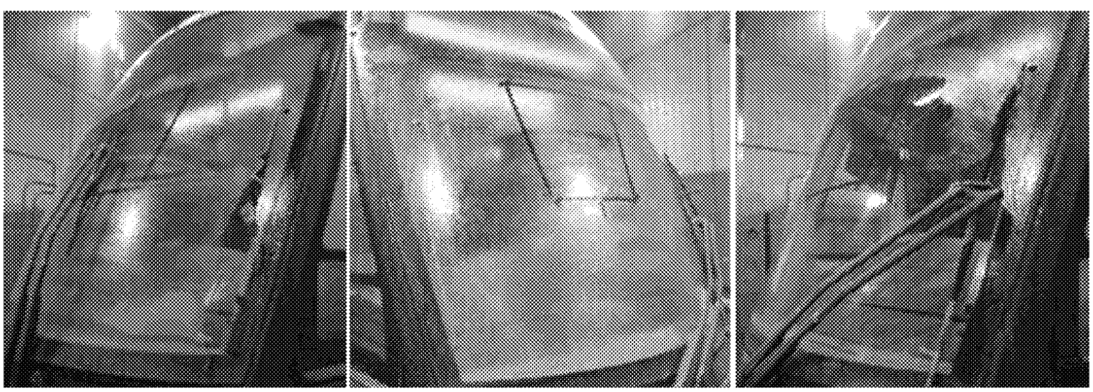


Figure 144 - Wipe at 10:10 / 10:40 / 11:00

Assessing the wiper defects with respect to Figure 135, a note of 0 (zero) is assigned based on the fact that the blade was missing portions of the visibility area due to either a frozen blade or ice persisting on the windshield after the numerous wipe attempts.

5.5 Sanding Test

5.5.1 *Test at Low Temperature, -38°C*

5.5.1.1 Purpose

The purpose of the Sanding Test at -38°C was to demonstrate that heater activation occurs and to measure sand ejector performance. Data recorded included the following.

- Sandbox activation
- Sand flow rate
- Heater activation vs External temperature

5.5.1.2 Results

Chamber temperature set points were set to achieve -38°C, however due to one of six chamber compressors malfunctioning a minimum temperature of -35°C was achieved. Chamber conditions were subsequently met later in the test program, at which point Alstom declined to re-test. Alstom confirmed that the sandbox was full of sand (18L ± 0.5L), the train pneumatic system was at operational pressure between 8.5 and 9.5 bars and compressed air supplied to the ejector was at 1.2 bars ± 0.2 bars. Orientation of ejectors was as set by Alstom, with bags installed by NRC personnel to capture the sand discharged as shown in Figure 145.

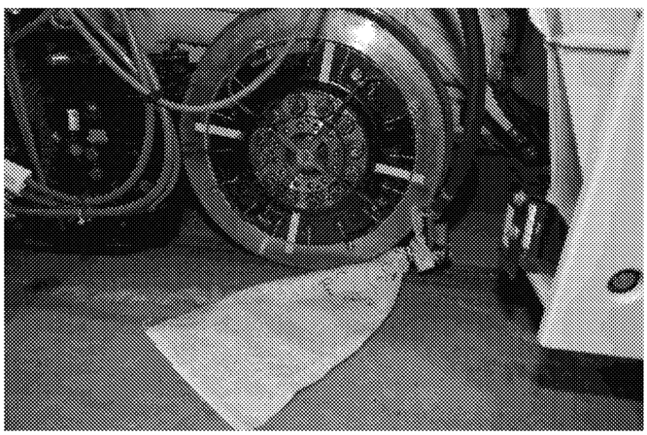


Figure 145 - Bags Installed to Capture Ejected Sand

Only the LCC ejectors were tested, with the two nozzles pointed in the forward direction tested first followed by the two nozzles pointed in the rearward direction. Monitored as events in Figure 146, the sand heater is indicated as being ON until approximately 14:34:20 while the nozzle activations occur for t=4s (14:33:19.0 until 14:33:23.0) and t=3.5s (14:36:12.0 until 14:36:15.5).

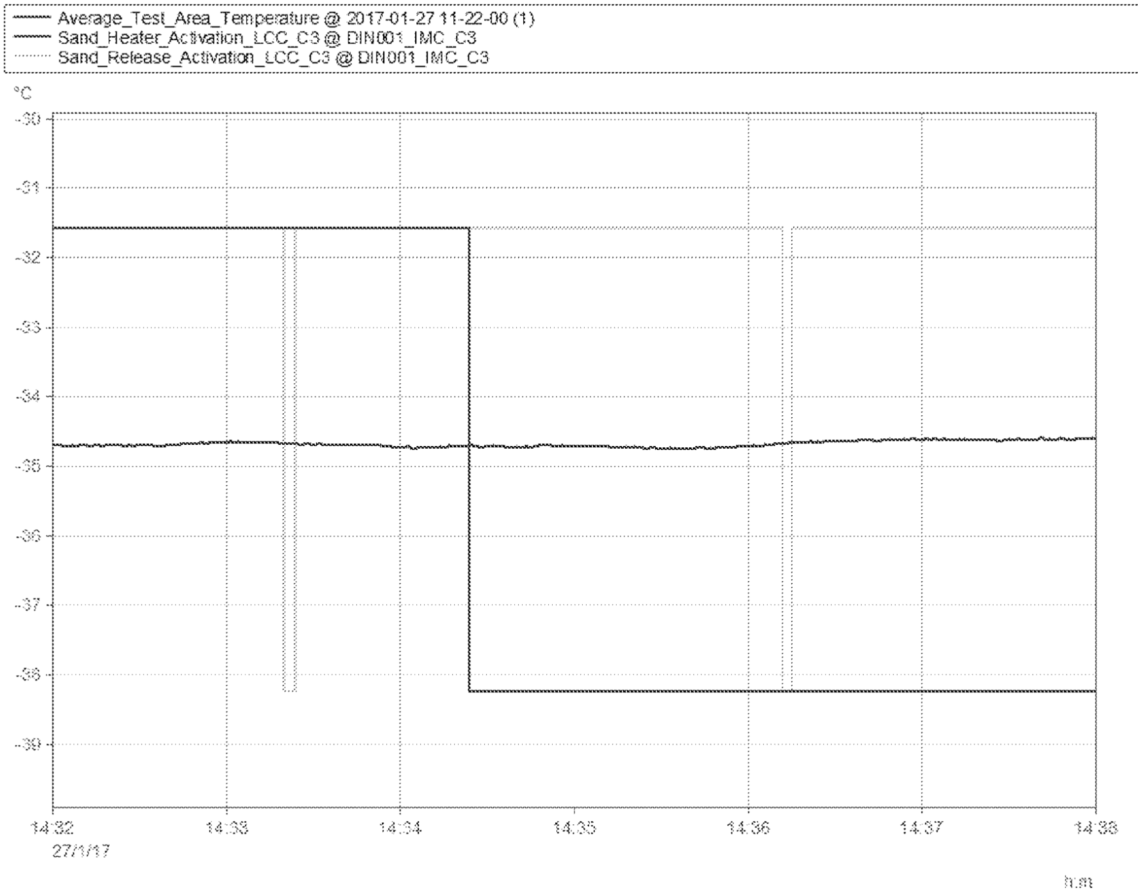


Figure 146 - Sand Heater and Nozzle Activation Events

Quantities of sand ejected and calculated flow rates are as shown in Table 11 . Flow rates for all four nozzles exceeded the range of $600 \leq Q \leq 800$ g/min calculated over the application time which was within the $2s < t < 5s$ allowable range.

Table 11: Sand Activation Results

Nozzles Activated		Activation (s)	Sand Ejected (g)	Flow rate (g/min)
LCC Forward	Right Side	4.0	68.4	1026
	Left Side		81.7	1226
LCC Rearward	Right Side	3.5	55.8	957
	Left Side		59.3	1017

.

5.6 Vehicle Battery Discharge Tests

5.6.1 *Discharge Test, Aged Battery at -40°C*

5.6.1.1 Purpose

The purpose of the Discharge Test, Aged Battery was to ensure the train maintains all required auxiliary functions for a specified duration after the loss of normal high voltage power supply utilizing a discharged, aged battery.

5.6.1.2 Results

Chamber temperature set points were set to achieve a temperature of -40°C, with the APS Battery Temperature and Average Car Temperature monitored throughout the duration of the test as shown in Figure 147. The High voltage power supply to the train remained on leading up to the start of the discharge at 13:04 to allow the battery heater to remain active. Alstom was concerned a thermal switch protecting the battery (which opens at -25°C and closes at -16°C) would open overnight prior to commencing the test and as a result a charge would not be able to be applied to confirm a fully charged battery prior to the controlled discharge of 25Ah

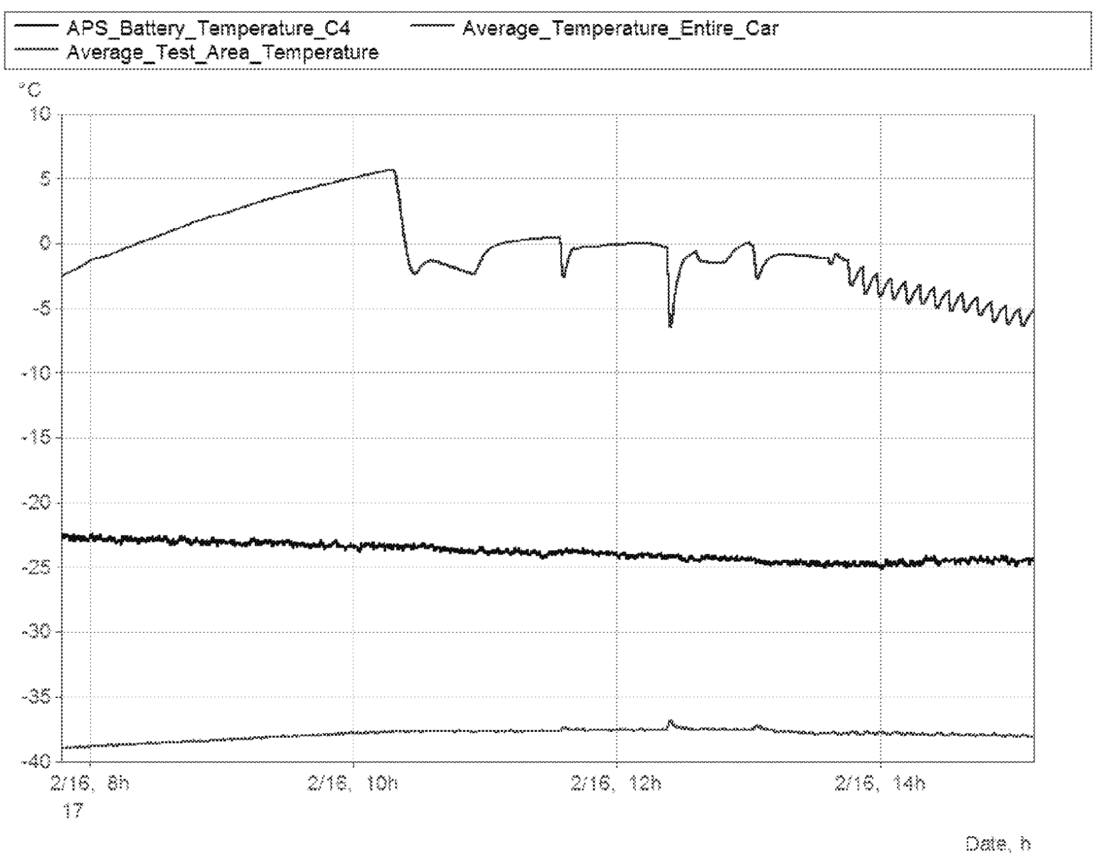


Figure 147 - Vehicle Battery Discharge Test, Chamber & APS Battery Temperatures

The car temperature remained at approximately -22°C throughout the duration of the test as Alstom instructed that solar and passenger load be applied, as shown in Figure 148, to ensure certain equipment, such as the doors, would be operational.

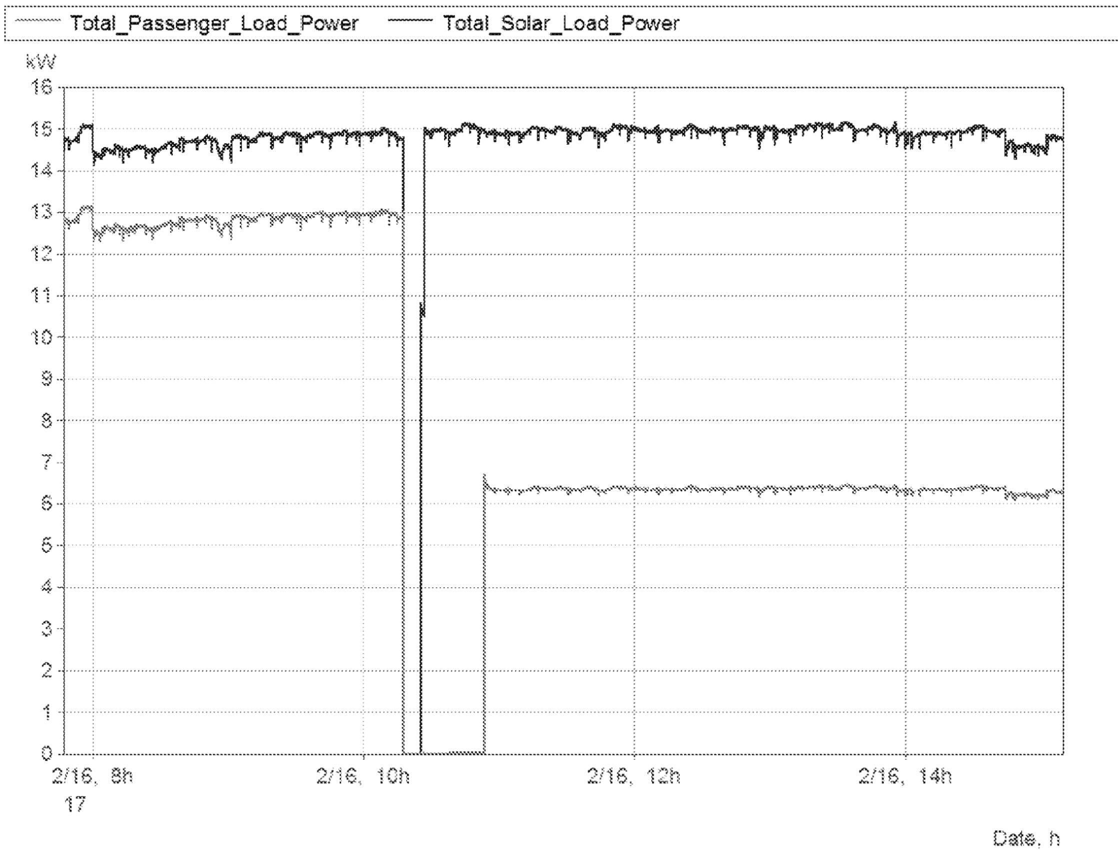


Figure 148 - Vehicle Battery Discharge Test, Solar and Passenger Loads

Prior to starting the discharge, with the Auxiliary Power Supply (APS) providing high voltage power, Alstom activated the HVAC to confirm equipment was powered and/or operational as per Table 12.

Table 12: Battery Discharge Test Load Profile Action List

Legend :

Supplied and operational	Supplied but not operational	Not supplied

		Punctual loads for 90min							
Equipment/Mode	Normal mode before HV loss (1 APS is operational)	At t=0s : Loss High Voltage	At t = 30s	At t = 5min	At t = 2min and every 2min	At t = 6min 30s and every 6min 30s	At t = 45min	up to 90min	Manual Control
Pantograph									
Pantograph control				Manual control for one cycle : lowering and raising			Manual control for one cycle : lowering and raising		Yes: Pantograph control
Brake									
Track Brakes		Manually activated one time for 30s max	Manually deactivated						Yes: applied Emergency brake
Brake electronic									
Brake hydraulic		Automatically activated one time for 30s max	Automatically deactivated						No (Brake electronic)
HVAC									
HVAC electronics				Automatically deactivated					No (TCMS)
Traction									
Propulsion control unit				Automatically deactivated					No (TCMS)
Fan Propulsion			Automatically deactivated						No (Traction Electronic)
Pre-heater Propulsion			Automatically deactivated						No (Traction Electronic)
Cab Heater									
Cabin Booster (busy cab)				Automatically deactivated					No (TCMS)
Cabin heater fan(busy cab)				Automatically deactivated					No (TCMS)
Driver seat heater (busy cab)			Automatically deactivated						No (TCMS)
Sanding									

Table 12: Battery Discharge Test Load Profile Action List, cont'd

		Ponctual loads for 90min							
Equipment/Mode	Normal mode before HV loss (1 APS is operational)	At t=0s : Loss High Voltage	At t = 30s	At t = 5min	At t = 2min and every 2min	At t = 6min 30s and every 6min 30s	At t = 45min	up to 90min	Manual Control
Sanding nozzles heater			[illegible]						No (TCMS)
Sanding scatters heater			[illegible]						No (TCMS)
Coupler									
Heater coupler			[illegible]						No (TCMS)
Compressor									
Air compressor dryer heater			[illegible]						No (TCMS)
Air dryer		[illegible]							No (Air compressor)
Doors									
All Door electronics									
Doors panels (one side)						Manually activated for one opening/closing cycle			Yes
Passengers Lighting									
Normal lighting		[illegible]							No (TCMS)
Emergency lighting (30%)									
Lighting									
HeadLights									
APEX									No (TCMS)
Tail Lights									
Red marker Light									
Amber marker Light									No (TCMS)
Brake/Stop lights									
Twin indicators									No (TCMS)
Turn light									No (TCMS)
Windshield									
Windshield wiper									
Windshield defroster (busy cab)		[illegible]							No (TCMS)
APS									
Electronics									
TCMS									
TCMSs									
MPU									
DDU									

Table 12: Battery Discharge Test Load Profile Action List, cont'd

		Ponctual loads for 90min							
Equipment/Mode	Normal mode before HV loss (1 APS is operational)	At t=0s : Loss High Voltage	At t = 30s	At t = 5min	At t = 2min and every 2min	At t = 6min 30s and every 6min 30s	At t = 45min	up to 90min	Manual Control
Gateway									
Switch Ethernet									
APC									
Automatic Counting Passenger									
PA/PIS									
PIS control									
Displays (lateral/interior, head)				Automatically deactivated					No (TCMS)
PEI									
Radio					Manually activated one time for 20s max				Yes
PLD				Automatically deactivated					No (TCMS)
Amplis (FA)					Manually activated for 20s max				Yes
EVR									
Caméras									
Horn					Manually activated one time for 5s max				Yes
Modem data radio									
VSR									
Retrovision				Automatically deactivated					No (TCMS)

By drawing approximately 50A (1.2kW) for 30 minutes from 13:04 as per Figure 149 using a load bank, 25Ah was discharged to simulate the battery aged to a 0.89 coefficient.

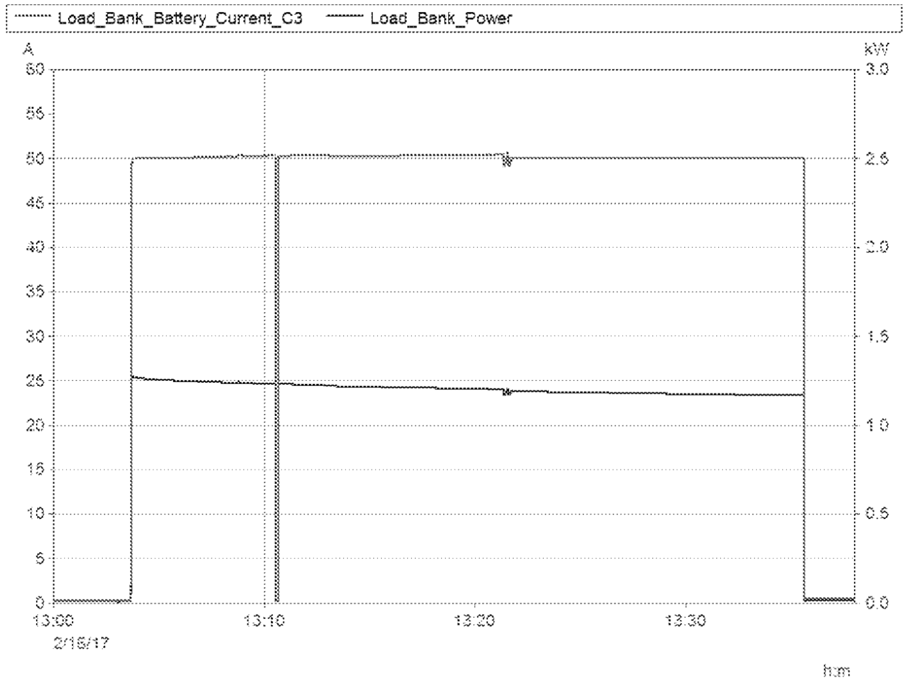


Figure 149 - 25Ah Battery Discharge, 50A for 30 minutes

At the conclusion of the discharge, the battery voltage was at 23.3V as shown in Figure 150.

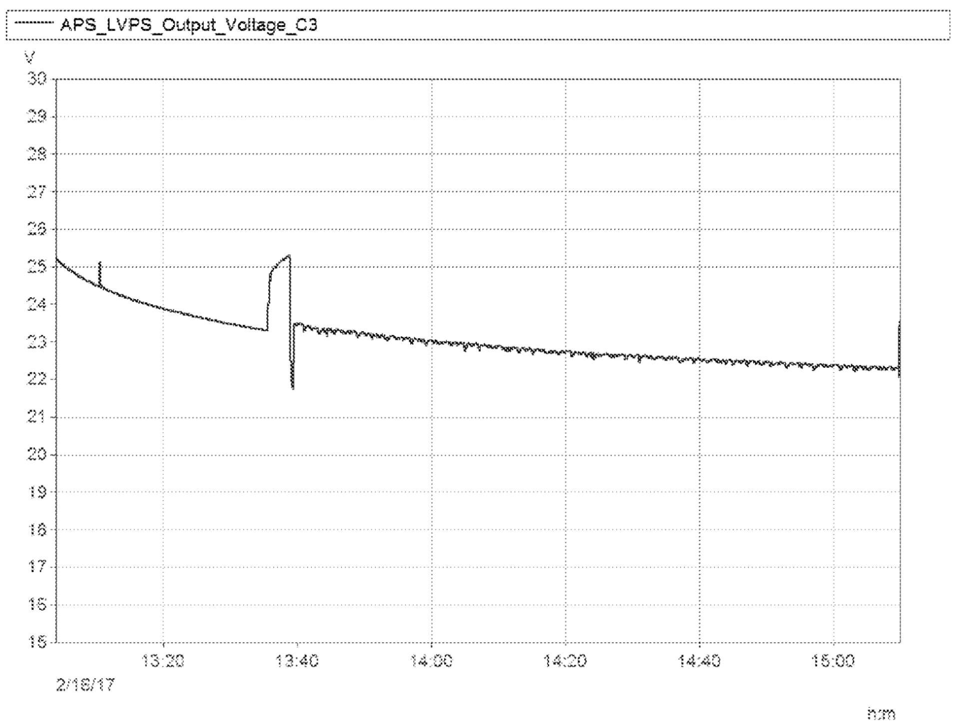


Figure 150 - Vehicle Battery Discharge Test, Battery Voltage

At 13:41 or t=0s, the load bank was used to simulate the hydraulic brakes by drawing ~200W (9.0A @ 23V) for 30 seconds. Sequentially, at 13:43 or t=2min, and every 2 minutes thereafter for the duration of the 90 minute test the load bank was used to simulate the PA and radio communication system by drawing ~150W (6.0A @ 23V) for 20 seconds as per Figure 151.

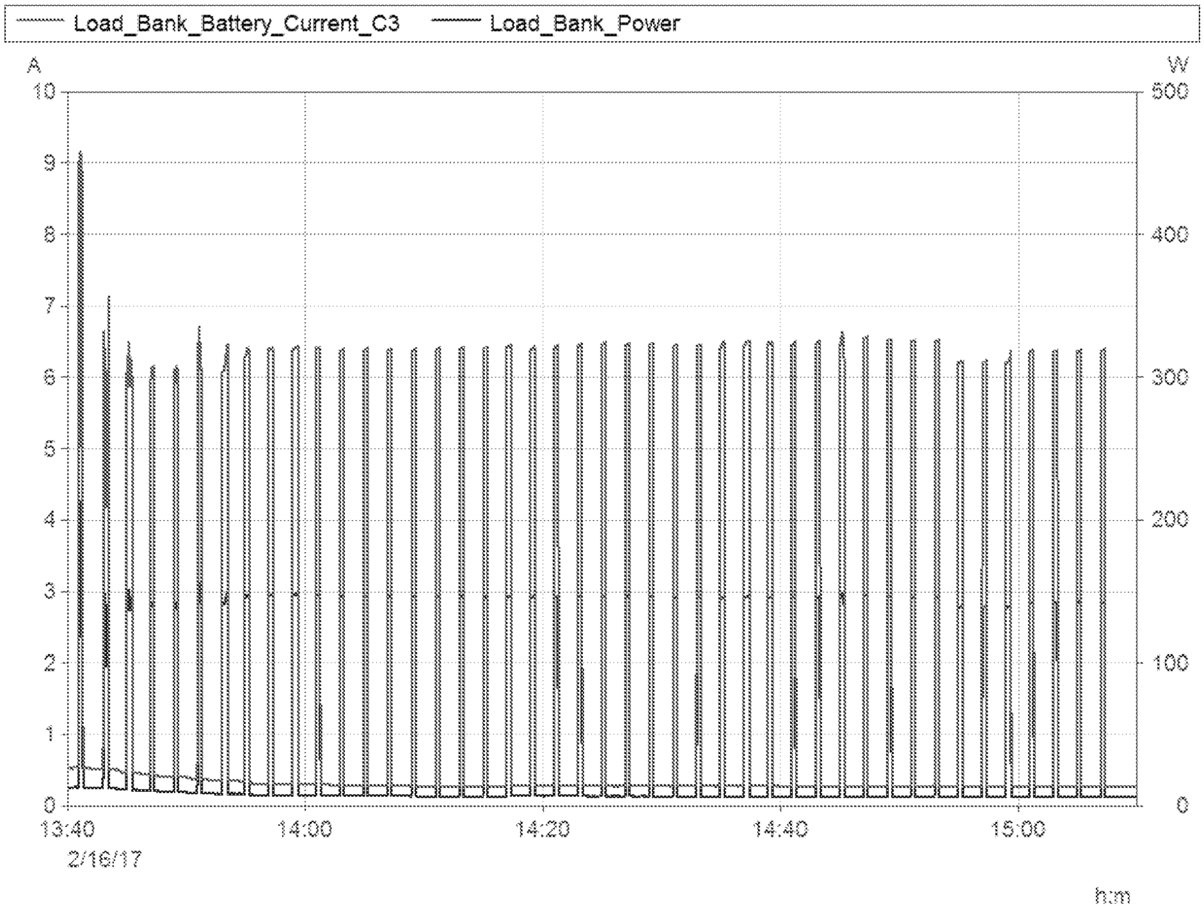


Figure 151 - Simulated Loads, Track Brakes, PA and Radio Communication

The status of other equipment, with regard to being powered and/or operational or deactivated as per Table 12, was monitored by Alstom, with the traces provided showing events (1=On, 0=Off, powered or deactivated) covering approximately the first 40 minutes of the test. Figure 152 shows active events.

The track brakes were activated for 30 seconds at t=0s, the horn was activated for 5 seconds at t=2min, and the doors were cycled at t=6min30s and every 6 minutes 30 seconds thereafter for the duration of the 90 minute test. The pantograph events were not recorded but were observed at t=5min and t=45min, while the LO_Winterization_Heater variable was manually deactivated at t<0s and includes all heating related equipment including Pre Heater Propulsion, Driver Seat Heater, Sanding Nozzles, Heater Coupler and the Air Compressor Dryer Heater.

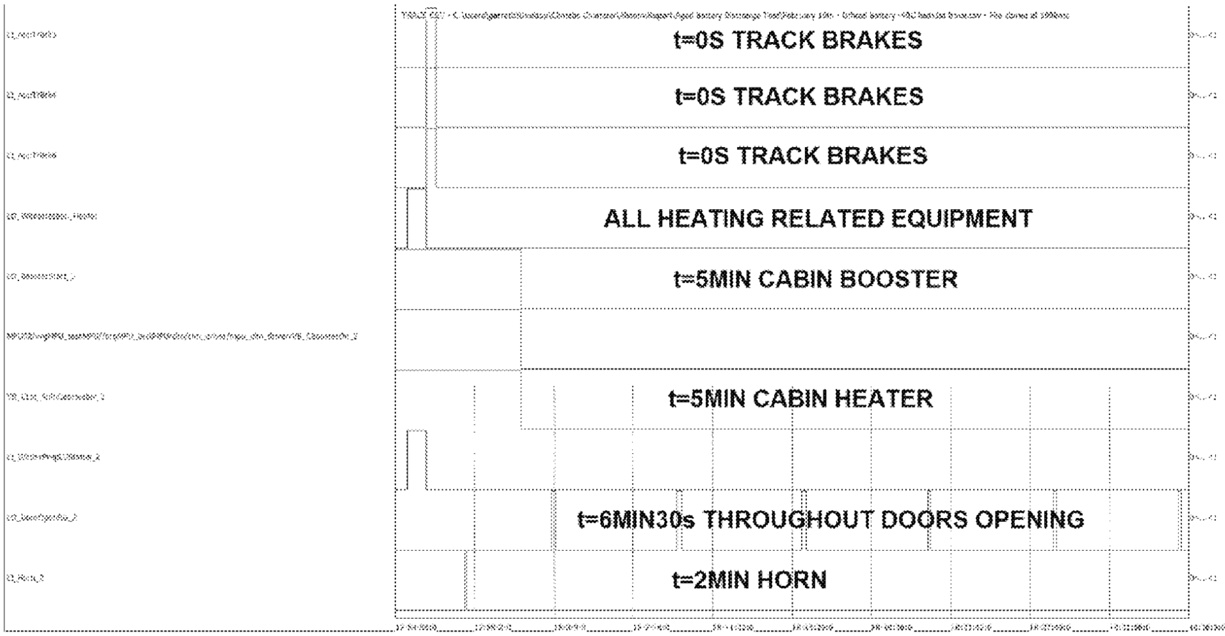


Figure 152 - Vehicle Battery Discharge Test, Active Event Signals

At the conclusion of the test battery voltage was recorded at 22.3V, with APS circuits monitored and data recorded for voltage, current, power and frequency (where applicable).

5.6.2 ***Train Start Test at -25°C***

5.6.2.1 Purpose

The purpose of the Train Start Test was to ensure the train can start with all required auxiliary functions utilizing a discharged, aged battery.

5.6.2.2 Results

Chamber temperature set points were set to achieve a temperature of -25°C, with the APS Battery Temperature and average car temperature monitored throughout the duration of the test as shown in Figure 153. 4kW of heat was added to the battery compartment during the test as Alstom was concerned a thermal switch protecting the battery (which opens at -25°C and closes at -16°C) would open overnight prior to commencing the test and as a result a charge would not be able to be applied to confirm a fully charged battery prior to the controlled discharge of 25Ah.

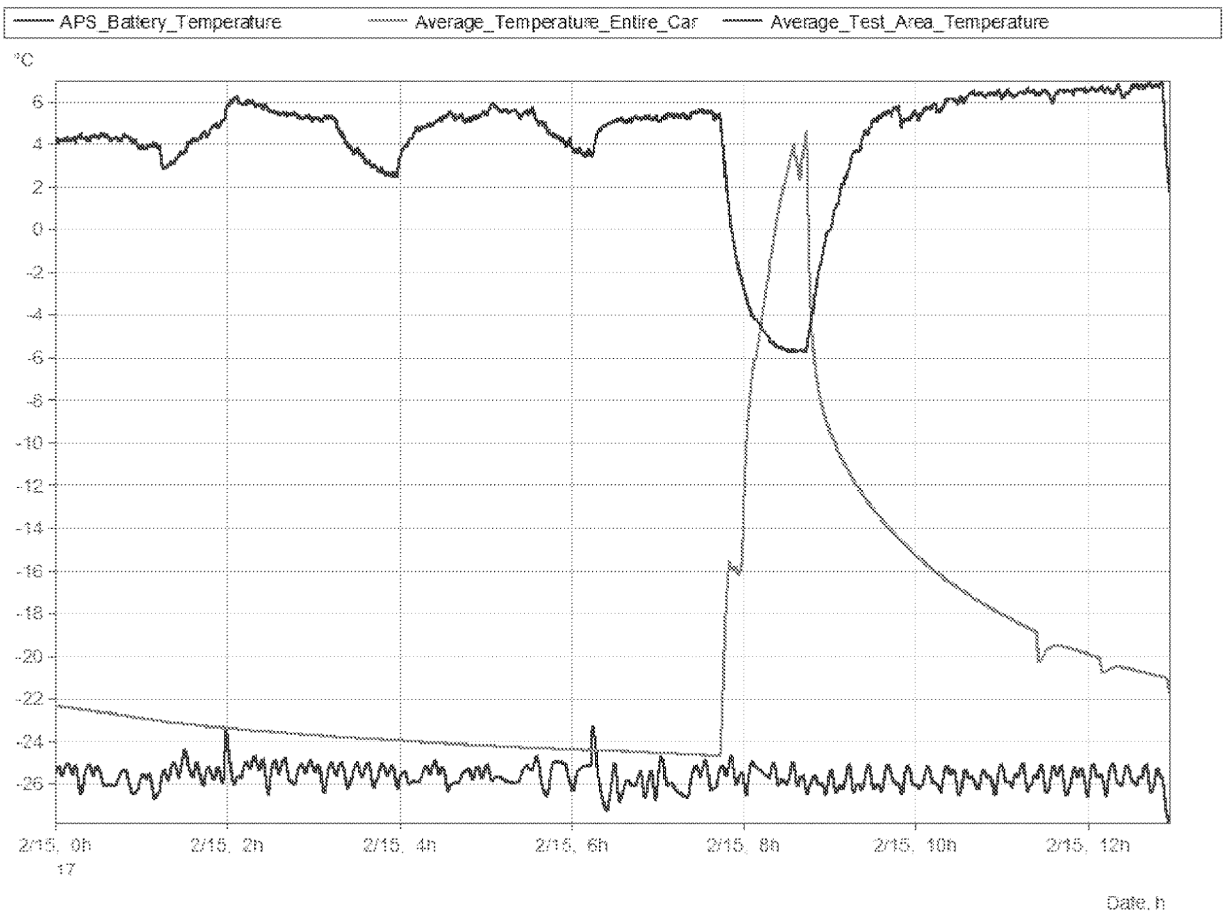


Figure 153 - Chamber & APS Temperatures, Test in Winter Conditions

With the Auxiliary Power Supply (APS) providing high voltage power, at 07:45 Alstom activated the HVAC (temperature rise observed inside car) as well as the following equipment to confirm operability.

- track brakes;
- pantograph control;
- PA and radio communication, to be simulated during test
- horn;
- doors opening and closing.

By drawing approximately 10A (240W) for 2.5 hours from 08:50 as per Figure 154 using a load bank, 25Ah was discharged to simulate the battery aged to a 0.89 coefficient.

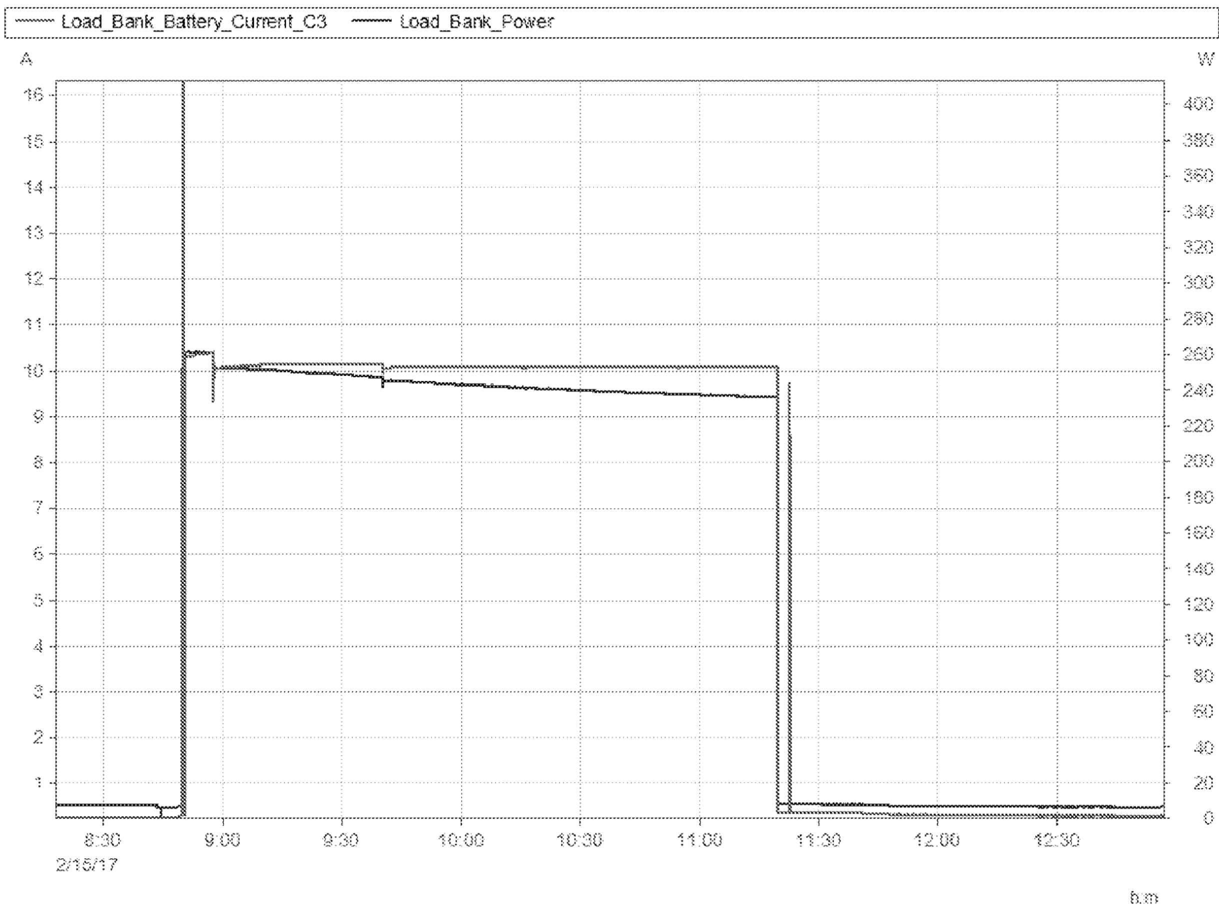


Figure 154 - 25Ah Battery Discharge, 10A for 2.5 hours

At the conclusion of the discharge, battery voltage was at 23.6V.

At 11:23, the load bank was used to simulate the PA and radio communication system by drawing ~200W (8.5A @ 24V) for 20 seconds as per Figure 155 .

Figure 155 - PA and Radio Communication, Simulated Load 8.5A @ 24V for 20s

Sequentially, Alstom activated the track brakes, the horn, and opened and closed the doors to confirm operability. Each of these actions was observed and is evidenced by the event signals shown in Figure 156, while the raising and lowering of the pantograph was observed.

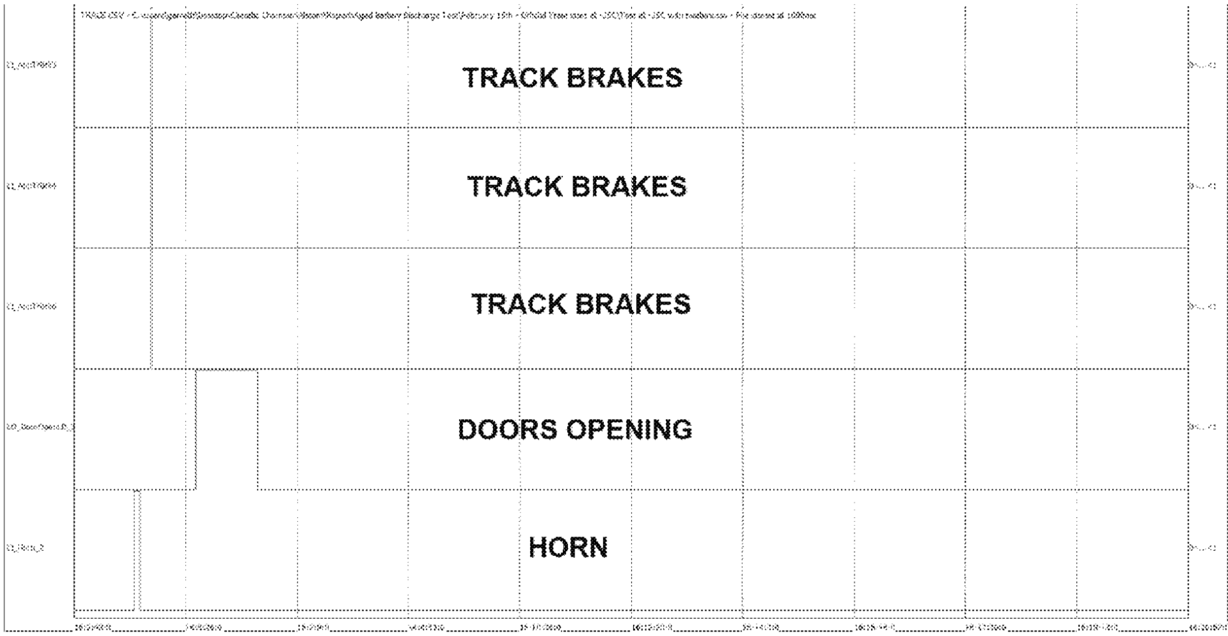


Figure 156 - Train Start Test, Active Event Signals

At the conclusion of the test battery voltage was recorded at 22.6V, with APS circuits monitored and data recorded for voltage, current, power and frequency (where applicable).

6 REFERENCES

[1] Citadis Spirit Climatic Room Climatic Conditions, ADD0000939178, Release B. Alstom Transport, 2015-12-01.

[2] Citadis Spirit Climatic Room: Climatic Comfort, ADD0000939184, Release C. Alstom Transport, 2015-11-19.

[3] Citadis Spirit Auxiliary Power Systems Tests, ADD0000939034, Release 0. Alstom Transport, 2014-11-14.

[4] Citadis Spirit Windshield Wipers, ADD0000939216, Release A. Alstom Transport, 2014 -12-14.

[5] Citadis Spirit Sanding, ADD0000939056, Release A. Alstom Transport, 2015-06-01.

[6] Citadis Spirit Vehicle Battery Discharge Test, ADD0000939031, Release B. Alstom Transport, 2015-11-19.

[7] Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, MIL–STD-810G, Test Methods 506.5, Rain, Procedure II.

[8] Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, MIL–STD-810G, Test Methods 521.3, Icing/Freezing Rain.

[9] SAE Surface Vehicle Recommended Practice, Windshield Defrosting Systems Test Procedure and Performance Requirements - Trucks, Buses and Multipurpose Vehicles, SAE J1381.

7 ACRONYMS AND ABBREVIATIONS

Alstom	Alstom Transport Canada Incorporated
AST	Automotive and Surface Transportation
APS	Auxiliary Power System
DAS	Data Acquisition System
HVAC	Heating, Ventilation & Air Conditioning
Hz	Hertz
LCC	Long Central Car
LMC2	Long Motor Car
LVPS	Low Voltage Power Supply
NRC	National Research Council
T_s	Surface Temperatures
T_{im}	Mean Interior Temperature
T_{em}	Mean Exterior Temperature
T_{ic}	Temperature Setpoint

APPENDIX A.

INTERIOR SENSIBLE AND LATENT LOAD CALCULATIONS

Simulated Solar Loads

As per Alstom calculations, 15kW total distributed as follows:

Train cab = 1.35 kW

LMC Passenger Area = 6.1 kW

Gangway between cars = 0.5 kW

LCC Passenger Area = 7.0 kW

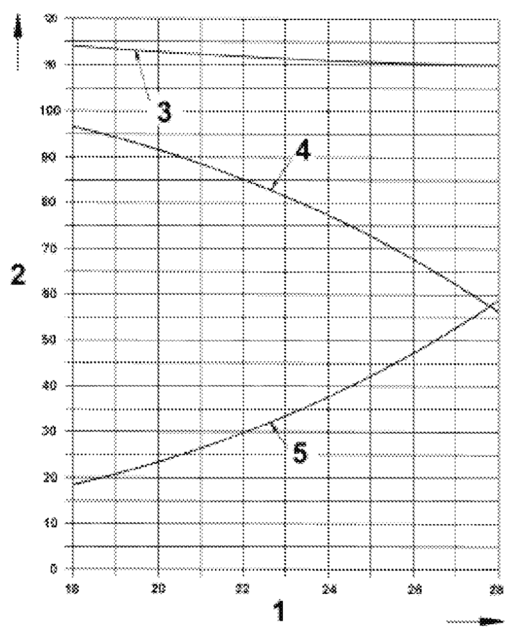
Total Solar Load = 15.0 kW

Calculation of Simulated Sensible & Latent Loads - Passengers

Passenger Sensible Load

AW2 Passenger Load (LMC/LCC) = 150 passengers (half car)

Based on heat emission chart of EN 14750, Annex D, Figure D1 at 21°C design condition:



Key

1 Mean interior temperature (Tim)

2 Heat emission W

3 Total heat

4 Sensible heat

5 Latent heat

Figure 157 - Heat emitted, person seated and wearing normal cloth (EN14750 Annex D Fig. D1)

Sensible load per passenger = 88W, Latent load per passenger = 27 W

Total Passenger Sensible Load = 88 W/Pass* 150 Pass = 13.20 kW (1)

Total Passenger Latent Load = 27 W/Pass * 150 Pass = 4.05 kW

Calculation of Steam Required to Simulate Latent Load

Passengers emit all water as saturated vapor at 36°C (96.8°F) by aspiration or perspiration. Water condenses on evaporator at 53°F

hg = 1103 BTU/lbw

hf = 21.1 BTU/lbw

Passengers load 4.05 kW = 13,831 BTU/hr

Q = 13,831/(1103-21.1) = 12.78 lbw/h = 5,797 gw/h = **97ml/min**

Sensible Load Correction for Steam

Steam is generated at 212°F and latent vapor is generated at 97°F. The difference is the extra heated added by using steam:

Enthalpy at 212°F = 1150.2 BTU/lbw

Enthalpy at 97°F = 1103.4 BTU/lbw

Extra Sensible added = 1150.2-1103.4 = 46.8 BTU/lbw

Q_{450} = 5,797 gw/hr * 46.8 BTU/lbw * 0.0022 lbw/ml * 1ml/1gw = 597 BTU/hr

Correction to Sensible load from steam = 597 BTU/hr = 0.175 kW

Sensible Load = 13.2 kW – 0.175 kW = **13.02 kW**

Simulated Loads Summary

- Sensible Heat Load: **Q_S = 13.0 kW**
- Latent Heat Load:

CITADIS SPIRIT
Investigation Test Procedure

Windshield and Gradient winter test

14/01/2018	H.DELIGNE	N.BOUSQUET	L.GOUDGE	ALSTOM Ottawa 805 Belfast Road
DATE	ESTABLISHED	CHECKED	APPROVED	

DISTRIBUTION	Confidentiality Category		Control Category		
	Restricted ☐	*Normal* ☒	*Controlled* ☐	*Not Controlled* ☒	

Appendix B	Rel.	Lang.	N.Shts
	B	en	12

REVISIONS

Version/ Release	Auteur/ Author	Date (fr : jj mois. aaaa) *(en : dd Month. yyyy)*	Page / Paragraph	Commentaires/ Comments
A	N.BOUSQUET	14/11/2018	ALL	Initial draft
B	H.DELIGNE	14/01/2019	4.1 4.2	Procedure modified according comments from OLR-ALS-1758. Addition of the gradient test.

CONTENTS

LIST OF DATA SHEETS

LIST OF FIGURES

1 INTRODUCTION

1.1 Scope

This document applies to the Alstom Transportation, Inc. (Alstom) test of Citadis Spirit Ottawa LRT (Light Rail Transit) trains.

1.2 Objective

This document describes 2 investigative tests:

The windshield test measures the thermal performance of the defrosting system. This test will replicate the service wake up conditions from layover mode in cold weather and measure the temperature rise of the windshield with the defroster off and on.

The gradient test will confirm the measured stratification observed in the CC car during the climate room tests.

2 TEST SETUP

2.1 General Test Conditions

Tests will be performed on a complete trainset ready for service:

LMC1 + IMC1 + LCC + LMC2

2.2 Ambient Conditions

Sub-zero ambient temperatures are required for this test (-10°C minimum).

2.3 Configuration of Vehicle under Test

Train configuration as per test sheet.

2.4 Data to Be Recorded

2.4.1 Windshield test

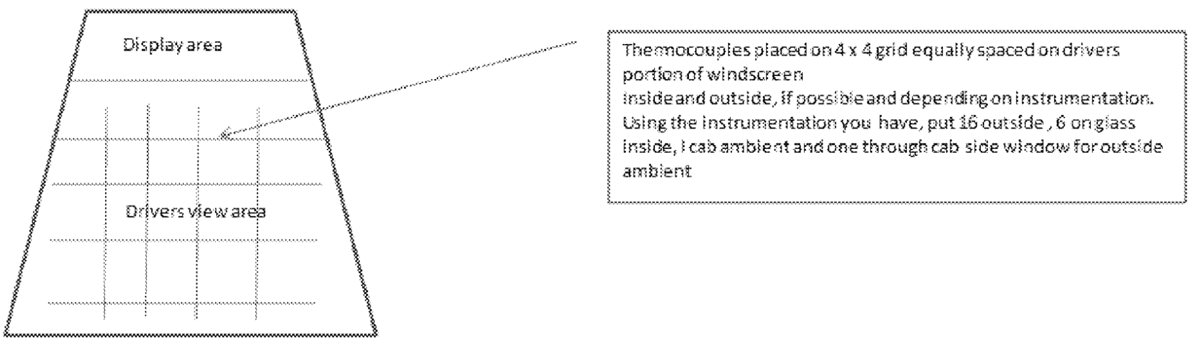


Figure 1: Thermocouple placement for the windshield winter test

2.4.2 Gradient test

For the gradient test a tripod with 3 thermocouples placed at different heights will be moved along the CC car.

One thermocouples will be placed anywhere outside the LRV in order to record the external temperature.

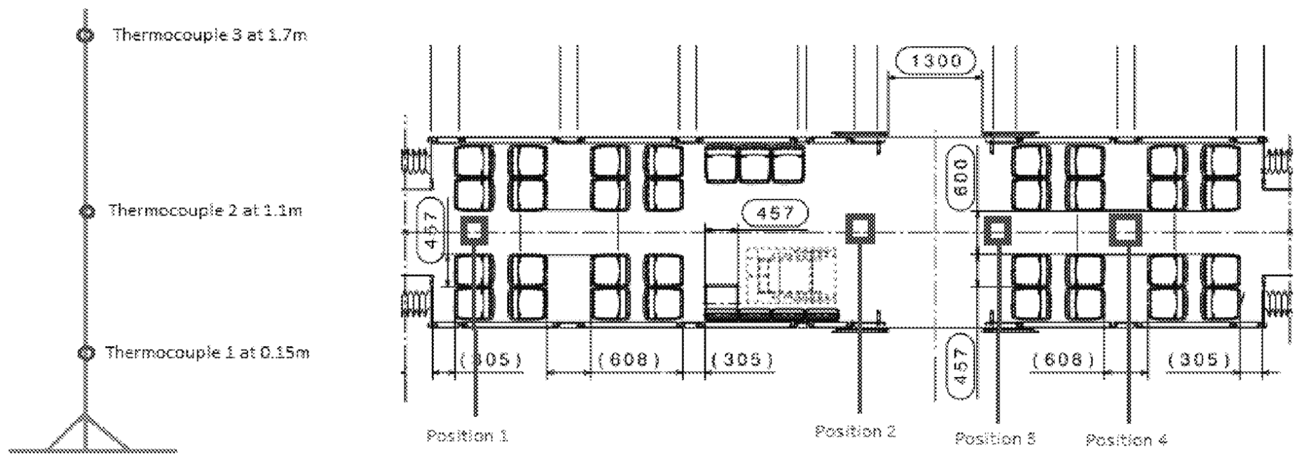


Figure 2: Thermocouple placement for Gradient test

2.5 Tooling and Personnel

For these tests the necessary tools are:

- Data acquisition system
- 22 thermocouples for windshield test, 4 for gradient test
- Train key
- Crew key

Two people from validation team are needed to perform this test.

2.6 Pre-Requisite Tests

- Train routine tests performed and passed
- Airflow retrofit completed

3 SAFETY REQUIREMENTS

High voltages are present during most of the tests. Use extreme caution when working around energized equipment and wiring. Refer to and or comply with applicable Alstom Environmental, Health, and Safety (EHS) Procedures. The Safety Procedures are located in Alstom's PRISMA database.

Testing will be witnessed by OLRTC and/or OC Transport and their designated representatives, at their discretion to achieve confidence by them that the vehicle complies with the requirements of the project agreement.

Witnesses must receive safety training from Alstom EHS representatives, or test laboratory representatives as appropriate, prior to entering any test station.

WITNESSES

Witnesses MUST remain on the vehicle, or at specific test observation areas at all times, unless escorted by test personnel.

Witnesses ARE NOT free to move unescorted in and out of the test area.

NOTE:

Before performing any test, read the job safety analyses (JSA) applicable for the test.

The JSA is prepared and retained at the test site.

DANGER – HIGH VOLTAGE

Avoid contact with the Third Rail or Catenary. Exposure can result in serious injury or death

DANGER – MOVING VEHICLE

Only qualified people are to operate a moving vehicle.

The area around the vehicle under test is restricted to authorized personnel only.

Insure that the vehicle is properly chocked to prevent unwanted motion for static tests.

DANGER

High voltages exposed on open terminals and electrical contacts can cause serious injury or death.

All testing and maintenance is to be performed by trained and experienced personnel

WARNING

Isolate any AC powered test equipment from ground

4 TEST PROCEDURE

4.1 Windshield Winter Test

4.1.1 Specific Test Conditions

TITLE : Windshield Winter Test	**Name:**	**Date:**
TRAIN INITIAL CONFIGURATION :	**Vehicle Type :**	

PRE-NECESSARY CARRIED OUT PROCEDURES:

Category :	**Nominal**
Test Type :	**Static**
HV Presence :	**Yes**
Train State:	**Layover**
MS position in CAR1 Mc1:	**OFF**
MS position in CAR1 Mc2:	**OFF**
TBH position in CAR1 Mc1:	**Neutral**
TBH position in CAR1 Mc2:	**Neutral**

PARTICULAR CONFIGURATION AND PRELIMINARY CHECKS:

Action	Target	Localization
Interior cab temperature stable in layover mode overnight	4°C	Cab
Defroster	OFF	Cab
Defroster timer extended (PI_WWD_DefrostTimer)	36000s	TrainTracer
Cab Heater Setpoint	22°C	Cab (CAID)
Cab Heater Fan	MAX	Cab (CAID)
Cab Booster	MAX	Cab (CAID)
Air grid closed at the driver feet heater outlet	Closed	Under driver desk

SPECIFIC TOOLS:

CONFIGURATION SOFTWARE / HARDWARE :

MPU:	
DDU:	
HVAC:	

SAFETY PRECAUTIONS: Standard precautions carried out in 1500 Volts, 480 Volts, and 110 Volts environment.

4.1.2 Test Description and Methodology

#	ACTIONS	RESULTS
1.	Access train with EAD such that it does not wake up (do not use crew doors)	**Train in layover mode**
2.	Start the recording of thermos-couples. Record initial conditions for 15 minutes	**Interior temperature stable at 4°C**
3.	Select MS switch to RM to wake up train	**Train wakes up** **Cab Heater is at 22°C** **Cab Heater Fan is at MAX** **Booster fan is at MAX**
4.	Record windshield temperature until stable (ie. no change for 15 minutes)	**Windshield Temperature stable**
5.	Turn on the defroster	**Defroster ON**
6.	Record windshield temperature until stable (ie. no change for 15 minutes)	**Windshield Temperature stable**
7.	Stop the recording	**Recording stopped**
8.	Measure with the recordings, the windshield temperature rise and time to stabilize	**Results noted in Data Sheet 1**

Data Sheet 1: Windshield Winter Test	
Temperature Rise with Defroster OFF	**Time to Stabilize**
Temperature Rise with Defroster ON	**Time to Stabilize**
Comments:	

4.2 Gradient Winter Test

4.2.1 Specific Test Conditions

TITLE : Windshield Winter Test	Name:	Date:
TRAIN INITIAL CONFIGURATION :	Vehicle Type :	

PRE-NECESSARY CARRIED OUT PROCEDURES:

Category :	**Nominal**
Test Type :	**Static**
HV Presence :	**Yes**
Train State:	**Active cab**
MS position in CAR1 Mc1:	**RM**
MS position in CAR1 Mc2:	**OFF**
TBH position in CAR1 Mc1:	**Neutral**
TBH position in CAR1 Mc2:	**Neutral**

PARTICULAR CONFIGURATION AND PRELIMINARY CHECKS:

Action	Target	Localization
Interior LRV temperature stable	20-22°C	Car

SPECIFIC TOOLS:

CONFIGURATION SOFTWARE / HARDWARE :

MPU:	
DDU:	
HVAC:	

SAFETY PRECAUTIONS: Standard precautions carried out in 1500 Volts, 480 Volts, and 110 Volts environment.

4.2.2 Test Description and Methodology

#	ACTIONS
1.	Place the tripod on position 1 (Figure 2)
2.	Start the recording of thermos-couples. Record for 15 minutes
3.	Stop the recording and save it as position 1.
4.	Place the tripod on position 2 (Figure 2)
5.	Start the recording of thermos-couples. Record for 15 minutes
6.	Stop the recording and save it as position 2.
7.	Place the tripod on position 3 (Figure 2)
8.	Start the recording of thermos-couples. Record for 15 minutes
9.	Stop the recording and save it as position 3.
10.	Place the tripod on position 4 (Figure 2)
11.	Start the recording of thermos-couples. Record for 15 minutes
12.	Stop the recording and save it as position 4.
13.	For each recording calculate the average value of each thermocouple and evaluate the gradient for each position.

5 TESTS AND RESULTS (TEST REPORT RELEASE)

5.1 Test Date and Test Location and Weather Conditions if Applicable

Fill this when the test report is released

5.2 Test Participants

Fill this when the test report is released

The name of all active and observing test participants shall be included in the test report. Name, company, function, and dates of attendance shall be provided.

5.3 Test Summary

For large multi-part tests provide a single page summary table, one row for each major test section with pass/fail/pass with exceptions status filled out.

5.4 Data Sheets, Test Results

Fill this when the test report is released

Completed and signed data sheets shall be provided along with any raw data in a suitable format.

5.5 Anomalies

Fill this when the test report is released

Anomalies will be tracked until closure. All anomalies and their resolution shall be reported in the test report.

5.6 Recommendations

Fill this when the test report is released

Recommendations will be included in the test report as appropriate

6 OPEN POINTS

Fill this when the test report is released

CITADIS SPIRIT
Investigation Test Report

Windshield and Gradient winter test

ADD0000939180-D-Appendix C

14/01/2018	H.DELIGNE	N.BOUSQUET	L.GOUDGE	ALSTOM	
DATE	ESTABLISHED	CHECKED	APPROVED	Ottawa	
DISTRIBUTION	Confidentiality Category: *Restricted* ☐ *Normal* ☒		Control Category: *Controlled* ☐ *Not Controlled* ☒	805 Belfast Road	

Appendix C	Rel.	Lang.	N.Shts
	A	en	15

REVISIONS

Version/ Release	Auteur/ Author	Date (fr : jj mois. aaaa) *(en : dd Month. yyyy)*	Page / Paragraph	Commentaires/ Comments
A	H.DELIGNE	22/02/2019	ALL	Initial draft

CONTENTS

1 INTRODUCTION

1.1 Scope

This document reports on Alstom Transportation, Inc. climate comfort and climatic conditions testing of the Citadis Spirit 404 Light Rail Vehicle (LRV).

1.2 Objective

This document describes the results obtained during the investigation test as discussed between Alstom and the City in the CRE-0230.

2 TEST SETUP

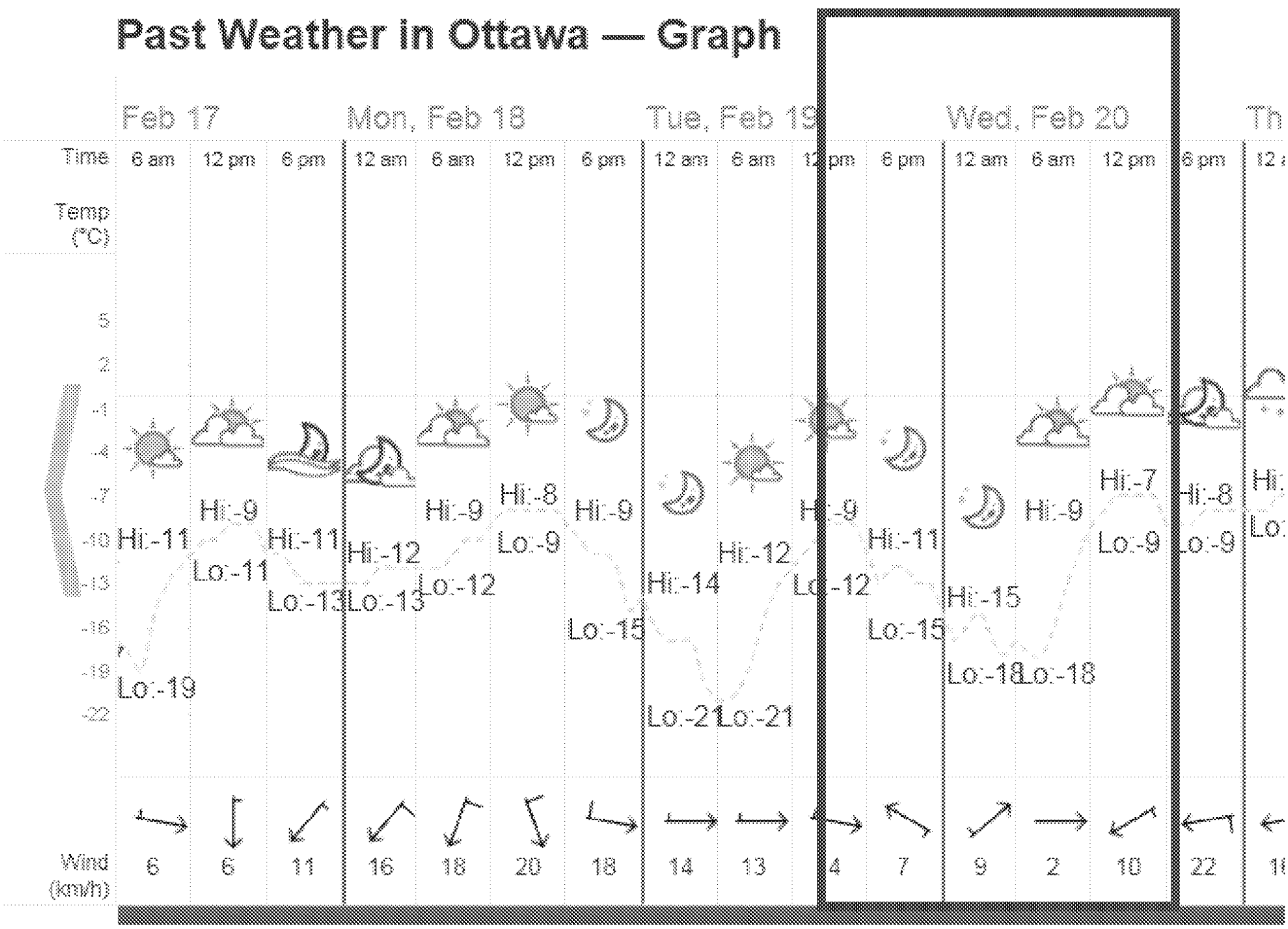
2.1 General Test Conditions

Tests were performed on a complete trainset (LRV35 aka New LRV2):

- MC1 + IMC1 + CC + MC2

2.2 Ambient Conditions

Through all the test the external temperature was below 0°C.



2.3 Configuration of Vehicle under Test

Train configuration as per test sheet.

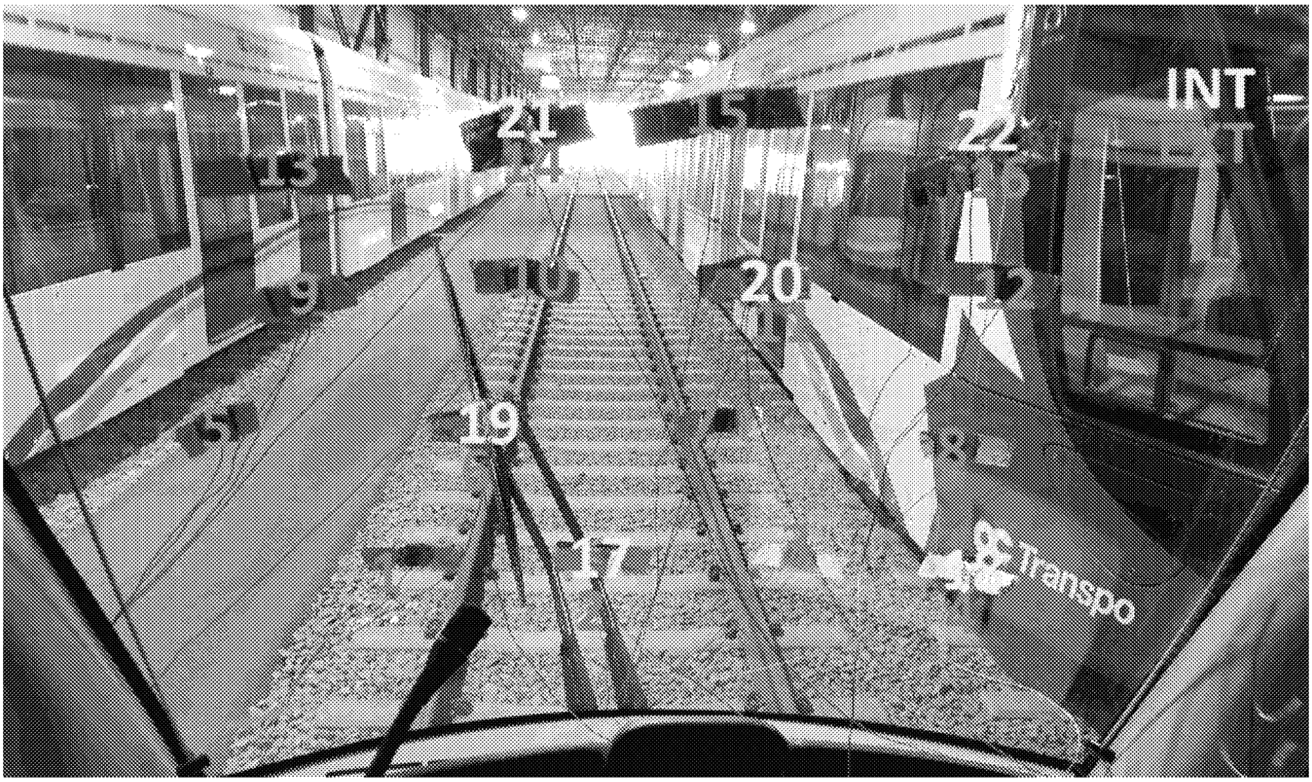
2.4 Data Recorded

2.4.1 Windshield test

16 thermocouples were placed on the windshield outside and 6 inside.

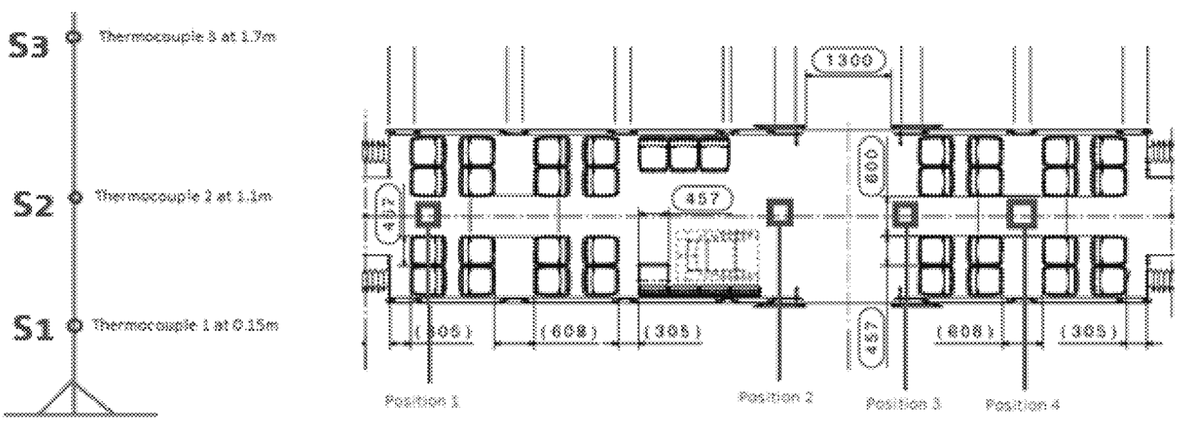
In order to insure that the defroster was correctly working the current consumption of the defroster has been recorded with a current clamp linked to the data acquisition system.

The figure below gives the reference of the thermocouple locations.



2.4.2 Gradient test

The figure below gives the thermocouple reference and the reference of the position through LCC car.



2.5 Test Date(s) and Test Location(s)

Windshield and Gradient investigative tests were performed in the Ottawa MSF Shed on 19 and 20 of February 2019.

2.6 Test Participants

Name	Company	Function	Dates of Presence
Simon BELET	Alstom	Train Manager / Validation Specialist	19/02/2019 20/02/2019
Joseph MARCONI	OLRT	OLRT representative	19/02/2019 20/02/2019
Eric DUBE	City of Ottawa	City representative	19/02/2019 20/02/2019
Matt PIETERS	City of Ottawa	City representative	19/02/2019 20/02/2019
André DROSTE	City of Ottawa	City representative	19/02/2019 20/02/2019
Casey HAWLEY	City of Ottawa	City representative	19/02/2019 20/02/2019

3 TEST RESULTS

3.1 Windshield Winter Test

3.1.1 Specific Test Conditions

TITLE : Windshield Winter Test	**Name: BELET Simon**	**Date: 19/02/2019**
TRAIN INITIAL CONFIGURATION :	**Vehicle Type : LRv35 (new Lrv2)**	

PRE-NECESSARY CARRIED OUT PROCEDURES:

Category :	**Nominal**
Test Type :	**Static**
HV Presence :	**Yes**
Train State:	**Layover**
MS position in CAR1 Mc1:	**OFF**
MS position in CAR1 Mc2:	**OFF**
TBH position in CAR1 Mc1:	**Neutral**
TBH position in CAR1 Mc2:	**Neutral**

PARTICULAR CONFIGURATION AND PRELIMINARY CHECKS:

Action	Target	Localization
~~Interior cab temperature stable in layover mode overnight~~	~~4°C~~	~~Cab~~
Defroster	OFF	Cab
Defroster timer extended (PI_WWD_DefrostTimer)	36000s	TrainTracer
Cab Heater Setpoint	22°C	Cab (CAID)
Cab Heater Fan	MAX	Cab (CAID)
Cab Booster	MAX	Cab (CAID)
~~Air grid closed at the driver feet heater outlet~~	~~Closed~~	~~Under driver desk~~

SPECIFIC TOOLS:

CONFIGURATION SOFTWARE / HARDWARE :

MPU:	**1.2.3.35**
DDU:	**1.4.0.5**
HVAC:	**V2.0.4 (set-point 19°C)**

SAFETY PRECAUTIONS: Standard precautions carried out in 1500 Volts, 480 Volts, and 110 Volts environment.

3.1.2 Variations with procedure:

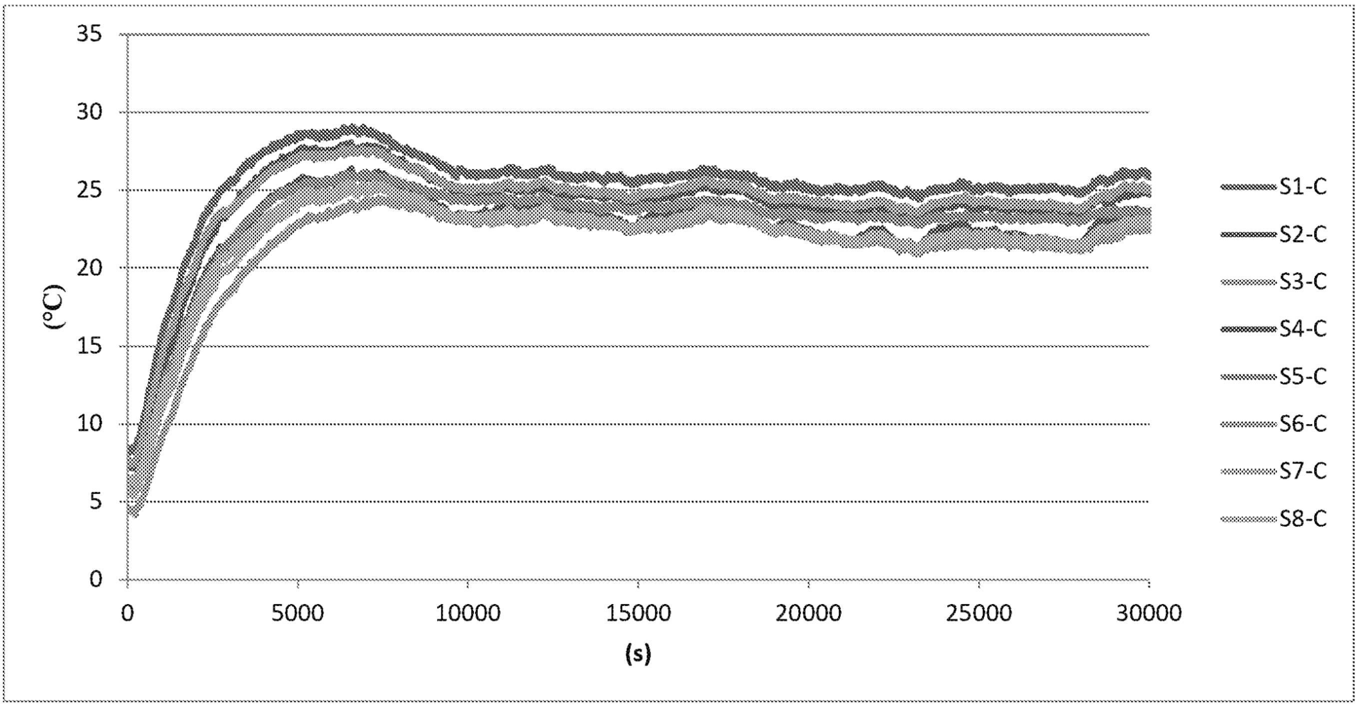
-**Interior Cab temperature:** The procedure stated the target value for Layover to be 4°C, actually this is wrong the target value is 6°C, moreover as cab heater and booster are required to be let ON the cabin will be at higher temperature than the 6°C.

Note: The day of the test the City wanted the cabin to be colder than it was (9°C) in order to see a condition where the driver has switched the heater in the cab, all HVACs and cabin heater were switched OFF and the door let open until the City decided to start the test.

-**Air grid at driver foot**: as the windshield defogger and the foot heater use the same air duct the position of the grid has an important impact on the air flow blown on the windshield, by request of the City the air grid at driver foot was opened.

3.1.3 Results Summary

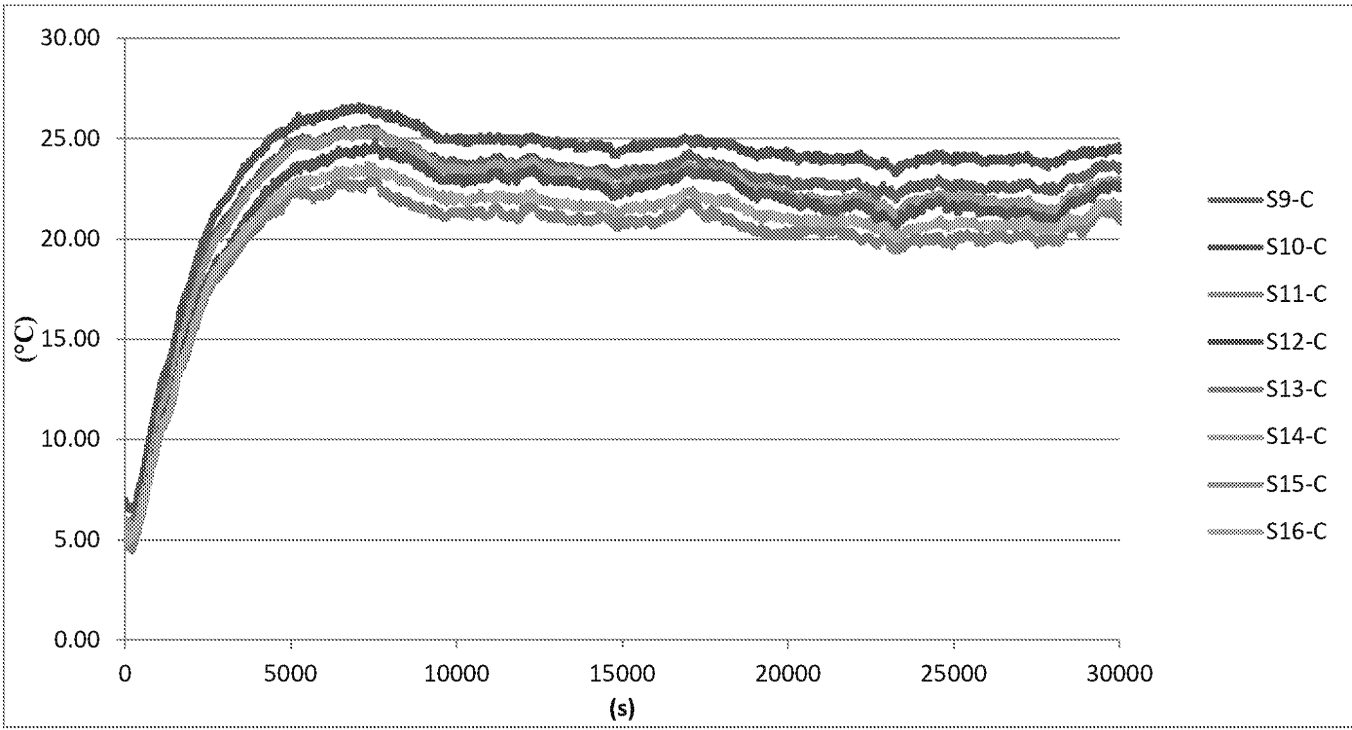
Sensors 1 to 8:



Max temperature (°C)							
S1	S2	S3	S4	S5	S6	S7	S8
29.1011	28.0747	27.7224	26.3941	26.1828	24.5123	25.4683	25.2569

Min Temperature (°C)							
S1	S2	S3	S4	S5	S6	S7	S8
8.16951	7.15312	7.37451	5.79458	6.05623	4.13414	6.21724	5.33167

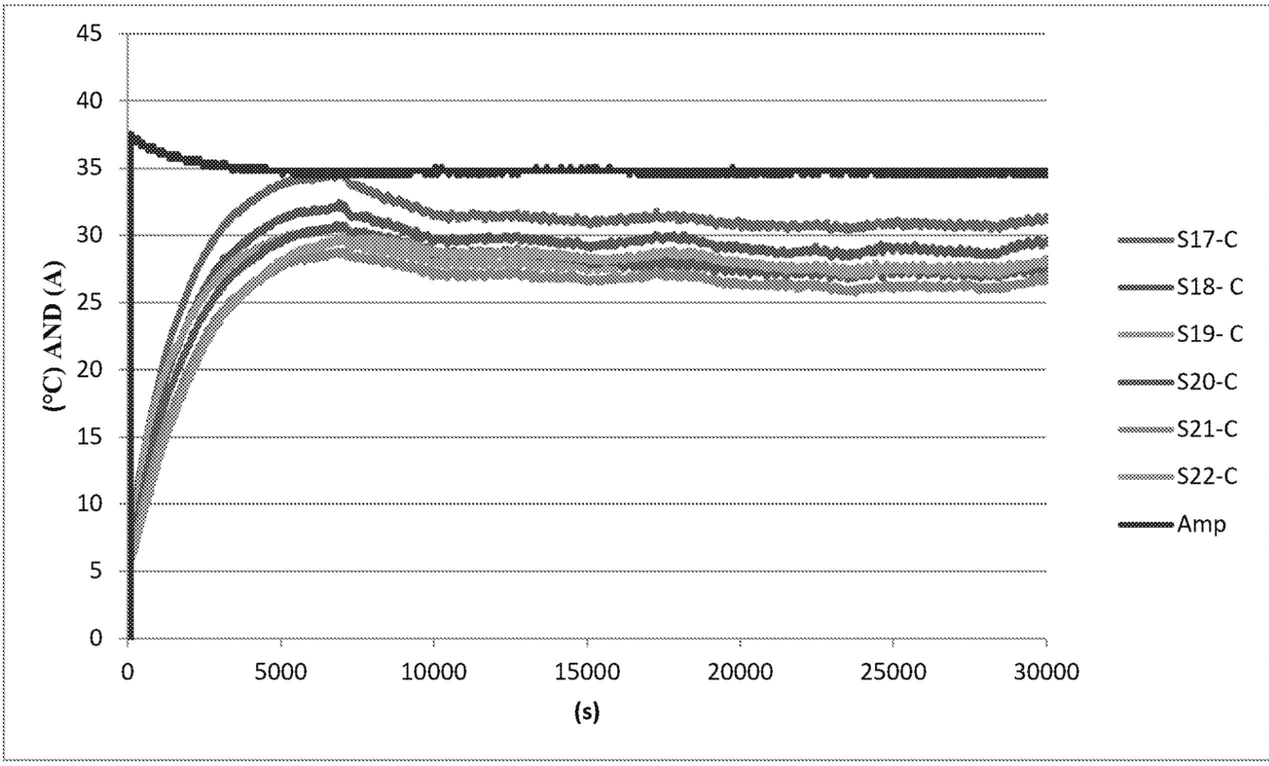
Sensors 9 to 16:



MAX Temperature (°C)							
S9	S10	S11	S12	S13	S14	S15	S16
25.60	26.68	25.42	24.90	23.02	23.73	24.81	25.80

Min Temperature (°C)							
S9	S10	S11	S12	S13	S14	S15	S16
5.65	6.46	5.43	4.44	4.48	4.83	5.62	5.88

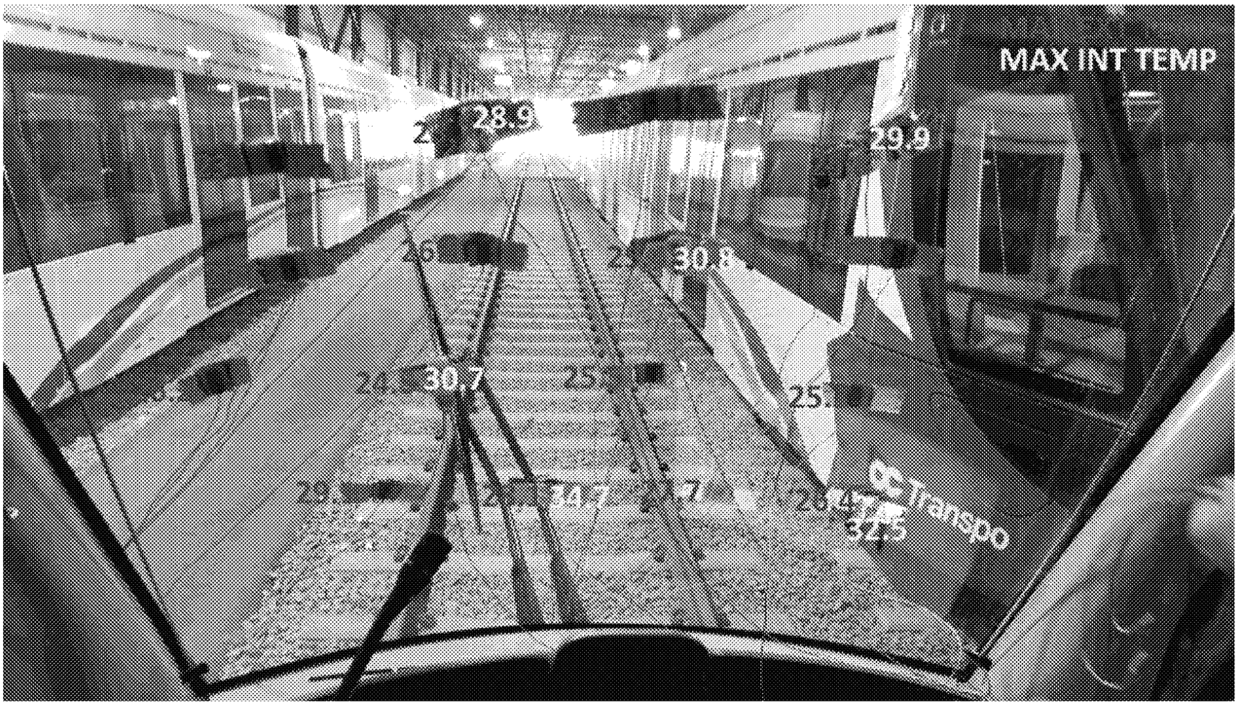
Sensors 17 to 22, and current consumption of the windshield's heater (Amp curve):



Max temperature					
S17	S18	S19	S20	S21	S22
34.6862	32.4824	30.6911	30.8421	28.8797	29.8961

Min temperature					
S17	S18	S19	S20	S21	S22
9.17584	7.4047	7.52546	7.01224	6.23737	5.93547

Max temperature reached on the windshield



3.1.4 Conclusion

The maximum stabilized temperature on the windshield is reached after 1h30.

3.2 Gradient Winter Test

3.2.1 Specific Test Conditions

TITLE : Windshield Winter Test	**Name:BELET Simon**	**Date:20/02/2018**
TRAIN INITIAL CONFIGURATION :	**Vehicle Type : LRv35 (new Lrv2)**	

PRE-NECESSARY CARRIED OUT PROCEDURES:

Category :	**Nominal**
Test Type :	**Static**
HV Presence :	**Yes**
Train State:	**Active cab**
MS position in CAR1 Mc1:	**RM**
MS position in CAR1 Mc2:	**OFF**
TBH position in CAR1 Mc1:	**Neutral**
TBH position in CAR1 Mc2:	**Neutral**

PARTICULAR CONFIGURATION AND PRELIMINARY CHECKS:

Action	Target	Localization
Interior LRV temperature stable	20-22°C	Car

SPECIFIC TOOLS:

CONFIGURATION SOFTWARE / HARDWARE :

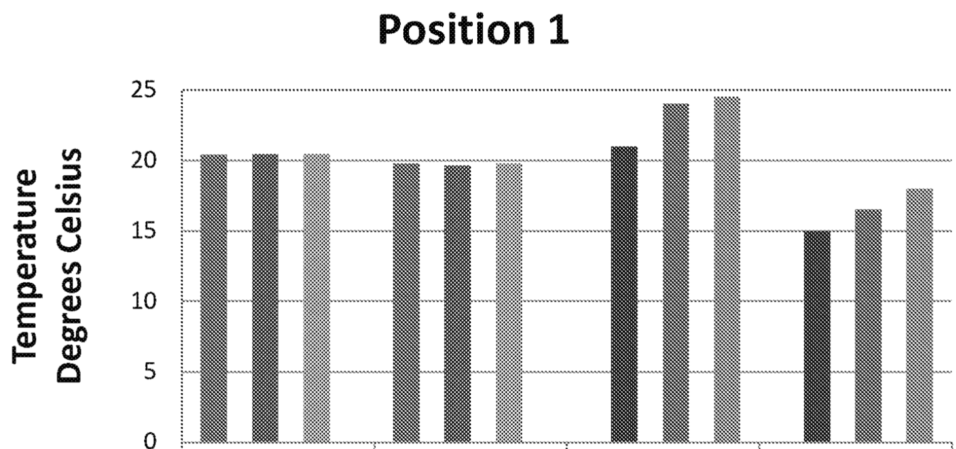
MPU:	**1.2.3.35**
DDU:	**1.4.0.5**
HVAC:	**V2.0.4 (setpoint 19°C)**

SAFETY PRECAUTIONS: Standard precautions carried out in 1500 Volts, 480 Volts, and 110 Volts environment.

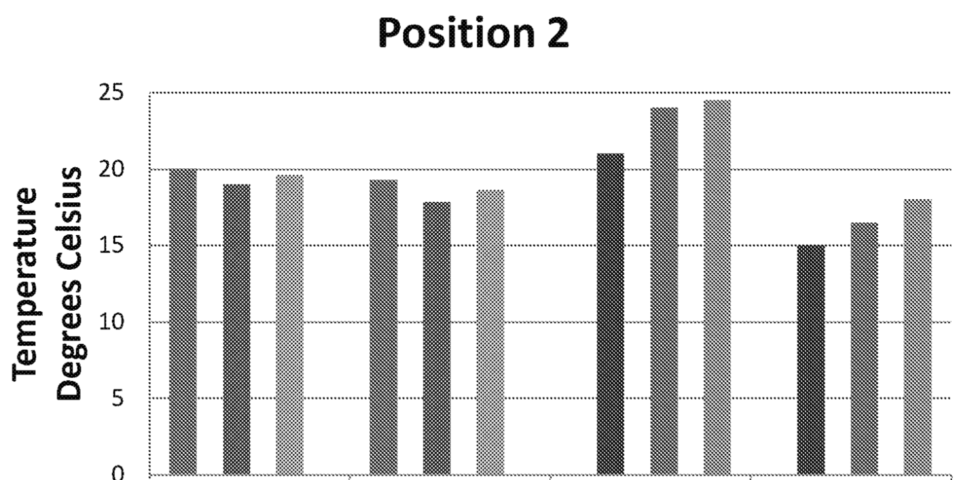
3.2.2 Variations with procedure:

-**Interior LRV temperature**: as the set point has been modified to 19°C the interior temperature stabilizes at 19°C not 20-22°C like specified in the procedure

3.2.3 Results Summary

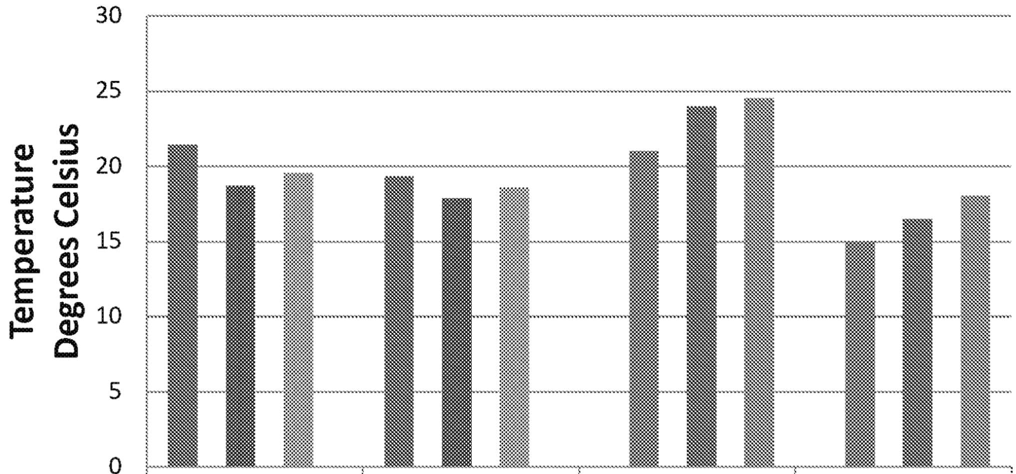


	Max	Min	Simul Max	Simul Min
S1	20.3863	19.7523		
Simul S1			21	15
S2	20.4467	19.6517		
Simul S2			24	16.5
S3	20.4266	19.7926		
Simul S3			24.5	18



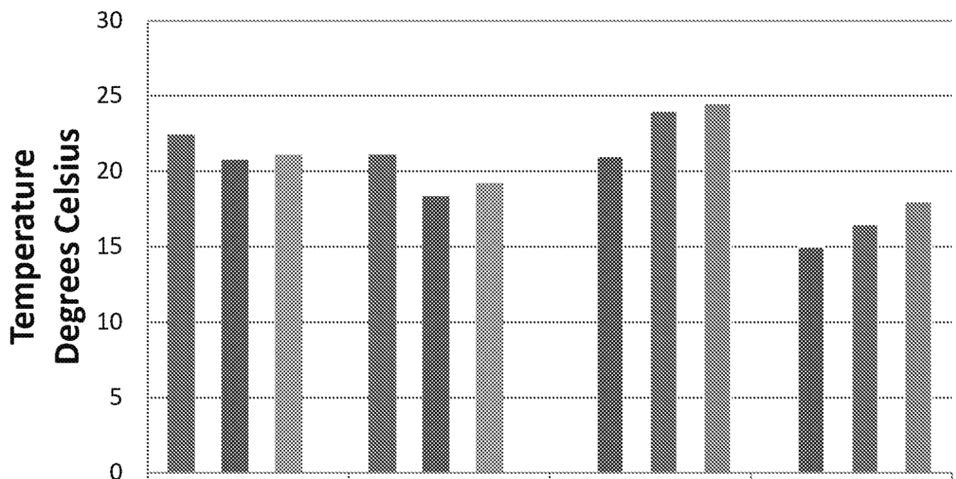
	Max	Min	Simul Max	Simul Min
S1	20.014	19.2995		
Simul S1			21	15
S2	19.0077	17.8604		
Simul S2			24	16.5
S3	19.6316	18.6252		
Simul S3			24.5	18

Position 3



	Max	Min	Simul Max	Simul Min
S1	21.4329	19.3498		
Simul S1			21	15
S2	18.7158	17.8604		
Simul S2			24	16.5
S3	19.5209	18.585		
Simul S3			24.5	18

Position 4



	Max	Min	Simul Max	Simul Min
S1	22.4292	21.1008		
Simul S1			21	15
S2	20.7385	18.3233		
Simul S2			24	16.5
s3	21.1008	19.1989		
Simul S3			24.5	18

3.2.4 Conclusion:

The results exceed the requirement, the test demonstrate that the gradient of temperature is less than expected on our own simulation. This also confirms that the original climate room gradient results had an issue, either with respect to door sealing or implementation of the modification mock-up that lead to the poor performance.

4 ANALYSIS

Based on the results of these investigative tests, Alstom will apply the following modifications to all the fleet:

-HVAC temperature set point rose to 19°C

-Windshield defroster automatic switch off after 60min instead of 15min previously

-Authorisation of cabin heater in non-active cab

5 GENERAL CONCLUSION

With all modifications listed in section 4, and the ones took after the climatic room test, the HVAC performances are considered as passed.