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16. Abstract This report describes results of a research program that is a follow-up project to previous work documented in NHTSA's, "*Potential Alternative Methodology for Evaluating Flammability of Interior Automotive Materials"* to improve the repeatability and reproducibility of evaluating the flammability of interior materials that are difficult to test per Federal Motor Vehicle Safety Standard No. 302. The project objectives are: (1) evaluate and improve on the microscale combustion calorimeter (MCC) test method and associated performance criteria for assessing flammability of materials, (2) evaluate repeatability of material flammability assessment of different materials (including layered materials) using the improved MCC test method and associated performance criteria, (3) compare the assessment of materials using the improved MCC test method to using the ASTM International E2102 apparatus, and (4) develop performance criteria for use with the improved MCC test method for interior materials in motorcoaches and other large buses for different evacuation times.			
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List of Key Acronyms and Abbreviations

AM	automotive materials
ASET	available safe egress time (seconds or minutes)
BB	Bluebird
CHF	critical heat flux for ignition (kW/m^2)
CFAST	consolidated model of fire and smoke transport (software program)
CSR	constant spread rate (mm/s)
FDS	fire dynamics simulator
FGC	fire growth capacity (J/g·K)
FMVSS	Federal Motor Vehicle Safety Standards
FSR	flame spread rate (mm/s)
HRR	heat release rate (kW)
MARHE	maximum average rate of heat evolution (kW/m^2)
MCC	microscale combustion calorimeter
MLC	mass loss calorimeter
OEM	original equipment manufacturer
RSET	required safe egress time (seconds or minutes)

List of Symbols

h_c	net calorific value of MCC specimen, area under the Q(t) curve (kJ/g)
$h_{c,gas}$	specific heat of combustion of specimen pyrolysis gases, $h_c/(1\text{-}Yp)$ (kJ/g)
HRR_{peak}	peak heat release rate in MLC test, normalized by specimen area (kW/m^2)
m_i	initial MCC specimen mass (mg)
m_f	final MCC specimen mass after MCC test is complete (mg)
Q_{max}	maximum value of the specific heat release rate, Q(t) (W/g)
Q(t)	specific heat release rate as a function of time measured in the MCC (W/g)
Q(T)	specific heat release rate as a function of MCC specimen temperature (W/g)
t_{ig}	ignition time in MLC test (seconds)
$t_{ULH = 1.5\ m}$	time to upper layer interface height reaching 1.5 m
$t_{ULT = 65°C}$	time to upper layer temperature reaching 65°C
$t_{ULT = 95°C}$	time to upper layer temperature reaching 95°C
T_{ig}	surface temperature at ignition (°C or K)
T_{max}	temperature at which Q_{max} occurs (°C or K)
T_0	reference temperature (25°C or 298.15 K)
$T_{5\%}$	surrogate ignition temperature (i.e., the temperature at which the cumulative specific heat release reaches 5% of h_c) (°C or K)
$T_{95\%}$	burnout temperature (i.e., the temperature at which the cumulative specific heat release reaches 95% of h_c) (°C or K)
Y_p	pyrolysis residue (i.e., fraction of the initial specimen mass that is left at the end of the MCC test, m_f/m_i (g/g)

Definition of Terms for MLC Testing

heat flux	exposure incident heat flux level for a given test series (kW/m^2)
m_i	initial mass of specimen (g)
ML_{total}	total mass loss of specimen after test (g)
t_{ig}	ignition time observed by test operator (seconds)
MLR_{avg}	average mass loss rate of specimen between ignition and end of test (g/m^{2}s)
MLR_{max}	maximum mass loss rate of specimen between ignition and end of test (g/m^{2}s)
HRR_{180s}	heat release rate averaged over first 180 seconds after observed ignition (kW/m^2)
HRR_{max}	maximum heat release rate during test (kW/m^2)
THR	total heat released (area under heat release rate curve) (MJ/m^2)

Greek Symbols

δ	thickness of the material as tested in the FMVSS No. 302 (m)
ΔT_{ig}	equal to $T_{ig} - T_0$ (°C or K)
$\Delta T_{5\%}$	equal to $T_{5\%} - T_0$ (°C or K)
β	heating rate of specimen in MCC apparatus (K/s)
η_c	heat release capacity (J/g·°C or J/g·K), Q_{max}/β
ρ	bulk density of the material (kg/m^3)

Executive Summary

This report describes research and testing of flammability of interior motor vehicle materials. This work is a continuation of research detailed in the National Highway Traffic Safety Administration's *Potential Alternative Methodology for Evaluating Flammability of Interior Automotive Materials* (Huczek et al., 2021) to improve the repeatability and reproducibility of evaluating the flammability of interior motor vehicle materials that are difficult to test per Federal Motor Vehicle Safety Standards No. 302 (e.g., rigid non-planar materials, parts smaller than the FMVSS No. 302 specimen size, etc.). This alternative method is also applicable to simple materials that are easy to prepare for testing.

The goal of the previous study was to identify a potential alternative existing small-scale fire test method with improved repeatability for which FMVSS No. 302 equivalent pass/fail criteria can be established. Three alternative small-scale test methods were considered. These included ASTM D3801, ASTM D7309, and ASTM E1354 (ASTM International, 2020, 2021a, 2023). The microscale combustion calorimeter, as described in ASTM D7309, was found to be the most suitable of the methods considered to serve as an alternative to FMVSS No. 302. In the previous study performance criteria were developed based on the MCC test parameters that were equivalent to FMVSS No. 302 pass/fail criteria. In this report MCC_AM test refers to the MCC test method and test parameters specified in the prior study for automotive materials.[1]

The scope of the current effort was to conduct additional research to augment the previous results. Specifically, the objectives of this research were to do the following.

1) Evaluate and improve on the MCC_AM test method and associated performance criteria for assessing flammability of materials.
2) Evaluate repeatability of material flammability assessment of different materials (including layered materials) using the MCC_AM test method and associated performance criteria.
3) Compare the assessment of materials using the MCC_AM test method with ASTM E2102, Standard Test Method for Measurement of Mass Loss and Ignitability for Screening Purposes Using a Conical Radiant Heater (ASTM International, 2021b). The ASTM E2102 test is referred to as the mass loss calorimeter test throughout this document.
4) Develop performance criteria for the MCC test method for interior motor vehicle materials in motorcoaches and other large buses for different evacuation times. For longer evacuation times, the performance criteria may be more stringent than those based on performance in FMVSS No. 302.

To meet the objectives, the project was structured in six tasks.

- Task 1: Test Material Procurement
- Task 2: MCC Tests Using Different Vehicle Makes and Models (Objective 1)
- Task 3: MCC Repeatability Tests (Objective 2)

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[1] See section "MCC Test Results and Material Properties Used in the Analysis" on page 62 of *Potential Alternative Methodology for Evaluating Flammability of Interior Automotive Materials*, (Huczek et al., 2021). https://rosap.ntl.bts.gov/view/dot/55583/dot_55583_DS1.pdf

- Task 4: MLC (ASTM E2102) Tests on Materials From Task 2 (Objective 3)
- Task 5: Literature Review of Egress Time for Buses (Objective 4)
- Task 6: Develop Performance Criteria, Specific to Motorcoaches and Buses, of Various Stringency Levels (Objective 4)

Task 1

The first task was to procure all the required materials necessary to satisfy the test requirements given in Tasks 2 to 6. For Task 2 it was decided to use original equipment manufacturer floor covering, headliner, seat cover, and seat padding materials from five vehicles of different makes and models. It was decided to use a subset of these OEM materials for Tasks 3 and 4, and to supplement the subset for Task 3 with additional OEM and aftermarket materials. For the small-scale tests in Task 6, it was decided to acquire aftermarket motorcoach and school bus materials.

Task 2

All materials passed FMVSS No. 302.

The alternative methodology to FMVSS 302 developed in the previous project predicted a pass for all Task 2 materials in the current project with one exception (Honda Civic seat cover). In the present project, a modified version of the alternative methodology was developed to predict FMVSS No. 302 pass/fail based on $T_{5\%}$ instead of T_{ig}.

A new method was developed to assess the effect of variability in the composition of the sample on the repeatability of the MCC test results. The new method uses an Arrhenius reaction rate model to quantify MCC sample composition in terms of the contribution of each component to the heat release rate measured in the test.

Task 3

The purpose of this task was to assess the benefits in terms of improved repeatability by performing six replicate MCC tests instead of three.

Three additional MCC tests were conducted on samples of Task 2 materials that showed the highest variability in the FMVSS No. 302 tests.

In addition, six tests were performed on four materials taken from OEM parts of two vehicles and two aftermarket materials (a carpet sold by the yard and molded to fit a specified motor vehicle).

The supplemental materials passed FMVSS No. 302 as predicted by the alternative methodology.

The effect on the average MCC test parameter values of performing six replicate MCC tests compared to three is very small. The effect on the estimate of the average composition was larger for some materials. The main benefit of performing six instead three replicate MCC tests is a higher confidence that the average composition is representative of the actual composition.

Task 4

Specimens of the two Task 2 floor covering, headliner, seat cover, and padding materials that had the highest variability for the FMVSS No. 302 replicates were tested in duplicate at three heat flux levels (20, 35, and 50 kW/m^2) in an MLC equipped with a chimney and thermopile.

The critical heat flux for ignition and corresponding ignition temperature were inconsistent with the values for the same flammability properties derived from the MCC data. Better agreement perhaps could have been obtained if MLC ignition data over a wider range of heat fluxes had been available but further investigation is needed to explain the discrepancies.

The MLC HRR measurements were used to calculate the maximum average rate of heat evolution for the eight materials that were tested. The MARHE was proposed in a journal article as a small-scale fire test performance metric to qualify wall and ceiling materials for use in buses based on a recent study funded by the European Commission.

Task 5

In this task we reviewed five studies that involved evacuation trials, three studies that involved full-scale bus fire tests, and two studies that used fire models to simulate fire growth in a bus.

A review of five studies that document the results of evacuation trials in school buses and motorcoaches results in the recommendation to use a conservative egress rate in fire safety engineering analyses of 27 people per minute (ppm) for evacuations in normal conditions and 13 ppm under more challenging circumstances (e.g., when visibility is poor).

Full-scale bus fire experiments resulted in a time to untenable conditions at specified locations ranging from 2 to 11 minutes. However, the available safe egress time is highly dependent on the specifics of the fire scenario and the fire performance of the materials involved.

Task 6

Two approaches were explored to establish MCC criteria for different stringency levels for use in buses.

For the first approach an attempt was made to develop logistic regression models that could be used to predict different levels of performance in FMVSS No. 302. There are different ways to pass FMVSS No. 302. A material that does not ignite is a better performer compared to a material that spreads flame to the end of the specimen at a rate below the 102 mm/min pass/fail threshold. This effort was not successful.

The second approach involved the use of MCC data to predict whether the MARHE for a material exceeds a specified threshold or not. The fire growth capacity seemed to be an MCC parameter that is suitable for this purpose. The Federal Aviation Administration (FAA) uses the FGC to qualify components of passenger aircraft interior materials without the need for retesting to measure the HRR of the material in the Ohio State University calorimeter.

The question remains what the MARHE thresholds should be for large surface area materials to achieve a specified ASET in buses. Consolidated model of fire and smoke transport simulations of a simple bus fire scenario were used to illustrate how such a MARHE threshold could be determined.[2] Future work may be needed to further explore establishing MARHE thresholds for realistic bus fire scenarios based on experiments and modeling using Fire Dynamics Simulator.

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[2] CFAST is a computer program that fire investigators, safety officials, engineers, architects, and builders can use to simulate the impact of past or potential fires and smoke in a specific building or transportation vehicle environment. CFAST is a two-zone fire model used to calculate the evolving distribution of smoke, fire gases, and temperature throughout compartments of a building or transportation vehicle during a fire. (Adapted from www.nist.gov/el/fire-research-division-73300/product-services/consolidated-fire-and-smoke-transport-model-cfast).

Conclusions

A summary of the conclusions from the project are as follows.

1. The validity of the alternative method developed in the previous project was confirmed based on new FMVSS No. 302 and MCC data for 24 motor vehicle interior materials (only one false negative was recorded).
2. A new method was developed to assess the effect of variability in the composition (in terms of contributions to the HRR) of the sample on the repeatability of the MCC test results. The effect of this variability generally was found to be relatively small, although there were some outliers.
3. The effect on the average MCC test parameter values of performing six replicate MCC tests compared to three is very small. The main benefit of performing six instead three replicate MCC tests is a higher confidence that the average composition is representative of the actual composition of a test article (e.g., layered materials).
4. The MLC proved to be a useful test method to measure the MARHE of interior materials used in motor vehicle equipment. However, the underlying reasons for the discrepancies between MLC and MCC derived ignition properties are unknown.
5. A review of five studies that document the results of evacuation trials in school buses and motorcoaches was carried out. Conservative egress rates in fire safety engineering analyses are: 27 ppm for evacuations in normal conditions, and 13 ppm under more challenging circumstances (e.g., when visibility is poor).
6. An attempt to develop logistic regression models that could be used to predict different levels of performance in FMVSS No. 302 (e.g., no sustained ignition versus burn rate less than 102 mm/min) was not successful.
7. Based on limited available data, it seems that the FGC could be used to determine whether the MARHE for a material exceeds a specified threshold or not. If confirmed by additional data and analysis, this would provide a mechanism to develop performance criteria for use with the MCC test method for interior materials in motorcoaches and other large buses for different evacuation times.
8. CFAST simulations of a simple bus fire scenario were used to illustrate how a MARHE threshold to achieve a specified ASET could be determined.

Introduction

This report describes research and testing into the flammability of interior motor vehicle materials. The work described here is a continuation of previous related research found in NHTSA's *Potential Alternative Methodology for Evaluating Flammability of Interior Automotive Materials* (Huczek et al., 2021) to improve the repeatability and reproducibility of evaluating the flammability of interior materials that are difficult to test per FMVSS No. 302 (e.g., rigid non-planar materials, parts smaller than the FMVSS No. 302 specimen size, etc.). This alternative method is also applicable to simple materials that are easy to prepare for testing.

The goal of the previous research was to identify an alternative existing small-scale fire test method for use in determining compliance with FMVSS No. 302 with improved repeatability. Three alternative small-scale test methods were considered. These included ASTM D3801, ASTM D7309, and ASTM E1354 (ASTM International, 2020, 2021a, 2023). The MCC, as described in ASTM D7309, was found to be the most suitable method to serve as an alternative to FMVSS No. 302. In the previous study performance criteria were developed based on the MCC test parameters that were equivalent to FMVSS No. 302 pass/fail criteria. In this report MCC_AM test refers to the MCC test method and test parameters specified in the prior study for AM.[3]

The scope the of current effort was to conduct additional research to augment the previous results. Specifically, the objectives of this research were to do the following.

1) Evaluate and improve on the MCC_AM test method and associated performance criteria for assessing flammability of materials.
2) Evaluate repeatability of material flammability assessment of different materials (including layered materials) using the MCC_AM test methodology and associated performance criteria.
3) Compare the assessment of materials using the MCC_AM test method to using the ASTM International (2021b) E2102, Standard Test Method for Measurement of Mass Loss and Ignitability for Screening Purposes Using a Conical Radiant Heater. This test is referred to as the MLC test throughout this document.
4) Develop performance criteria for use with the MCC test method for interior materials in motorcoaches and other large buses for different evacuation times. For longer evacuation times, the performance criteria may be more stringent than those based on performance in FMVSS No. 302.

The outcome of the research is to produce potential alternative test procedures or performance criteria with demonstrated improved repeatability. This report describes the work plan tasks and research results.

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[3] See section "MCC Test Results and Material Properties Used in the Analysis" on page 62 of *Potential Alternative Methodology for Evaluating Flammability of Interior Automotive Materials*, (Huczek et al., 2021). https://rosap.ntl.bts.gov/view/dot/55583/dot_55583_DS1.pdf.

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Program Structure Overview

Table 1 shows a breakdown of the work plan tasks designed to reach the research objective. Additional information, mostly in the form of data sets, are available for reference in several appendices at the end of this report.

Table 1. Work tasks

Task Number	Task Description
1	Test Material Procurement
2	MCC Tests From Different Vehicle Makes and Models (Objective 1)
3	MCC Repeatability Tests (Objective 2)
4	MLC (ASTM E2102) Tests on Materials From Task 2 (Objective 3)
5	Literature Review of Egress Time for Buses (Objective 4)
6	Develop Performance Criteria of Various Stringency Levels (Objective 4)

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Task 1: Test Material Procurement

The first subtask of the proposed technical plan was to procure all the required materials necessary to satisfy the test requirements given in Tasks 2 through 6.

For Task 2 it was decided to use OEM headliner, floor covering, seat cover, and seat padding materials from five vehicles of different makes. It was decided to use a subset of these OEM materials for Tasks 3 and 4, and to supplement the subset for Task 3 with additional OEM and aftermarket materials.

No materials were necessary for Task 5. However, Braun et al. (1990), for example, concluded that small-scale tests are poor representatives of real-world fire behavior of seating assemblies in buses. This explains why a recent proposal of flammability requirements for bus interior materials (El Houssami et al., 2023), which is based on the European standard EN 45545-2 for interior materials used in passenger railcars, specifies acceptance criteria that are based on performance of an entire seat assembly in a full-scale fire test. Consequently, it may have been helpful to examine full-scale fire tests on seating assemblies in Task 6. However, full-scale testing was outside the scope of the current project. For the small-scale tests in Task 6, it was decided to acquire aftermarket motorcoach and school bus materials.

Additional details for each of the material sets that were used are provided in the following subsections that focus on a given task.

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Task 2: MCC Tests From Different Vehicle Makes and Models

The following subsections give details on material selection, the test matrix, test results, and analysis of the tests conducted.

Task 2: Material Selection and Test Matrix

This task consisted of conducting MCC tests on floor covering, headliner, seat cover, and seat padding materials from five different vehicle makes and models to evaluate the MCC_AM test procedure and associated performance criteria.

Tables 2 to 6 show parts identified for testing from popular 2020 model year passenger vehicles (SUVs, minivans, pickup trucks, compacts, mid-size sedans) and the corresponding manufacturer websites for online procurement of these materials.[4]

Table 2. Task 2 test parts – 2020 Chevrolet Equinox

2020 Chevy Equinox	https://gmpartsnow.com
Component	**Part No.**
Floor Mats, Carpet, Rear	84052382
Seat Cushion Pad	84566975
Cushion Cover	84555793
Headliner	84489859

Table 3. Task 2 test parts – 2020 Dodge Grand Caravan

2020 Dodge Grand Caravan	www.factorychryslerparts.com
Component	**Part No.**
Carpet, Floor	0ZQ88DX9AI
Frame, Second-Row Seat Cushion	6NU07DX9AA
Frame, Rear Seat Back	
Headliner	6QW151DAAC

Table 4. Task 2 test parts – 2020 Ford F150

2020 Ford F150	https://parts.ford.com
Component	**Part No.**
Floor Carpet	1613000
Rear Seat Cushion Pad	1663841
Rear Seat Cushion Cover	1863805
Roof Headlining	1851944

Table 5. Task 2 test parts – 2020 Honda Civic

2020 Honda Civic	www.hondafactoryparts.com
Component	**Part No.**
Carpet Assembly Floor	83301-7GG-A11ZA
Pad, Rear Seat Cushion	82137-TBA-A21
Cover Rear Seat Cover Trim	82131-TGG-A31ZB
Lining Assembly, Roof	83200-TGG-A61ZA

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[4] All vehicles are ranked within the top three most popular vehicles of their type by J. D. Power and Associates.

Table 6. Task 2 test parts – 2020 Toyota Camry

2020 Toyota Camry	https://autoparts.toyota.com
Component	**Part No.**
Carpet Assembly Floor, Front	5851006701B2
Seat Cushion Pad, Rear	7150306270
Cover, Rear Seat Cushion (Bench Type)	7107506K90B0
Headliner	6331006C70B0

The test plan consisted of performing MCC tests (ASTM D7309 Method A) in triplicate on specimens of the four materials from each vehicle. For the Grand Caravan, the padding samples were taken from the seat bottom cushion and the cover material samples were taken from the seat back. This is because the Grand Caravan is the only vehicle in the test fleet where the seat padding and cover are not separated. Tests on specimens from the seat cover/padding combination of this vehicle were performed in Task 3. In addition, five FMVSS No. 302 tests were performed on specimens of each material from each vehicle. Table 7 shows the test matrix for this task.

For the FMVSS No. 302 specimens, flat 4×14-in. specimens were prepared from the procured parts, which is difficult to do for small parts or materials that are curved. For the MCC specimens, much smaller specimens are required, and it generally was much easier to obtain the required specimens from the component. For the MCC test, a technician would first cut a 1×1-in. piece of the same material and from that piece the technician would prepare a mg-size MCC specimen. This was done by cutting a small section of material from the 1×1-in. piece, placing that smaller sample into a knife mill (e.g., food processor) for a nominal 1-minute duration and then extracting 2 to 10 mg specimens from the milled piece.

Table 7. Task 2 test matrix

Vehicle	**Component**	**MCC Replicates**	**FMVSS No. 302 Replicates**
2020 Chevrolet Equinox	Carpet	3	5
	Headliner	3	5
	Seat Cover	3	5
	Seat Padding	3	5
2020 Dodge Grand Caravan	Carpet	3	5
	Headliner	3	5
	Seat Cover	3	5
	Seat Padding	3	5
2020 Ford F150	Carpet	3	5
	Headliner	3	5
	Seat Cover	3	5
	Seat Padding	3	5
2020 Honda Civic	Carpet	3	5
	Headliner	3	5
	Seat Cover	3	5
	Seat Padding	3	5

Vehicle	Component	MCC Replicates	FMVSS No. 302 Replicates
2020 Toyota Camry	Carpet	3	5
	Headliner	3	5
	Seat Cover	3	5
	Seat Padding	3	5

Task 2: Test Results

Table 8 shows summary results for tests performed according to FMVSS No. 302 and Table 9 shows a summary of the average results for tests per the summary MCC-based method for the different vehicle parts tested in Task 2. Complete results of all replicate FMVSS No. 302 and MCC testing are tabulated in Appendix A and Appendix B.

Table 8. Summary of FMVSS No. 302 average test results for Task 2

Vehicle	Material	Average Burn Rate (mm/min)	Pass/Fail
Chevrolet Equinox	Headliner	17	Pass
	Carpet	NA	Pass
	Seat Padding	NA	Pass
	Seat Cover	28	Pass
Honda Civic	Headliner	19	Pass
	Carpet	33	Pass
	Seat Padding	NA	Pass
	Seat Cover	55	Pass
Toyota Camry	Headliner	26	Pass
	Carpet	38	Pass
	Seat Padding	45	Pass
	Seat Cover	63	Pass
Ford F150	Headliner	NA	Pass
	Carpet	23	Pass
	Seat Padding	52	Pass
	Seat Cover	40	Pass
Dodge Grand Caravan	Headliner	17	Pass
	Carpet	45	Pass
	Seat Padding and Cover	28	Pass

NA: Not applicable, the burn rate could not be calculated because the flame did not spread to the first mark or the specimen did not ignite.

Table 9. Summary of MCC average test results for Task 2

Material Description	m_i (mg)	m_f (mg)	η_c (J/g·K)	Q_{max} (W/g)	T_{max} (°C)	h_c (kJ/g)	Y_p (g/g)	$h_{c,gas}$ (kJ/g)
Equinox Carpet	4.06	0.91	281	278	461	25.3	0.224	32.7
Equinox Headliner	4.03	1.22	162	161	418	15.8	0.303	22.5
Equinox Seat Cover	3.03	0.13	231	229	429	22.0	0.043	23.0
Equinox Seat Padding	3.01	0.06	516	511	403	26.9	0.020	27.4
Grand Caravan Carpet	4.03	0.32	329	327	463	25.1	0.079	27.2
Grand Caravan Headliner	4.05	0.26	215	213	406	20.5	0.063	21.9
Grand Caravan Seat Cover	4.06	0.30	310	308	423	22.3	0.073	24.1
Grand Caravan Padding	4.01	0.16	513	508	409	23.5	0.041	24.5
F150 Carpet	4.05	0.46	162	160	430	17.7	0.114	20.0
F150 Headliner	3.04	0.38	254	251	409	21.5	0.125	24.6
F150 Seat Cover	4.03	0.24	264	261	392	22.5	0.059	23.9
F150 Seat Padding	3.04	0.19	408	404	404	26.0	0.062	27.7
Civic Carpet	4.08	0.50	365	360	448	18.2	0.122	20.8
Civic Headliner	3.03	0.73	110	108	406	16.2	0.242	21.4
Civic Seat Cover	3.02	0.29	289	286	364	21.6	0.097	23.9
Civic Padding	3.03	0.05	586	581	407	28.0	0.017	28.5
Camry Carpet	5.03	0.27	518	514	472	30.2	0.054	31.9
Camry Headliner	4.06	1.43	116	115	423	12.7	0.353	19.5
Camry Seat Cover	4.07	0.24	271	269	429	22.8	0.059	24.2
Camry Seat Padding	4.07	0.24	530	525	404	28.2	0.059	30.0

Task 2: Data Analysis

Predictions of FMVSS No. 302 Performance

In the previous NHTSA project to develop a potential alternative methodology to FMVSS No. 302 for evaluating flammability of interior AM (Huczek et al., 2021), two sets of alternative pass/fail criteria were developed based on an analysis of MCC data for 37 motor vehicle interior materials. These alternative criteria identified are as follows.

1. MCC parameter-based criteria:
    a. Materials 3.2 mm or less in thickness are expected to pass FMVSS No. 302 when at least one of the following criteria is met: $\eta_c \leq 200$ J/g·K **or** $T_{ig} \geq 310$°C.
    b. Materials that are more than 3.2 mm thick are expected to pass FMVSS No. 302 when at least one of the following, less stringent, criteria is met: $\eta_c \leq 300$ J/g·K **or** $T_{ig} \geq 290$°C.
2. Physics-based criterion:
    a. Materials are expected to pass FMVSS No. 302 if the following criterion is met: $\rho\delta(T_{ig} - T_0) \geq 85$ kg·K/m^2.

Where:

η_c = Heat release capacity (J/g·°C or J/g·K)

T_{ig} = Surface temperature at ignition (°C or K)

ρ = Bulk density of the material (kg/m^3)

δ = Thickness of the material as tested in the FMVSS No. 302 (m)

T_0 = Reference temperature (25°C or 298.15 K)

The heat release capacity, η_c, is equal to Q_{max}/β in, where Q_{max} is the maximum value of the specific HRR, Q(t), in J/g and β is the heating rate in K/s. The temperature at which Q_{max} occurs is denoted as T_{max}. The method for estimating T_{ig} is discussed in the next subsection.

Table 10 shows which of the Task 2 materials tested in the MCC are expected to pass FMVSS No. 302. This table does not only present the results of the evaluation based on T_{ig}, but also based on another temperature, $T_{5\%}$ that corresponds to a cumulative specific heat release equal to 5 percent of the total (= area under the Q(t) curve, which is equal to h_c in J/g). This temperature is used by the FAA as a surrogate for the ignition temperature in a recently developed MCC-based methodology (Safronava & Lyon, 2022) to determine whether small changes to aircraft cabin materials (e.g., because an original component is no longer available) can have a sufficient impact on the material's fire performance such that (expensive) re-qualification will be needed. The assessment is based on the FGC in J/g·K, which is calculated as follows:

$$\mathrm{FGC} = \left(\frac{h_c}{T_{95\%} - T_{5\%}}\right)\left(\frac{T_{95\%} - T_0}{T_{5\%} - T_0}\right) \qquad [1]$$

Where $T_{95\%}$ is referred to as the burnout temperature (i.e., the temperature at which the cumulative specific heat release reaches 95% of h_c) and T_0 is the reference temperature (25°C). Selected MCC parameters (Q_{max}, T_{max}, $T_{5\%}$, $T_{95\%}$ and h_c) are shown in Figure 1, which shows a typical Q(T) curve for black poly (methyl methacrylate).

Based on the MCC data obtained in the present project and in the previous related research (Huczek et al., 2021) it was determined that $T_{ig} \approx 1.0164\ T_{5\%} - 27$, with temperature in °C. This relationship can be used to establish equivalent MCC parameters based FMVSS No. 302 pass/fail criteria for $T_{5\%}$. The corresponding lower limits when $T_{5\%}$ is used instead of T_{ig}, are 332°C and 312°C for 1.a and 1.b above. It also was determined that $\Delta T_{ig} \approx 0.9287\ \Delta T_{5\%}$, with $\Delta T_{ig} = (T_{ig} - T_0)$ and $\Delta T_{5\%} = (T_{5\%} - T_0)$. Consequently, if the physics-based criterion is used with $T_{5\%}$ instead of T_{ig}, the limiting value of $\rho\delta(T_{5\%} - T_0)$ is estimated at $85/0.9287 = 91.5$ kg×K/m^2. The equivalent criteria are given below.

1. MCC parameter-based criteria:
    a. Materials 3.2 mm or less in thickness are expected to pass FMVSS No. 302 when at least one of the following criteria is met: $\eta_c \leq 200$ J/g·K **or** $T_{5\%} \geq 332$°C.
    b. Materials that are more than 3.2 mm thick are expected to pass FMVSS No. 302 when at least one of the following, less stringent, criteria is met: $\eta_c \leq 300$ J/g·K **or** $T_{5\%} \geq 312$°C.
2. Physics-based criterion:
    a. Materials are expected to pass the FMVSS No. 302 if the following criterion is met: $\rho\delta(T_{5\%} - T_0) \geq 91.5$ kg·K/m^2.

The values in the second and third column in Table 10 are the measured density and thickness of the material described in the first column. Columns four, five, and six contain the average values for η_c, T_{ig}, and $T_{5\%}$ calculated from the results of all MCC tests. Values that do or do not meet the MCC parameter-based criteria are shaded in green or orange, respectively. Column 7 shows whether the material is expected to pass or fail the FMVSS No. 302 test based on the criteria for η_c and T_{ig} specified in 1.a and 1.b above. Column 8 shows whether the material is expected to pass or fail the FMVSS No. 302 test based on the modified MCC-based parameter criteria for $T_{5\%}$ instead of T_{ig}. The last two columns show whether the material is expected to pass or fail the FMVSS No. 302 test using the physics-based criteria for T_{ig} and $T_{5\%}$.

Table 10. FMVSS No. 302 pass/fail predictions based on MCC data for the Task 2 materials

Material Description	**ρ (kg/m^3)**	**δ (mm)**	**η_c (J/g·K)**	**T_{ig} (°C)**	**$T_{5\%}$ (°C)**	**Pass/Fail η_c & T_{ig}**	**Pass/Fail η_c & $T_{5\%}$**
Equinox Carpet	382	7.26	281	269	295	**PASS**	**PASS**
Equinox Headliner	95	9.92	162	249	268	**PASS**	**PASS**
Equinox Seat Cover	348	2.58	231	220	243	**FAIL**	**FAIL**
Equinox Seat Padding	59	10.49	516	224	252	**FAIL**	**FAIL**
Grand Caravan Carpet	139	11.75	329	343	365	**FAIL**	**FAIL**
Grand Caravan Headliner	94	9.34	215	235	258	**PASS**	**PASS**
Grand Caravan Seat Cover	95	6.00	310	249	279	**FAIL**	**FAIL**
Grand Caravan Seat Padding	62	8.02	513	254	310	**FAIL**	**FAIL**
F150 Carpet	254	11.57	162	233	263	**PASS**	**PASS**
F150 Headliner	88	12.60	254	229	250	**PASS**	**PASS**
F150 Seat Cover	114	6.38	264	220	242	**PASS**	**PASS**
F150 Seat Padding	49	10.00	408	211	239	**FAIL**	**FAIL**
Civic Carpet	127	12.01	365	399	409	**PASS**	**PASS**
Civic Headliner	93	9.68	110	228	249	**PASS**	**PASS**
Civic Seat Cover	184	2.12	289	217	237	**FAIL**	**FAIL**
Civic Seat Padding	47	12.36	586	221	249	**FAIL**	**FAIL**
Camry Carpet	340	2.50	518	397	419	**PASS**	**PASS**
Camry Headliner	111	6.90	116	257	269	**PASS**	**PASS**
Camry Seat Cover	75	6.90	271	241	268	**PASS**	**PASS**
Camry Seat Padding	40	12.40	530	221	250	**FAIL**	**FAIL**

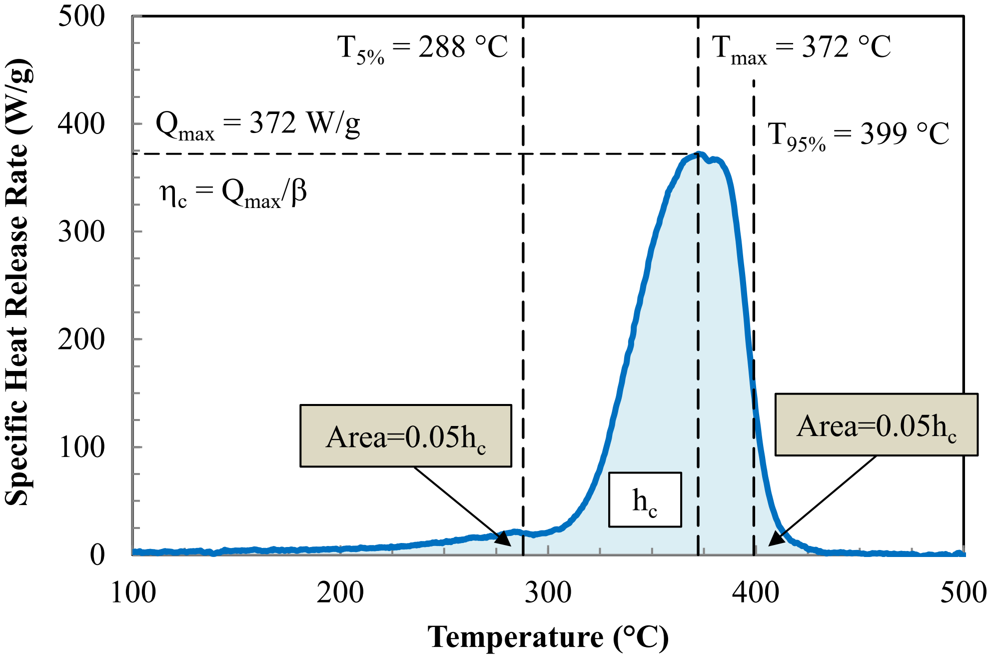

Figure 1. Q(T) curve measured in the MCC for black polymethyl methacrylate

Regardless of whether T_{ig} or $T_{5\%}$ are used, the prediction for FMVSS No. 302 performance of the material is always the same, provided the modified criteria limits are used for $T_{5\%}$.

Methods to Determine T_{ig} and MCC Sample Composition

All materials that were tested in Task 2 consist of several components that thermally degrade over different temperature ranges. Each component is associated with a peak or a shoulder (for example, Figure 2 shows that reaction 3 for Test 2 leads to a shoulder in the Q(T) curve) in the Q(T) curve. For example, Figure 2 shows that the Equinox seat cover consists of four components. Each component has different thermal degradation characteristics. The thermal degradation reaction of the first component reaches a peak at 260 to 270°C. The second component results in a small peak in the Q(T) curve at 310 to 320°C, which is barely noticeable for two of the three MCC tests. The thermal degradation reactions of the third and fourth component reach a peak at approximately 400 and 440°C, respectively.

Figure 2 illustrates that there were some differences in the composition of the Equinox seat cover samples that were tested in the MCC. The Q(T) curves for the second and third test are very close, which implies that the composition of the samples used in these tests was nearly identical. The Q(T) curve for the first test shows higher peaks for the first three reactions and a lower peak for the fourth reaction, which shows that the composition of the sample used in the first test was significantly different compared to the samples used in the second and third test. Consequently, the repeatability of the MCC tests is not only affected by random variations in the measurements but also by random variations in sample composition. To alleviate this, a method was developed to characterize the composition of each sample in a series of repeat tests and estimate the kinetic reaction rate parameters for a sample with "average" composition.

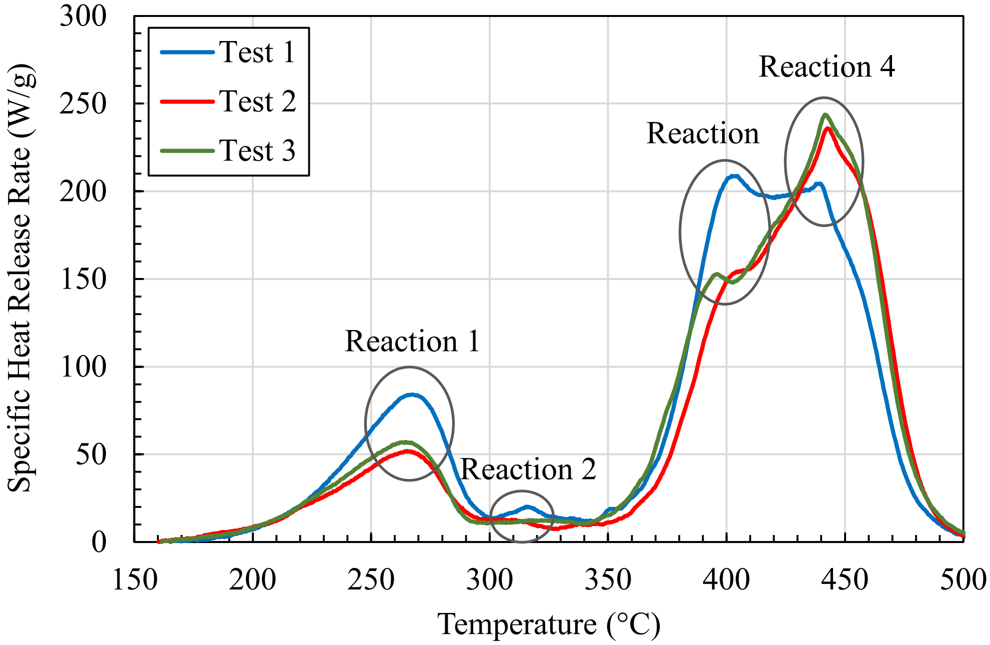

Figure 2. Peak thermal degradation rates for components of the Equinox seat cover

The method assumes that the rate of conversion from a solid to a gaseous fuel is a single step thermal decomposition process that can be described by the following Arrhenius reaction rate model.

$$\frac{d\alpha}{dt} = (1-\alpha)^{n} A \exp\left(\frac{E}{RT}\right) \qquad [2]$$

where α is the conversion or degree of advancement of the reaction (varies between 0 and 1), t is time in seconds, n is the reaction order, A is the frequency factor (s^{-1}), E is the activation energy (J/mol), R is the universal gas constant (8.314 J/mol·K), and T is temperature in K. Assuming a constant heat of combustion, which is consistent with the assumption of a single step thermal degradation reaction, α can be expressed as follows.

$$\alpha(t) \equiv \frac{\int_0^t Q(\tau)d\tau}{h_c} = \frac{Q_{cumul}(t)}{h_c} \qquad [3]$$

where $Q_{cumul}(t)$ is the cumulative specific HRR at time t in J/g. Note that, because the heating rate β is constant (~1 K/s for all MCC tests performed in the present study), Q(t) is of similar shape as Q(T) but slightly compressed or stretched depending on whether β is slightly larger or smaller than 1 K/s.

With this assumption the Q(t) curves for a MCC test sample with several overlapping reactions (such as the Q(t) curve for the Equinox seat cover) can be modeled by combining the Arrhenius reaction models (Equation 3) for all contributors (components) to the thermal degradation of the material as shown in Equation 4.

$$\mathrm{Q(t)} = \mathrm{h_c}\frac{\mathrm{d}\alpha}{\mathrm{dt}} = \mathrm{h_c}\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{c_i}\frac{\mathrm{d}\alpha_{\mathrm{i}}}{\mathrm{dt}} = \mathrm{h_c}\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{c_i}\,(1-\alpha_{\mathrm{i}})^{\,\mathrm{n_i}}\mathrm{A_i}\exp\left(\frac{\mathrm{E_i}}{\mathrm{RT}}\right) \qquad [4]$$

where c_i is a weighting factor equal to the contribution of reaction i (or component i) to the total heat release (h_c). It is important to note that, in this study, the "composition" of the sample is defined in terms of the contribution of each component to h_c and not in terms of the mass fractions of the components. Because the weighting factors must add up to one, a model that involves N reactions requires that 4N -1 parameters must be estimated.

The method was implemented in two steps. Each step involves the use of a set of Microsoft Excel VBA macro workbooks. The first set of macro workbooks is used to estimate the Arrhenius model parameters (c_i, n_i, A_i and E_i for i = 1…N) for each MCC sample that was tested by fitting Equation 4 to the Q(t) curve measured in the test. The second set of macro workbooks is used to estimate the kinetic reaction rate parameters (n_i, A_i and E_i for i = 1…N) for a sample with "average" composition, i.e., with c_i equal to the average of the c values for reaction i obtained with the first set of macro workbooks for each of the MCC tests conducted on a sample of the material. Based on the available data, the "average" composition is the best estimate of the material's actual composition. Both sets of workbooks use the GRG (generalized reduced gradient) method in Excel Solver to estimate the model parameters, although a genetic algorithm can also be used. The single peak property method (Lyon & Safronava, 2013) is used to obtain initial estimates of the kinetic parameters for each reaction.

Once the Arrhenius model parameters have been estimated, the kinetic parameters for the first reaction (the decomposition reaction that starts at the lowest temperature and can generate flammable volatiles at a sufficient rate for ignition) can be used to estimate the ignition temperature, T_{ig}. Because α_1 is very small at ignition (typically a few percent based on the calculations presented in Appendix G), neglecting α_{ig} results in conservative (low) estimates for T_{ig}. Equation 2 at ignition can therefore be simplified to

$$\mathrm{c_1 h_c}\left(\frac{\mathrm{d}\alpha_1}{\mathrm{dt}}\right)_{\mathrm{ig}} \equiv \mathrm{Q}^* \text{ » } \mathrm{c_1 h_c A_1}\exp\left(\frac{\mathrm{E_1}}{\mathrm{RT_{ig}}}\right) \qquad [5]$$

where Q* is the specific HRR at ignition. Equation 5 can then be rearranged to express T_{ig} as a function of A_1 and E_1.

$$\mathrm{T_{ig}}\text{»}\ \frac{\mathrm{E_1}}{\mathrm{R}\ln\left(\frac{\mathrm{A_1\,h_c}}{\mathrm{Q}^*}\right)} \qquad [6]$$

Lyon and Safronava (2013) calculated Q* for a typical polymer and obtained a value of 20 W/g corresponding to sustained ignition in the cone calorimeter. They tested specimens of 16 polymers in the cone calorimeter and obtained reasonable agreement between measured or inferred (from the critical heat flux) surface temperatures at sustained piloted ignition and those calculated from Equation 5. A value of 20 W/g for Q* is used to estimate T_{ig} in the present study.

Figures 3 to 5 show the contributions of the four components to the Q(T) curve for MCC tests 1 to 3 on the Equinox seat cover. Figure 6 shows the principal results of the second macro workbook calculations for the Equinox seat cover.

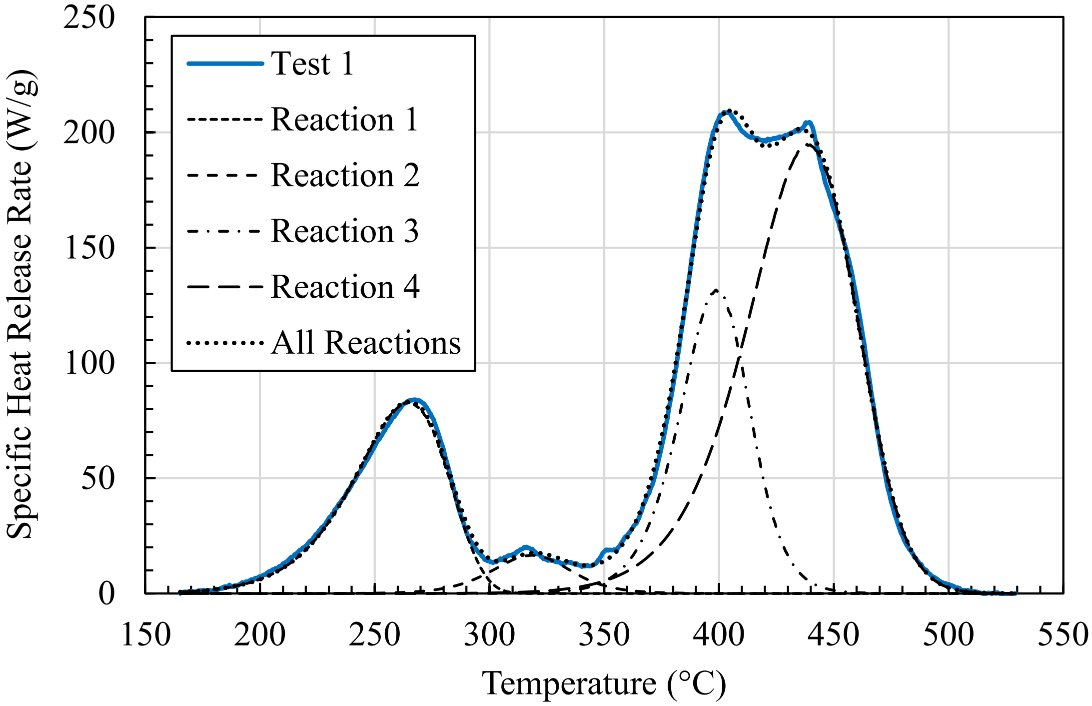

Figure 3. Component contributions to the Q(T) curve for Test 1 on the Equinox seat cover

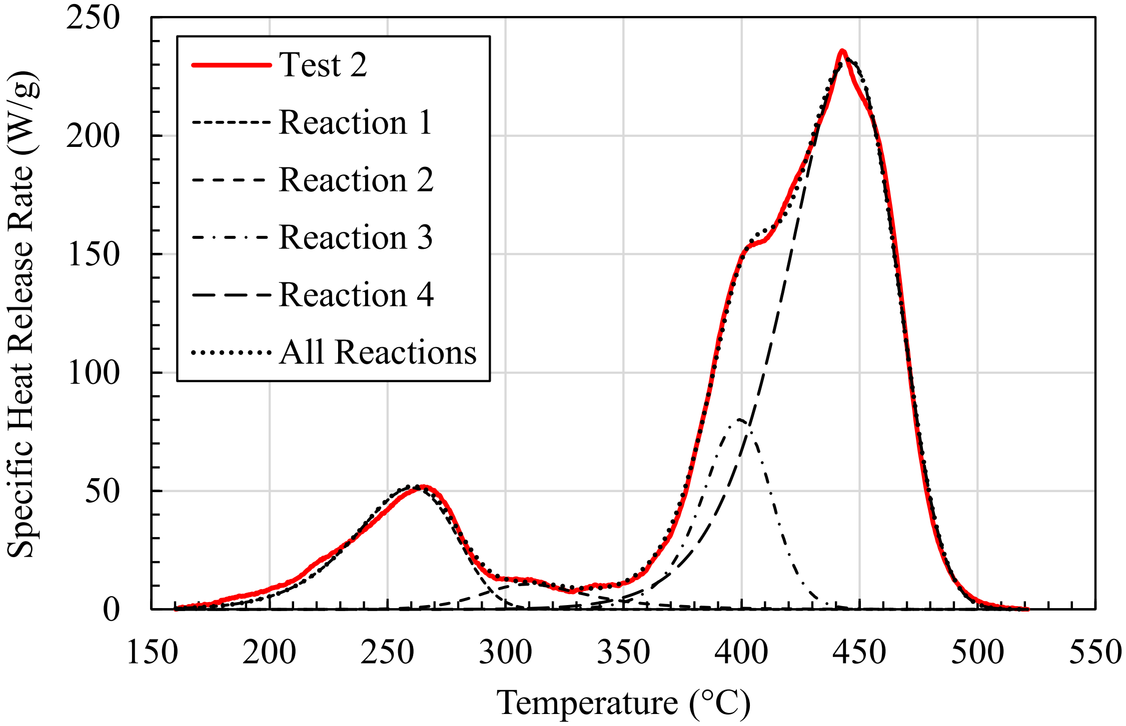

Figure 4. Component contributions to the Q(T) curve for Test 2 on the Equinox seat cover

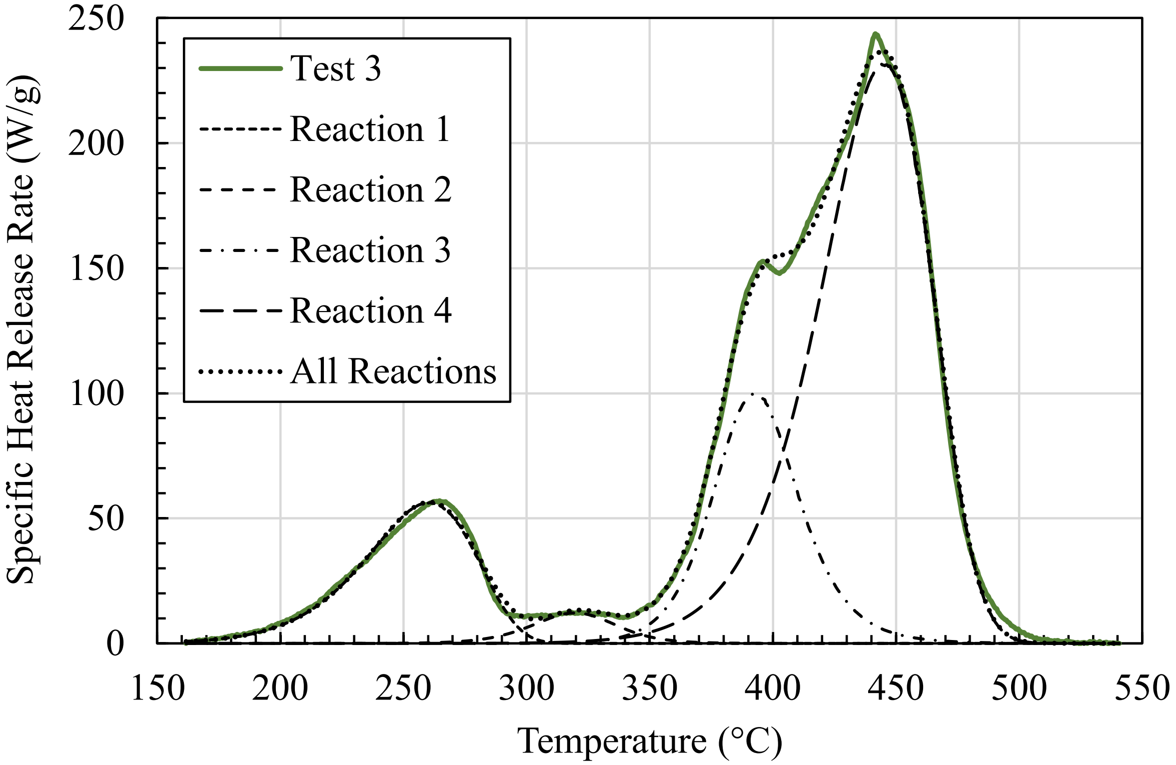

Figure 5. Component contributions to the Q(T) curve for Test 3 on the Equinox seat cover

Chevy Equinox Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.00	3.07	3.03				3.03	0.035
m_f (mg)	0.11	0.16	0.12				0.13	0.026
η_c (J/g·K)	210	237	246				231	18.8
Q_{max} (W/g)	209	236	244				229	18.4
T_{max} (°C)	402	443	442				429	23.0
h_c (kJ/g)	22.7	21.0	22.3				22.0	0.90
Y_p (g/g)	0.037	0.052	0.040				0.04	0.008
$h_{c,gas}$ (kJ/g)	23.6	22.1	23.2				23.0	0.75

	c_1	c_2	c_3	c_4
Test 1	0.192	0.030	0.310	0.467
Test 2	0.140	0.027	0.351	0.481
Test 3	0.141	0.025	0.336	0.498
Test 4				
Test 5				
Test 6				
Average	0.158	0.027	0.333	0.482
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	220	243	464	0.993
Test 2	221	243	470	0.994
Test 3	220	244	469	0.989
Test 4				
Test 5				
Test 6				
Average	220	243	468	0.992

	R1	R2	R3	R4
A (1/s)	9.91E+08	1.99E+16	2.04E+20	9.20E+16
E (kJ/mol)	106	198	277	251
n	1.00	1.44	2.19	1.34

Physical Properties	
ρ (kg/m^3)	348
δ (mm)	2.58

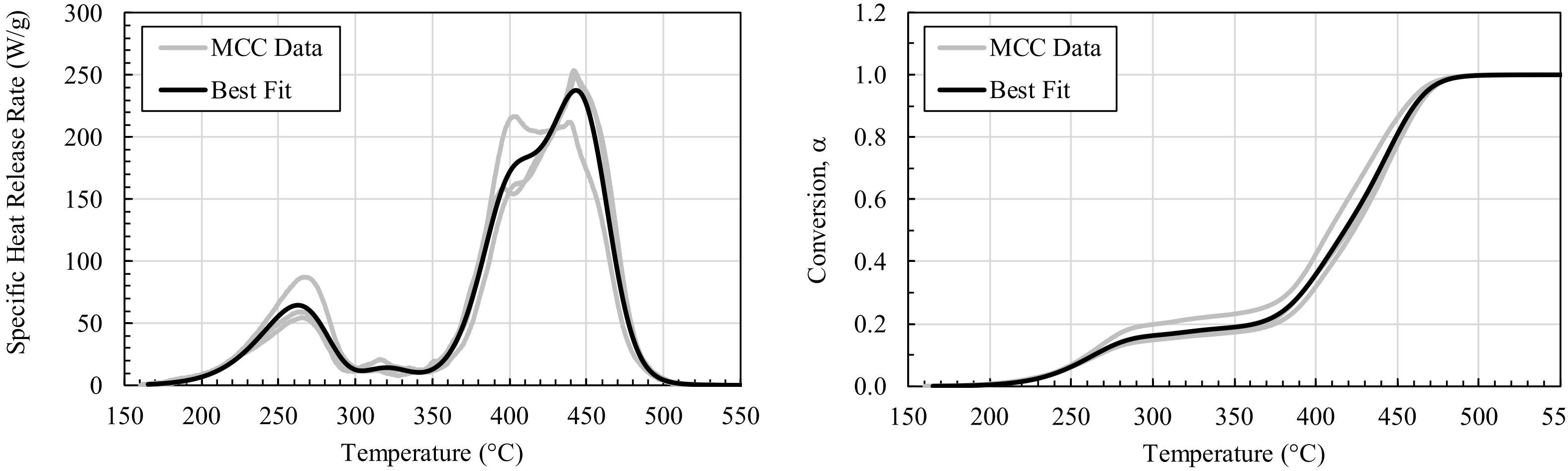

Figure 6. Principal results of the second macro workbook for the Equinox seat cover

Table 11 shows the mean values and standard deviations of c_i for the Task 2 materials. Detailed results of the Arrhenius model parameter calculations are in Appendix G.

Table 11. Mean values and standard deviations of c_i for the Task 2 materials

Material Description	**N**	**c_1**		**c_2**		**c_3**		**c_4**	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
Equinox Carpet	4	0.213	0.047	0.153	0.036	0.275	0.038	0.359	0.050
Equinox Headliner	4	0.197	0.017	0.036	0.001	0.436	0.035	0.331	0.048
Equinox Seat Cover	4	0.158	0.030	0.027	0.003	0.333	0.021	0.482	0.015
Equinox Seat Padding	3	0.152	0.030	0.041	0.003	0.807	0.029		
Grand Caravan Carpet	3	0.359	0.021	0.223	0.149	0.418	0.146		
Grand Caravan Headliner	4	0.122	0.009	0.040	0.001	0.266	0.010	0.572	0.018
Grand Caravan Seat Cover	3	0.061	0.007	0.144	0.018	0.795	0.015		
Grand Caravan Seat Padding	3	0.021	0.005	0.173	0.004	0.806	0.007		
F150 Carpet	4	0.055	0.019	0.146	0.079	0.554	0.065	0.245	0.161
F150 Headliner	4	0.152	0.034	0.034	0.004	0.432	0.121	0.382	0.150
F150 Seat Cover	4	0.132	0.026	0.071	0.014	0.384	0.038	0.412	0.049
F150 Seat Padding	3	0.162	0.022	0.070	0.014	0.769	0.008		
Civic Carpet	2	0.483	0.070	0.514	0.075				
Civic Headliner	4	0.304	0.059	0.140	0.095	0.321	0.184	0.235	0.205
Civic Seat Cover	4	0.296	0.025	0.069	0.005	0.508	0.056	0.126	0.064
Civic Seat Padding	3	0.178	0.003	0.043	0.009	0.779	0.008		
Camry Carpet	2	0.351	0.649	0.074	0.074				
Camry Headliner	3	0.298	0.053	0.603	0.096	0.099	0.047		
Camry Seat Cover	4	0.083	0.012	0.027	0.008	0.345	0.042	0.546	0.049
Camry Seat Padding	3	0.124	0.017	0.117	0.020	0.759	0.007		

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Task 3: MCC Repeatability Tests

The following subsections give details on material selection, the test matrix, test results, and analysis of the tests conducted for Task 3.

Task 3: Material Selection and Test Matrix

This task evaluated the repeatability of flammability performance of various single and multilayered materials using the MCC AM test method and performance criteria. Five FMVSS No. 302 tests and six repeat MCC tests (ASTM D7309 Method A) were performed on specimens from the five vehicle components listed in Tables 12 to 14. The materials in Table 14 were included to provide some information on the effect molding the carpet material could have on repeatability and test performance.

In addition, Task 3 required that three additional MCC tests be conducted on (at least) four Task 2 materials with the most variable FMVSS No. 302 results. Two methods were used to quantify the variability (standard deviation) of the FMVSS No. 302 burn rates.

1. Method 1 uses the standard deviation of all tests for which a burn rate is calculated and ignores materials that pass the FMVSS No. 302 test because of one of the following.
    a. The flame never reached the first mark.
    b. The flame extinguished within 60 seconds but did not propagate more than 51 mm beyond the first mark.
2. For case 1.a, Method 2 assigns a burn rate equal to 0 mm/min. For case 1.b, the burn rate in Method 2 is the extent of flame spread beyond the first mark divided by the time for the flame to travel this distance.

The results of the Task 2 FMVSS No. 302 burn rate variability calculations are given in Tables 15 to 18 for the carpet, headliner, seat cover, and seat padding materials. The variability is quantified by the estimate of the standard deviation. Six Task 2 materials were identified for additional testing in Task 3 as follows. The Honda Civic carpet and Chevy Equinox seat cover were selected based on Method 1 (cells shaded in orange on the left side of Tables 15 and 17). The Honda Civic and Toyota Camry seat covers were selected based on Method 2 (cells shaded in green on the right side of Table 17). Finally, both methods identified the Ford F150 and Toyota Camry seat padding materials (cells shaded on both sides of Table 18).

Table 12. Task 3 test parts – 2020 Dodge Grand Caravan

2020 Dodge Grand Caravan	www.factorychryslerparts.com
Component	**Part No.**
Sun Visor	1JE88DX9AA

Table 13. Task 3 test parts – 2020 Chevy Malibu

2020 Chevy Malibu	https://gmpartsnow.com
Component	**Part No.**
Door Trim Panel	84470240
Instrument Panel	84474275

Table 14. Task 3 test parts – 2015-2019 Honda Civic (aftermarket)

2015-2019 Honda Civic (aftermarket)	www.stockinteriors.com
Component	**Part No.**
Honda Civic Molded Carpet	23863
Extra Carpet by the Yard	4264

Table 15. FMVSS No. 302 burn rate variability calculations for Task 2 carpets

	Method 1: Carpet burn rates (mm/min)					**Method 2: Carpet burn rates (mm/min)**				
	Equinox	Caravan	F150	Civic	Camry	Equinox	Caravan	F150	Civic	Camry
Run 1	NA	41	22	34	38	0	41	22	34	38
Run 2	NA	53	27	22	42	0	53	27	22	42
Run 3	NA	36	27	46	45	0	36	27	46	45
Run 4	NA	49	22	26	29	0	49	22	26	29
Run 5	NA	47	16	39	39	0	47	16	39	39
Mean	NA	45	23	33	38	0	45	23	33	38
St dev	NA	7	5	10	6	0	7	5	10	6
	Identifies four most variable results					Identifies four most variable results				

Table 16. FMVSS No. 302 burn rate variability calculations for Task 2 headliners

	Method 1: Headliner burn rates (mm/min)					**Method 2: Headliner burn rates (mm/min)**				
	Equinox	Caravan	F150	Civic	Camry	Equinox	Caravan	F150	Civic	Camry
Run 1	17	18	NA	NA	24	17	18	0	0	24
Run 2	17	19	NA	NA	26	17	19	0	0	26
Run 3	NA	19	NA	24	28	0	19	0	24	28
Run 4	15	16	NA	NA	25	15	16	0	0	25
Run 5	20	16	NA	14	24	20	16	0	14	24
Mean	17	17	NA	19	26	14	17	0	8	26
St dev	2	2	NA	7	2	8	2	0	11	2
	Identifies four most variable results					Identifies four most variable results				

Table 17. FMVSS No. 302 burn rate variability calculations for Task 2 seat covers

	Method 1: Seat cover burn rates (mm/min)					**Method 2: Seat cover burn rates (mm/min)**				
	Equinox	Caravan	F150	Civic	Camry	Equinox	Caravan	F150	Civic	Camry
Run 1	12	NA	36	55	57	12	45	36	55	57
Run 2	NA	25	NA	NA	69	0	56	73	0	69
Run 3	41	23	44	NA	62	41	0	44	0	62

Run 4	13	30	NA	NA	NA	13	30	44	0	0
Run 5	46	32	NA	NA	NA	46	54	37	0	17
Mean	28	28	40	55	63	22	37	47	11	41
St dev	**18**	4	6	NA	6	20	23	15	**25**	**30**
	Identifies four most variable results					Identifies four most variable results				

Table 18. FMVSS No. 302 burn rate variability calculations for Task 2 seat padding materials

	Method 1: Seat padding burn rates (mm/min)					**Method 2: Seat padding burn rates (mm/min)**				
	Equinox	Caravan	F150	Civic	Camry	Equinox	Caravan	F150	Civic	Camry
Run 1	NA	NA	NA	NA	39	0	0	0	0	39
Run 2	NA	NA	43	NA	NA	0	0	43	0	0
Run 3	NA	NA	NA	NA	NA	0	0	0	0	0
Run 4	NA	NA	NA	NA	NA	0	0	0	0	0
Run 5	NA	NA	60	NA	52	0	53	60	0	52
Mean	NA	NA	52	NA	45	0	11	21	0	18
St dev	NA	NA	**12**	NA	**9**	0	23	**29**	0	**25**
	Identifies four most variable results					Identifies four most variable results				

Table 19. Task 3 test matrix

Vehicle	**Component**	**Part No.**	**MCC Replicates**	**FMVSS No. 302 Replicates**
Task 2.2 Repeat Tests	Chevy Equinox Seat Cover	84555793	3	NA
	Ford F150 Seat Padding	1663841	3	NA
	Honda Civic Carpet	83301-7GG-A11ZA	3	NA
	Honda Civic Seat Cover	82131-TGG-A31ZB	3	NA
	Toyota Camry Seat Cover	7107506K90B0	3	NA
	Toyota Camry Seat Padding	7150306270	3	NA
2020 Dodge Grand Caravan	Padding/Cover Combination	05170728AC	3	5
	Sun Visor	1JE88DX9AA	5	5
2020 Chevrolet Malibu	Door Trim Panel	84470240	6	5
	Instrument Panel	84474275	6	5
2015-2019 Honda Civic (aftermarket)	Extra Carpet by the Yard	4264	6	5

	Honda Civic Molded Carpet	23863	6	5

Table 19 shows the summary test matrix for Task 3. The test matrix included MCC and FMVSS No. 302 tests on a combination of the Dodge Grand Caravan seat padding and seat cover materials tested separately in Task 2.

Task 3: Test Results

Table 20 shows average burn rate results for the five replicate FMVSS No. 302 tests performed on each of the Task 3 materials. Table 21 shows summary MCC results for the first three tests on the Task 3 materials. Table 22 shows summary MCC results for all six tests on specimens of the same materials, except for the Grand Caravan seat cover/seat padding combination, for which only three replicate MCC tests were performed.

Complete results of all replicate FMVSS No. 302 testing are in Appendix C and all replicate MCC test results are in Appendix D.

Table 20. Task 3 FMVSS No. 302 average test results (not including Task 2 materials)

Vehicle	Material	Burn Rate (mm/min)	Pass/Fail
Grand Caravan	Seat Padding and Cover	28	Pass
	Sun Visor	39	Pass
Chevrolet Malibu	Door Trim Panel	45	Pass
	Instrument Panel	28	Pass
Honda Civic	Civic 2015-2019 Extra Carpet by the Yard	30	Pass
	Civic 2015-2019 Molded Carpet	36	Pass

Table 21. Average MCC results for tests 1-3 on Task 3 materials

Material Description	m_i	m_f	η_c	Q_{max}	T_{max}	h_c	Y_p	$h_{c,gas}$
	(mg)	(mg)	(J/g·K)	(W/g)	(°C)	(kJ/g)	(g/g)	(kJ/g)
Equinox Seat Cover	3.03	0.13	231	229	429	22.0	0.043	23.0
F150 Seat Padding	3.04	0.19	408	404	404	26.0	0.062	27.7
Civic Carpet	4.08	0.50	365	360	448	18.2	0.122	20.8
Civic Seat Cover	3.02	0.29	289	286	364	21.6	0.097	23.9
Camry Seat Cover	4.07	0.24	271	269	429	22.8	0.059	24.2
Camry Seat Padding	4.07	0.24	530	525	404	28.2	0.059	30.0
Caravan Cover/Padding	4.00	0.32	379	374	400	23.7	0.080	25.8
Caravan Sun Visor Foam	4.05	0.26	215	213	406	20.5	0.063	21.9
Caravan Sun Visor Plastic	4.04	0.00	1116	1107	469	42.9	0.000	42.9
Malibu Door Trim Panel	4.07	0.55	1012	1004	477	36.1	0.134	41.7
Malibu Instrument Panel	4.01	0.75	946	936	475	34.2	0.188	42.1
Aftermarket Carpet BTY	4.03	0.02	427	422	459	32.0	0.006	32.2
Aftermarket Molded Carpet	4.05	0.01	465	460	481	34.7	0.002	34.7

Table 22. Average MCC results for tests 1-6 on Task 3 materials

Material Description	m_i	m_f	η_c	Q_{max}	T_{max}	h_c	Y_p	$h_{c,gas}$
	(mg)	**(mg)**	**(J/g·K)**	**(W/g)**	**(°C)**	**(kJ/g)**	**(g/g)**	**(kJ/g)**
Equinox Seat Cover	3.03	0.12	233	231	428	22.6	0.040	23.6
F150 Seat Padding	3.05	0.14	408	403	406	26.3	0.046	27.5
Civic Carpet	4.07	0.46	370	366	449	19.5	0.112	21.9
Civic Seat Cover	3.53	0.25	300	296	364	21.0	0.074	22.7
Camry Seat Cover	4.06	0.22	273	272	423	22.6	0.055	23.9
Camry Seat Padding	4.06	0.15	511	506	402	27.7	0.037	28.8
Caravan Visor Foam	4.05	0.24	220	219	407	20.7	0.059	22.0
Caravan Visor Plastic	4.05	0.01	1128	1119	471	43.1	0.001	43.2
Malibu Door Trim Panel	4.05	0.55	1031	1022	479	36.3	0.135	41.9
Malibu Instrument Panel	4.03	0.77	938	927	476	34.0	0.190	42.0
Aftermarket Carpet BTY	4.04	0.02	403	399	459	31.4	0.005	31.6
Aftermarket Molded Carpet	4.05	0.00	475	470	480	34.3	0.001	34.3

Task 3: Data Analysis

Tables 23 and 24 shows the FMVSS No. 302 pass/fail predictions based on the MCC data obtained for the Task 3 materials in the first three tests versus pass/fail predictions based on the MCC data obtained in all six tests. The differences between the average values of η_c, T_{ig}, and $T_{5\%}$ for three versus six MCC tests are small as shown in Figures 7 to 9. Consequently, using MCC results from six versus three tests to determine the averages of η_c, T_{ig}, and $T_{5\%}$ does not change any of the FMVSS No. 302 pass/fail predictions.

Table 23. FMVSS No. 302 pass/fail predictions for three MCC tests on the Task 3 materials

Material Description	**ρ (kg/m^3)**	**δ (mm)**	**η_c (J/g·K)**	**T_{ig} (°C)**	**$T_{5\%}$ (°C)**	**P/F η_c & T_{ig}**	**P/F η_c & $T_{5\%}$**	**$\rho\delta\Delta T_{ig}$ (kg·K/m²)**	**$\rho\delta\Delta T_{5\%}$ (kg·K/m²)**
Equinox Seat Cover	348	2.58	231	220	243	FAIL	FAIL	**175**	**196**
F150 Seat Padding	49	10.0	408	208	236	FAIL	FAIL	**165**	**190**
Civic Carpet	127	12.0	365	398	409	**PASS**	**PASS**	**335**	**345**
Civic Seat Cover	184	2.12	289	217	237	FAIL	FAIL	**173**	**191**
Camry Seat Cover	75	6.90	271	241	266	**PASS**	**PASS**	**194**	**216**
Camry Seat Padding	40	12.4	530	225	253	FAIL	FAIL	**179**	**205**
Grand Caravan Visor Foam	67	2.77	215	235	258	FAIL	FAIL	**188**	**209**
Grand Caravan Visor Plastic	881	1.86	1116	403	427	**PASS**	**PASS**	**340**	**361**
Malibu Door Trim Panel	912	2.40	1012	416	439	**PASS**	**PASS**	**351**	**372**
Malibu Instrument Panel	999	3.00	946	413	437	**PASS**	**PASS**	**349**	**370**
Aftermarket Carpet BTY	334	2.90	427	381	402	**PASS**	**PASS**	**320**	**338**
Aftermarket Molded Carpet	270	3.40	465	379	400	**PASS**	**PASS**	**318**	**337**

Table 24. FMVSS No. 302 pass/fail predictions for six MCC tests on the Task 3 materials

Material Description	**ρ (kg/m^3)**	**δ (mm)**	**η_c (J/g·K)**	**T_{ig} (°C)**	**$T_{5\%}$ (°C)**	**P/F η_c & T_{ig}**	**P/F η_c & $T_{5\%}$**	**$\rho\delta\Delta T_{ig}$ (kg·K/m²)**	**$\rho\delta\Delta T_{5\%}$ (kg·K/m²)**
Equinox Seat Cover	348	2.58	233	220	243	FAIL	FAIL	**175**	**196**
F150 Seat Padding	49	10.0	408	211	239	FAIL	FAIL	**167**	**192**
Civic Carpet	127	12.0	370	399	409	**PASS**	**PASS**	**336**	**345**
Civic Seat Cover	184	2.12	300	217	237	FAIL	FAIL	**172**	**190**
Camry Seat Cover	75	6.90	273	241	268	**PASS**	**PASS**	**194**	**218**
Camry Seat Padding	40	12.4	511	221	250	FAIL	FAIL	**176**	**202**
Grand Caravan Visor Foam	67	2.77	220	237	261	FAIL	FAIL	**191**	**212**
Grand Caravan Visor Plastic	881	1.86	1128	406	430	**PASS**	**PASS**	**342**	**363**
Malibu Door Trim Panel	912	2.40	1031	419	442	**PASS**	**PASS**	**354**	**374**
Malibu Instrument Panel	999	3.00	938	414	435	**PASS**	**PASS**	**349**	**368**
Aftermarket Carpet BTY	334	2.90	403	380	401	**PASS**	**PASS**	**319**	**337**
Aftermarket Molded Carpet	270	3.40	475	380	402	**PASS**	**PASS**	**319**	**338**

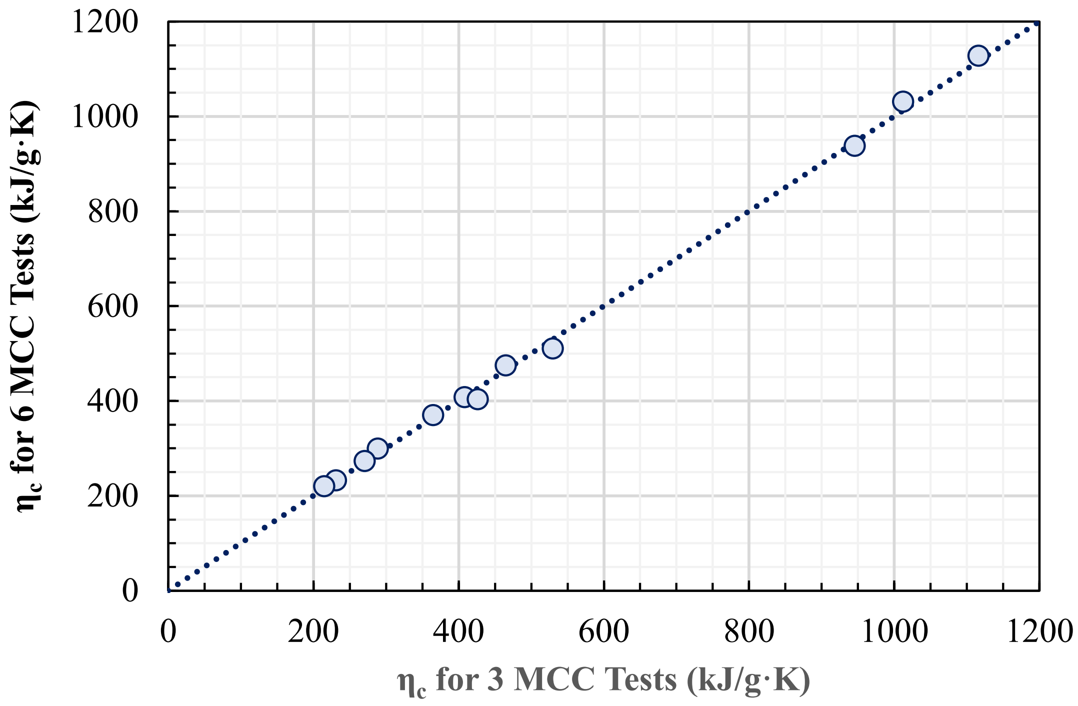

Figure 7. Effect of the number of replicate MCC tests on average η_c

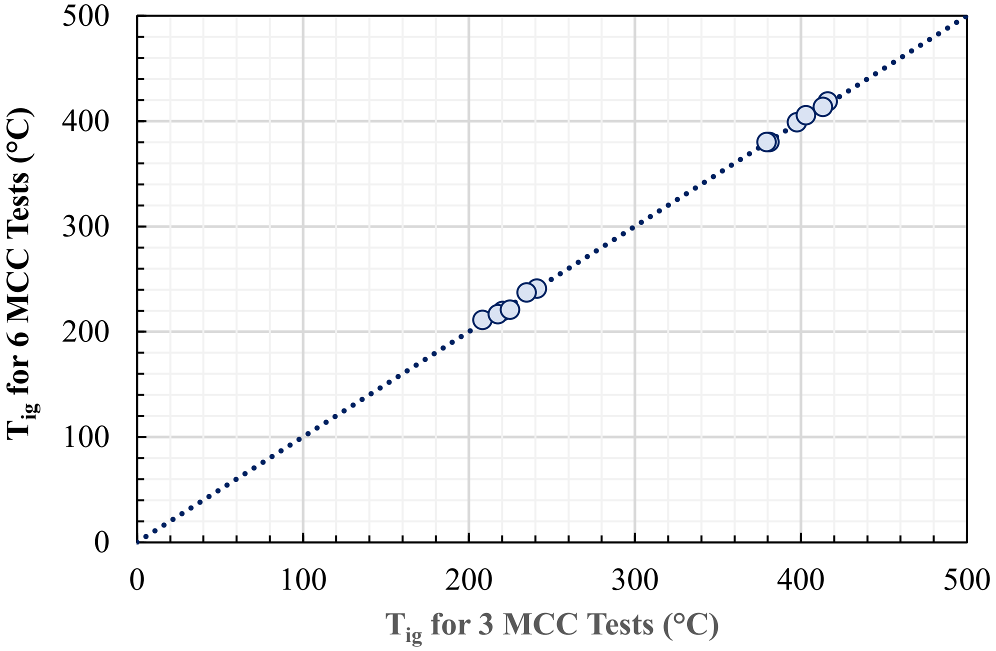

Figure 8. Effect of number of replicate MCC tests on average T_{ig}

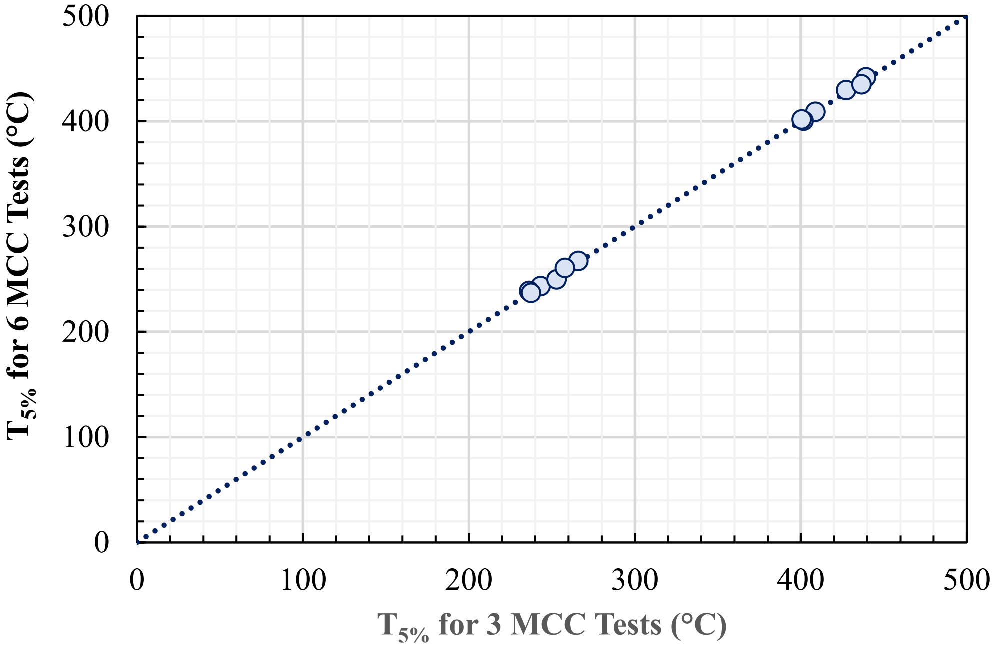

Figure 9. Effect of number of replicate MCC tests on average $T_{5\%}$

Table 25 and Figure 10 show that the number of replicate MCC tests does have a noticeable effect on the c_i estimates (see Appendix H for detailed results of the Arrhenius model parameter calculations). Presumably, the c_i values estimated based on data from six tests are a better estimate of the "true" composition compared to the c_i values based on three MCC tests. A possible approach to eliminate the effect of a rare outlier on the prediction of pass or fail in the

FMVSS No. 302 test involves running five replicate MCC tests and removing the lowest and highest values before calculating the average η_c, T_{ig}, and $T_{5\%}$.

Finally, it is clear from Tables 23 and 24 that the aftermarket Civic carpets (the molded version in particular) are somewhat more flammable (higher η_c and lower T_{ig} and $T_{5\%}$) than the OEM material. However, the effect is too small for it to cause a difference in the FMVSS No. 302 burn rate: 30 to 36 mm/min for the aftermarket materials (see Table 20) compared to 33 mm/min for the OEM material (see Table 8).

Table 25. Mean c_i values for the Task 3 materials based on data for 3 and 6 MCC tests

Material Description	**N**	**c_1**		**c_2**		**c_3**		**c_4**	
		3 Runs	**6 Runs**	**3 Runs**	**6 Runs**	**3 Runs**	**6 Runs**	**3 Runs**	**6 Runs**
Equinox Seat Cover	4	0.158	0.166	0.027	0.028	0.333	0.350	0.482	0.457
F150 Seat Padding	3	0.162	0.151	0.070	0.085	0.769	0.764		
Civic Carpet	2	0.483	0.420	0.514	0.579				
Civic Seat Cover	4	0.296	0.263	0.069	0.055	0.508	0.479	0.126	0.203
Camry Seat Cover	4	0.083	0.084	0.027	0.024	0.345	0.324	0.546	0.568
Camry Seat Padding	3	0.124	0.129	0.117	0.102	0.759	0.766		
Caravan Visor Foam	4	0.122	0.114	0.040	0.037	0.266	0.251	0.572	0.598
Caravan Visor Plastic	1	1.000	1.000						
Malibu Door Trim Panel	1	1.000	1.000						
Malibu Instrument Panel	1	1.000	1.000						
Aftermarket Carpet BTY	2	0.381	0.451	0.619	0.549				
Aftermarket Molded Carpet	3	0.315	0.297	0.103	0.081	0.582	0.622		

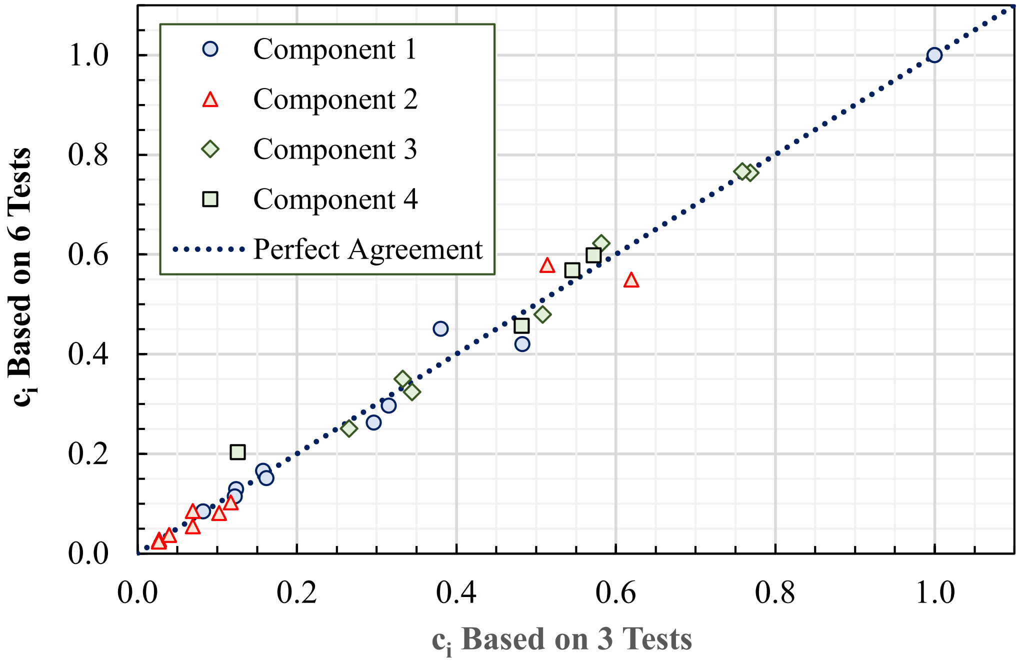

Figure 10. Effect of number of replicate MCC tests on c_i estimates

Task 4: MLC (ASTM E2102) Tests on Subset of Materials From Task 2

The following subsections give details on material selection, the test matrix, test results, and analysis of the tests conducted in Task 4.

Task 4: Material Selection and Test Matrix

For Task 4, MLC tests were performed according to ASTM E2102 on a subset of the Task 2 materials. Specifically, duplicate MLC tests were performed at three heat flux levels (25, 35, and 50 kW/m^2) on the two carpet, headliner, seat cover, and seat padding materials with the highest FMVSS No. 302 burn rate variabilities. The variabilities were based on the sum of the standard deviations calculated according to the two methods used to select Task 2 materials for additional testing in Task 3. The materials selected for Task 4 testing are shown in Tables 26 to 29 in red print.

Table 26. FMVSS No. 302 burn rate variability calculations to identify Task 4 carpets

	Method 1: Carpet burn rates (mm/min)					Method 2: Carpet burn rates (mm/min)				
	Equinox	**Caravan**	F150	**Civic**	Camry	Equinox	**Caravan**	F150	**Civic**	Camry
Run 1	NA	41	22	34	38	0	41	22	34	38
Run 2	NA	53	27	22	42	0	53	27	22	42
Run 3	NA	36	27	46	45	0	36	27	46	45
Run 4	NA	49	22	26	29	0	49	22	26	29
Run 5	NA	47	16	39	39	0	47	16	39	39
Mean	NA	45	23	33	38	0	45	23	33	38
St dev	NA	**7**	5	**10**	6	0	**7**	5	**10**	6

Table 27. FMVSS No. 302 burn rate variability calculations to identify Task 4 headliners

	Method 1: Headliner burn rates (mm/min)					Method 2: Headliner burn rates (mm/min)				
	Equinox	Caravan	F150	**Civic**	Camry	**Equinox**	Caravan	F150	**Civic**	Camry
Run 1	17	18	NA	NA	24	17	18	0	0	24
Run 2	17	19	NA	NA	26	17	19	0	0	26
Run 3	NA	19	NA	24	28	0	19	0	24	28
Run 4	15	16	NA	NA	25	15	16	0	0	25
Run 5	20	16	NA	14	24	20	16	0	14	24
Mean	17	17	NA	19	26	14	17	0	8	26
St dev	2	2	NA	**7**	2	8	2	0	**11**	2

Table 28. FMVSS No. 302 burn rate variability calculations to identify Task 4 seat covers

	Method 1: Seat cover burn rates (mm/min)					**Method 2: Seat cover burn rates (mm/min)**				
	Equinox	Caravan	F150	Civic	**Camry**	**Equinox**	Caravan	F150	Civic	**Camry**
Run 1	12	NA	36	55	57	12	45	36	55	57
Run 2	NA	25	NA	NA	69	0	56	73	0	69
Run 3	41	23	44	NA	62	41	0	44	0	62
Run 4	13	30	NA	NA	NA	13	30	44	0	0
Run 5	46	32	NA	NA	NA	46	54	37	0	17
Mean	28	28	40	55	63	22	37	47	11	41
St dev	**18**	4	6	NA	**6**	**20**	23	15	25	**30**

Table 29. FMVSS No. 302 burn rate variability calculations to identify Task 4 seat padding materials

	Method 1: Seat padding burn rates (mm/min)					**Method 2: Seat padding burn rates (mm/min)**				
	Equinox	Caravan	**F150**	Civic	**Camry**	Equinox	Caravan	**F150**	Civic	**Camry**
Run 1	NA	NA	NA	NA	39	0	0	0	0	39
Run 2	NA	NA	43	NA	NA	0	0	43	0	0
Run 3	NA	NA	NA	NA	NA	0	0	0	0	0
Run 4	NA	NA	NA	NA	NA	0	0	0	0	0
Run 5	NA	NA	60	NA	52	0	53	60	0	52
Mean	NA	NA	52	NA	45	0	11	21	0	18
St dev	NA	NA	**12**	NA	**9**	0	23	**29**	0	**25**

Table 30. Task 4 MLC test matrix

Component	**MLC Test Run Replicates at Each Heat Flux Exposure Level**		
	25 kW/m^2	**35 kW/m^2**	**50 kW/m^2**
Caravan Carpet	2	2	2
Civic Carpet	2	2	2
Equinox Headliner	2	2	2
Civic Headliner	2	2	2
Equinox Seat Cover	2	2	2
Camry Seat Cover	2	2	2
F150 Seat Padding	2	2	2
Camry Seat Padding	2	2	2

The MLC data were analyzed to determine if it is possible to correlate MLC performance to MCC performance and whether the MLC could be used as another alternative test method for evaluating flammability of interior vehicle materials. Table 30 shows the summary test matrix for this task.

Task 4: Test Results

Table 31 shows the average ignition time, t_{ig}, and peak HRR, HRR_{peak}, at the three heat fluxes for the Task 4 vehicle parts. Complete results of all replicate MLC testing are in Appendix E.

Table 31. Task 4 MLC summary ignition time and HRR test results

Component	Averages for the Two Tests Conducted at Each Heat Flux Level					
	25 kW/m²		35 kW/m²		50 kW/m²	
	t_{ig} (s)	HRR_{peak} (kW/m²)	t_{ig} (s)	HRR_{peak} (kW/m²)	t_{ig} (s)	HRR_{peak} (kW/m²)
Caravan Carpet	63	194	33	229	26	359
Civic Carpet	151	170	36	173	27	373
Equinox Headliner	No Ignition		36	94	14	171
Civic Headliner	48	68	21	102	10	163
Equinox Seat Cover	98	52	60	103	4	209
Camry Seat Cover	99	56	50	81	24	114
F150 Seat Padding	61	120	50	152	5	226
Camry Seat Padding	22	166	11	221	15	400

Task 4: Data Analysis

Critical Heat Flux for Ignition

The CHF is an important material-dependent flammability characteristic. Theoretically, it is not possible to ignite a material when it is exposed to a radiant heat flux that is lower than its CHF. Initially, the intent was to determine the CHF from the ignition data for the eight materials tested in the MLC using an established correlation that was developed for this purpose (Janssens, 2013). However, this resulted in unrealistic CHF values for four of the eight materials. The reasons for the unrealistic values fall in two categories: (1) the model does not fit the data (the material does not behave as a thermally thick solid at low heat fluxes), and (2) there are too few data points (ignition times < 10 seconds have high uncertainty and the corresponding data cannot be included for the analysis). However, the heat balance at the surface after very long times of thermal exposure provides a relationship between the CHF and the surface temperature at ignition, T_{ig}:

$$\mathrm{CHF} = \frac{h_c}{\varepsilon}\left(T_{ig} - T_a\right) + \sigma\left(T_{ig}^4 - T_a^4\right) \qquad [7]$$

where ε is the surface emissivity/absorptivity (~0.9 for plastics), h_c is the convection coefficient (~0.012 kW/m²·K for the MLC), T_{ig} is the surface temperature at ignition (K), T_a is the ambient/initial temperature (K), and σ is the Boltzmann constant ($5.67 \cdot 10^{-11}$ kW/m²·K⁴). Table 32 shows a comparison of the CHF determined from the ignition data obtained in the MLC and calculated from T_{ig} measured in the MCC. Except for two materials, CHF agreement is poor. The following observations offer a possible explanation for the discrepancies. First, all materials are fire retardant-treated, which is known to result in random scatter in the ignition times, at the lower heat fluxes. Second, most of the tested materials are relatively thin so that the ignition times at 20 kW/m² were accelerated by the fact that the MLC specimens were backed by ceramic fiber insulation. However, the ignition times at 50 kW/m² were generally too short for the insulated back to have an effect. Methods to analyze piloted ignition assume that the material is either thermally thin (ignition times are affected by the insulation) or thermally thick (results are not affected by the insulated back). These methods do not provide good results for an ignition data set that includes test results in the thermally thin and thick regimes. Both issues can be addressed by obtaining more data, but only a limited amount of data (two repeat tests at three heat fluxes) were available.

Table 32. Comparison between CHF from MLC versus MCC test data

Material	**Critical Heat Flux (kW/m²)**	
	From MLC	**From MCC**
Dodge Grand Caravan Carpet	NA	11.0
Honda Civic Carpet	14.9	14.5
Chevy Equinox Headliner	12.6	6.3
Honda Civic Headliner	7.5	5.4
Chevy Equinox Seat Cover	NA	5.0
Toyota Camry Seat Cover	3.8	5.8
Ford F150 Seat Padding	NA	4.7
Toyota Camry Seat Padding	5.2	5.1

Maximum Average Rate of Heat Evolution

A recent proposal of flammability requirements for bus interior materials (El Houssami et al., 2023), which is based on the European standard EN 45545-2 for interior materials used in passenger railcars, specifies acceptance criteria that are based on the MARHE for wall and ceiling panels. The MARHE is usually calculated from the HRR curve measured in the cone calorimeter at a heat flux of 50 kW/m². The MARHE acceptance limit in the proposal by El Houssami et al. (2023) is 90 kW/m².

The MARHE can also be estimated from the HRR curve measured in the MLC. It is equal to the maximum value of the average rate of heat evolution, which is equal to a running average of the HRR from time zero. Figure 11 shows the process to determine the MARHE from MLC HRR data for the Equinox headliner. The MLC MARHE values for all Task 4 materials are shown in Table 33. The use of the MARHE as an intermediate fire growth parameter to develop MCC performance criteria of different stringency levels will be examined in Task 6.

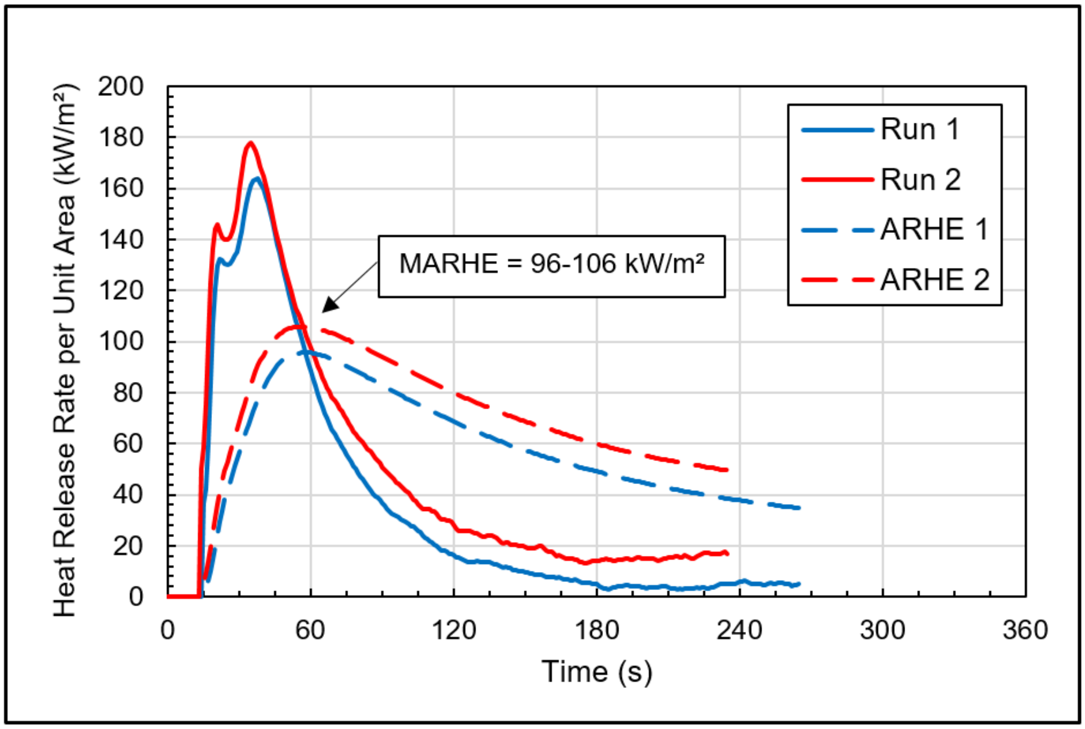

Figure 11. Determining MARHE from MLC HRR data for Equinox headliner

Table 33. MARHE values for Task 4 materials tested in the MLC

Material	**MARHE From MLC Data (kW/m^2)**		
	Test 1	**Test 2**	**Mean**
Honda Civic Carpet	186	217	201
Dodge Grand Caravan Carpet	209	211	210
Chevy Equinox Headliner	96	106	101
Honda Civic Headliner	105	112	109
Chevy Equinox Seat Cover	122	127	124
Toyota Camry Seat Cover	58	59	58
Ford F150 Seat Padding	163	174	169
Toyota Camry Seat Padding	289	264	276

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Task 5: Literature Review of Egress Time for Buses

The objective of Task 6 was to try to develop a flammability performance criterion for interior motor vehicle materials to provide reasonable assurance that the time to untenable conditions (referred to as the available safe egress time or ASET) in a motorcoach or large bus fire will exceed the time required for safe evacuation of the occupants (referred to as the required safe egress time or RSET). Conditions are untenable when it is no longer possible for the occupants to survive. Ideally, the design process of a bus that meets this level of fire safety consists of the following steps.

1. Establish the RSET for the type of bus and passengers under consideration.
2. Identify the fire scenarios for which the ASET needs to be estimated.
3. Define a baseline design for the type of bus under evaluation, e.g., a design that meets current fire and flammability regulations.
4. Use experimental data or modeling or both to determine the RSET for each of the selected scenarios.
5. If ASET ≥ RSET for all selected scenarios, the design is acceptable. If ASET < RSET for at least one of these scenarios, the design needs improvement and Step 4 will have to be repeated for the scenarios for which the ASET ≥ RSET criterion was not met. A common modification in Step 5 involves using interior motor vehicle materials with improved fire performance.

In preparation for Task 6 a literature search was conducted in Task 5 to identify studies that are pertinent to the objective of Task 6. To better estimate the effect of the flammability of interior motor vehicle materials on ASET, the scope of the search was widened to include passenger aircraft and railcars, which have some similarities to motorcoaches and large buses but have been studied in much more detail. Two types of publications were reviewed, i.e., publications that pertain to one or the other side of the RSET-ASET equation.

RSET Studies

In 1972 Sliepcevich et al. (1972a, 1972b) reported the results of egress trials for a 72-passenger school bus and 39-passenger motorcoach that were conducted in the early 1970s. The subjects wore goggles in some of the egress trials to simulate the conditions of darkness. Available egress paths were varied between trials. The results are summarized in Table 34 and Table 35 for the school bus and motorcoach trials (pps = people per second).

Table 34. Results of evacuation trials for a 72-passenger school bus

Trial No.	Goggles (Y/N)	Available Egress Paths				No. of Persons	Escape Time (s/min)	Escape Rate (pps/ppm)
		Front Door	Side Windows	Rear Exit Window	Rear Exit Door			
1	Y		✓	✓	✓	68	53/0.88	1.28/77
2	Y		✓	✓		66	86/1.43	0.77/46
3	N	✓	✓	✓	✓	68	31/0.52	2.19/132
4	Y		✓	✓	✓	68	57/0.63	1.19/72
5	Y	✓	✓	✓	✓	68	30/0.50	2.27/136

Table 35. Results of evacuation trials for a 39-passenger motorcoach

Trial #	Goggles (Y/N)	Available Egress Paths			No. of Persons	Escape Time (s/min)	Escape Rate (pps/ppm)
		Front Door	Side Windows	Rear Exit Door			
1	Y		✓		38	84.1/1.40	0.45/27
2	N		✓	✓	38	37.0/0.62	1.03/62
3	Y		✓	✓	38	31.6/0.53	1.20/72
4	N	✓	✓	✓	38	21.8/0.36	1.74/105

In 2009 the Volpe Center published a report of a two-year study (Pollard & Markos, 2009), which includes the results of egress trials from a motorcoach through four different evacuation paths using the front door, emergency exit windows, a wheelchair access door, and roof exit hatches of an overturned motorcoach. The egress trial results gave the basis for the motorcoach egress time estimates shown in Table 36.

Table 36. Motorcoach egress time estimates for four evacuation paths

Evacuation Path	No. of Exits	Opening Time (min)	Flow Rate (ppm/exit)	Escape Time* (s/min)	Escape Rate[†] (pps/ppm)
Front Door	1	0.05	36	93/1.61	0.58/35
Window	6	0.2	9	79/1.31[‡]	0.71/43
Wheelchair Access Door	1	0.2	25	146/2.44	0.38/23
Roof Hatch	2	0.1	12	146/2.43	0.38/23

* Escape time is based on 56 passengers who need to escape.

[‡] The report lists 1.2 minutes, which is incorrect because in 1.2 minutes only 54 passengers can escape.

[†] The escape rate is equal to 56 passengers divided by the escape time in minutes.

These results show that evacuation of passengers on a motorcoach could be achieved using any of these exits in less than 3 minutes. However, the authors point out that several obstacles may exist during an actual motorcoach emergency and gave the following examples.

- In a frontal motorcoach crash, the front door may be blocked, or the driver may be incapacitated. Without a driver to operate the door control, passengers may incur substantial delay in figuring out how to open the door.
- Passengers who try to use the emergency window exits may find it difficult to raise and maintain the windows at sufficient height to allow safe egress.
- The wheelchair-access door cannot be opened from inside of any of the motorcoaches currently in use.
- Emergency roof exit hatches are useful only when a bus is overturned on its side.

Additional egress trials in the second year of the study determined:

- a second door opening with a stairway provided a much faster egress path for passengers than a wheelchair-access door opening,
- egress from a wheelchair-access door opening was faster than through emergency window exits, and

- egress rates declined in low-light conditions, but the effect was not very large in the experiment, where the exit paths were free of hazards.

More recently, studies to determine the time needed to evacuate a bus were conducted in Japan (Chung et al., 2016) and China (Liang et al. 2018). Chung et al. (2016) performed nine egress trials in a 29-passenger bus to examine the effect of passengers taking luggage, passenger age (elderly versus younger adults), and evacuation through emergency exits on escape times. Escape rates for a bus with a single exit varied from 34 to 56 ppm with the lower rates for trials with evacuation through an emergency exit and with elderly passengers. Liang et al. (2018) performed three egress trials in which 63 passengers evacuated from a 70-passenger bus. The results are as follows.

- Trial 1 (front door open, back door closed): Escape time = 57 seconds, Escape rate = 67 ppm
- Trial 2 (front door closed, back door open): Escape time = 38 seconds, Escape rate = 100 ppm
- Trial 3 (front and back door open): Escape time = 27 seconds, Escape rate = 140 ppm

Finally, in October 2018 the National Association for Pupil Transportation organized a school bus fire demonstration and evacuation exercises in collaboration with the Lee’s Summit Fire Department near Kansas City, Missouri (Schlosser, 2018). Three buses were set up for the demo and exercises. One bus was used to measure the time for 30 volunteers to evacuate. Without seat belts fastened, it took the volunteers 1 minute 16 seconds to evacuate. With seat belts fastened evacuation only took 2 seconds longer. With eyes closed, to simulate the effect of poor visibility, evacuation time increased to 2 minutes 27 seconds. The purpose of the evacuation exercises was to show that seat belts have a negligible effect on the time to evacuate school buses in emergencies, but that evacuations can be significantly delayed due to poor visibility, for example, during fires.

A second bus was used to demonstrate how quickly fire spreads. The ignition source was a bale of hay placed in the front door. At 3 minutes following ignition, dark smoke had filled the bus and temperatures reached about 500°C. Clearly, conditions had become untenable well before that time. Firefighters used the third bus to show how much more difficult it is to safely escape from an overturned bus.

The evacuation exercises near Kansas City appear to be the most realistic and therefore it is recommended that the evacuation rates recorded in these trials (27 ppm for normal conditions and 13 ppm when egress is hampered by poor visibility, for example) be used in RSET-ASET analyses. The 27 ppm is equal to the escape rate recorded by Sliepcevich et al. (1972a) for window egress only and is slightly below that egress rate through the front door recorded in the Volpe trials.

ASET Studies

This section summarizes the results of studies that involved full-scale bus fire experiments in which the time to untenable conditions was measured or fire model simulations in which the time to untenable conditions was calculated.

Full-Scale Bus Fire Experiments

In 1989 the National Institute of Standards and Technology (NIST) started a program on behalf of NHTSA "to investigate the possibility of replacing the existing test method in FMVSS No. 302 with another test method or procedure that would improve the fire safety of school bus occupants" (Braun et al., 1990). The focus of the project was on seat assemblies because they represent the single largest type of fuel in the passenger compartment of a school bus. As part of the program, full-scale tests were performed on six commercially available school bus seat assemblies in a simulated school bus enclosure measuring 8.23 m long, 2.44 m wide, and 2.13 m high. Three seat assemblies were placed in the rear corner of the enclosure. The seat assembly located in the corner was exposed to a 100-kW natural gas box burner flame. Measurements were made of HRR; mass loss rate; concentrations and yields of CO, CO_2, O_2, HCN, and HCL; and upper layer and lower layer gas temperatures. Only one of the six seat assemblies produced an atmosphere that represented a significant toxicological threat to bus occupants. Two seat assemblies also produced untenable conditions in the test enclosure but only a thermal limit was exceeded. These seat assemblies produced incapacitating and lethal conditions in the enclosure within 120 to 170 seconds. The remaining three seat assemblies produced no untenable conditions.

Hammarström et al. (2008) performed three full-scale fire tests in a 49-passenger motorcoach. Test 1 simulated an engine fire and Test 2 involved a tire fire in a rear wheel well, neither of which propagated into the passenger compartment. In Test 3, a 100-kW propane burner was placed in the rear luggage compartment, simulating a rear engine fire. The fire was allowed to penetrate and subsequently spread into the passenger compartment. Measurements inside the passenger compartment included gas temperatures (thermocouple trees and thermocouples at various locations), toxic gas concentrations (Fourier-transform infrared spectroscopy), and visibility (four video cameras at eye level). Front and middle doors were open, all roof hatches were closed, and all lighting (overhead and on the floor) was turned on. ASET was estimated at 4 to 5 minutes with visibility quickly decreasing to a few meters. With lighting turned off, estimated ASET was reduced to 2 to 4 minutes depending on the time of day (night versus day).

A full-scale test was conducted at NIST to determine the time for conditions to become untenable in the passenger compartment of a motorcoach with a tire fire (Johnsson & Yang, 2019). A mock-up of a motorcoach front end was constructed and attached to the rear half of an actual motorcoach. Temperatures, heat fluxes, gas concentrations, and visibility were measured and analyzed regarding tenability criteria. It took 2 minutes for a seat to ignite after the fire penetrated through a broken window. Between 5 and 6 minutes following penetration, thermal conditions started to become untenable in the rear half of the motorcoach and became completely untenable in approximately 9 minutes. The front of the motorcoach became thermally untenable at approximately 11 minutes following fire penetration. Thermal conditions were generally more severe at earlier times than toxic gas conditions. Combination of the incapacitating thermal and toxic gas effects would shorten tenability time and time to escape. In addition to tenability, visibility conditions (evaluated 1.5 m from the floor) deteriorated significantly prior to fire penetration of the motorcoach. Within 30 seconds after penetration, visibility decreased to less than 2 m. Poor visibility could have made egress difficult several minutes before conditions became untenable.

Bus Fire Simulations

The study by NIST on school bus seat assemblies (Braun et al., 1990) involved computer simulations with HAZARD I[5] (Bukowski et al., 1989) to assess the impact of varying the ignition source strength on the development of untenable conditions. These computer simulations showed that an ignition source of about 500 kW could produce conditions in the enclosure that would lead to incapacitation of bus occupants. Ignition sources greater than 1,000 kW could develop lethal conditions in an enclosure of the size used in the study. The simulations also showed that temperature, and possibly radiant heat flux, and not smoke toxicity represent the most immediate threats to life safety.

Hammarström et al., (2008) also performed three sets of bus fire simulations using Fire Dynamics Simulator (version 4), a computational fluid dynamics code developed at NIST specifically to model fires (McGrattan & Forney 2006). The bus measured 12.37 m long, 2.24 m wide, and 2.07 m high, and had two doors (front and middle) and two roof hatches. All simulations assumed a rapidly developing arson fire involving an upholstered seat in the rear of the bus. The first set of simulations was conducted to evaluate the effect of open versus closed roof hatches on smoke layer development. The purpose of the second set was to assess the effect of open versus temporarily closed doors. The final simulation was meant to examine the effect of flame spread over fiber felt material covering the ceiling. It is difficult to tell what the effects are because quantitative results are not given. However, based on the images in the report the ASET for the flame spread scenario is 2 minutes or less. For the best-case scenario (open doors and roof hatches), the ASET may be a few minutes longer.

Some Observations

ASET in bus fires that originate outside the passenger compartment can be increased by providing adequate separation between the fire and the passenger compartment. For fires that originate inside the passenger compartment, ASET can be increased by using interior motor vehicle materials with improved fire performance.

The NIST school bus seat study (Braun et al., 1990) reached the following conclusion:

> No one simple small-scale test should be used to measure the fire performance of a material when exposed to an ignition source. Since consideration must be given to a combination of factors, such as ease of ignition, flame spread, rate of heat release, generation of gaseous species, smoke development, and toxicity of the combustion products, examination [of] individual results for each of the parameters considered for the development of hazardous conditions in a school bus enclosure reveals that similarities and differences depend on the exposure conditions and geometry of the enclosure. These additional parameters are not considered in small-scale testing and no simple method exists for translating these parametric values into full-scale assessments of tenability or escape times.
>
> Therefore, a full-scale test protocol that can form the basis for compliance testing of seat assemblies for use in school buses is outlined. This test protocol is based on seat

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[5] HAZARD I is a sequence of procedures implemented in computer software to calculate the development of hazardous conditions resulting from a compartment fire over time, to calculate the time needed by occupants to escape under those conditions, and to estimate the resulting loss of life based on assumed occupant behavior and tenability criteria. HAZARD I, which includes a two-zone fire model (early version of CFAST), was developed at NIST in the late 1980s.

> assembly tests in a standardized room. The acceptance level is determined by calculating the tenability conditions in the enclosure and comparing these results to tenability limits. To make sure that unknown toxicants are not producing an unusually toxic atmosphere in the bus enclosure, it may be necessary to perform animal toxicity testing. (p. v)

Since this school bus seat study has been completed, tremendous progress has been made in our ability to model full-scale bus fire scenarios based on small-scale flammability data, as is evident from successes in modeling fire growth in passenger railcars, which is like fires in buses (e.g., Chiam, 2005; Capote et al., 2008; White, 2010; Guillaume et al., 2014; Trulli et al., 2018).

Task 6: Develop Performance Criteria of Various Stringency Levels for Buses

Task 6 included two subtasks. The first subtask involved MCC testing and data analysis for various bus interior materials. The second subtask explored approaches to develop MCC performance criteria of various stringency levels for use in buses.

MCC Testing of Bus Interior Materials Floor Coverings

The following subsections give details on material selection, the test matrix, test results, and analysis of the tests conducted.

Task 6: MCC Material Selection and Test Matrix

Tables 37 to 39 show parts identified for MCC testing in support of this task.

Table 37. Task 6 test parts – aftermarket Bluebird school bus parts

Bluebird (Aftermarket)	https://midwestbusparts.com
Component	**Part No.**
13" Wide Ribbed Flooring, Black, Sold/Yd.	20-FF-1300B
Bluebird Back 39" 42 oz, Dark Blue Pigskin, 99+	12-FB-B3910
Bluebird 39" Hi-Back Foam, 2010+	12-125-139
Used Seat Bottom Foam, Cover & Board	12-FC-U39-UD

Table 38. Task 6 test parts – aftermarket IC school bus parts

IC Bus (Aftermarket)	https://midwestbusparts.com
Component	**Part No.**
38 1/8" Wide Smooth Flooring, Black, Sold/Yard	20-FF-3810B
IC 39" Hi-Back Foam, 2010+	12-FB-IC3910
Seat Bottom with IC Gray Cover, Foam, and Board	12-580-239-UD
IC Hi-Back 39" W/Plastic Closure, Grey, 2010+	12-5810-139

Table 39. Task 6 test parts – aftermarket Coach Bus Parts

Aftermarket Coach Bus Parts	www.coachbusparts.com
Component	**Part No.**
Coach & Equipment - Cab Plywood	212526 (2616515)
Freedman Olefin Seat Back Cover	231543
Freedman Polyester Seat Bottom Cover	182009 (82009)
FTA Foam	107329 (7329)
RCA Black Ribbed Rubber	107223 (7223)

Table 40 shows a summary of the test matrix for this task.

Table 40. Task 6 test matrix

Vehicle	Component Test ID	Part No.	MCC Replicates
Bluebird Bus Parts	BB Ribbed Flooring	20-FF-1300B	3
	BB Blue Pigskin	12-125-139	3
	BB High-Back Foam	12-FB-B3910	3
	BB Seat Bottom Foam	12-FC-U39-UD	3
IC Bus Parts	IC Smooth Flooring	20-FF-3810B	3
	IC High-Back Foam	12-FB-IC3910	3
	IC Seat Bottom Foam	12-580-239-UD	3
	IC Seat Back Closure	12-5810-139	3
Coach Bus Parts	MC Plywood	212526 (2616515)	3
	MC Olefin Seat Cover	231543	3
	MC Polyester Seat Cover	182009 (82009)	3
	MC FTA Foam	107329 (7329)	3
	MC Ribbed Flooring	107223 (7223)	3

Task 6: MCC Test Results

Table 41 shows average MCC test parameters of the different bus parts. Complete results of all replicate MCC testing for this task are in Appendix F.

Table 41. Task 6 MCC average test results.

Material Description	m_i (mg)	m_f (mg)	η_c (J/g·K)	Q_{max} (W/g)	T_{max} (°C)	h_c (kJ/g)	Y_p (g/g)	$h_{c,gas}$ (kJ/g)
BB Ribbed Flooring	4.02	1.02	153	151	311	14.9	0.253	20.0
BB Blue Pigskin	4.05	0.83	117	116	309	15.1	0.205	19.0
BB High-Back Foam	4.03	0.04	406	401	408	25.5	0.011	25.8
BB Seat Bottom Foam	4.03	0.57	376	371	407	22.7	0.141	26.4
IC Smooth Flooring	4.04	1.10	146	145	316	13.3	0.273	18.3
IC High-Back Foam	4.04	0.05	454	449	411	26.0	0.013	26.4
IC Seat Bottom Foam	4.05	0.00	417	414	409	26.7	0.000	26.7
IC Seat Back Closure	4.02	0.83	124	123	297	15.3	0.205	19.2
MC Plywood	4.08	0.79	131	129	380	9.4	0.194	11.6
MC Olefin Seat Cover	4.02	0.55	280	277	443	16.9	0.138	19.6
MC Polyester Seat Cover	4.07	0.56	262	260	445	16.1	0.137	18.6
MC FTA Foam	4.03	0.19	450	444	409	25.1	0.048	26.4
MC Ribbed Flooring	4.04	2.23	115	113	402	14.2	0.552	31.7

Task 6: MCC Data Analysis

Table 42 shows the FMVSS No. 302 pass/fail predictions based on the MCC data obtained for the Task 6 materials. The Bluebird seat bottom foam is predicted to fail the FMVSS No. 302 tests.

Table 42. FMVSS No. 302 pass/fail predictions for MCC tests on the Task 6 materials

Material Description	**ρ (kg/m^3)**	**δ (mm)**	**η_c (J/g·K)**	**T_{ig} (°C)**	**$T_{5\%}$ (°C)**	**P/F η_c & T_{ig}**	**P/F η_c & $T_{5\%}$**	**$\rho\delta\Delta T_{ig}$ (kg·K/m²)**	**$\rho\delta\Delta T_{5\%}$ (kg·K/m²)**
BB Ribbed Flooring	1123	4.68	153	232	243	**PASS**	**PASS**	**1280**	**1420**
BB Blue Pigskin	1105	0.79	117	231	245	**PASS**	**PASS**	**195**	**212**
BB High-Back Foam	130	21.00	406	234	256	**FAIL**	**FAIL**	**532**	**596**
BB Seat Bottom Foam	25	7.50	376	230	249	**FAIL**	**FAIL**	**37**	**43**
IC Smooth Flooring	1327	3.00	146	235	245	**PASS**	**PASS**	**1266**	**1353**
IC High-Back Foam	27	18.00	454	227	253	**FAIL**	**FAIL**	**102**	**113**
IC Seat Bottom Foam	108	13.50	417	229	250	**FAIL**	**FAIL**	**327**	**370**
IC Seat Back Closure	910	0.79	124	237	248	**PASS**	**PASS**	**165**	**205**
MC Plywood	591	9.00	131	294	296	**PASS**	**PASS**	**1108**	**1264**
MC Olefin Seat Cover	375	0.75	280	348	386	**PASS**	**PASS**	**57**	**63**
MC Polyester Seat Cover	314	1.00	262	360	383	**PASS**	**PASS**	**61**	**68**
MC FTA Foam	59	15.00	450	211	242	**FAIL**	**FAIL**	**180**	**198**
MC Ribbed Flooring	1187	4.50	115	269	277	**PASS**	**PASS**	**2076**	**2191**

Table 43 shows the mean values and standard deviations of c_i for the Task 6 materials. Detailed results of the Arrhenius model parameter calculations are in Appendix I.

Table 43. Mean values and standard deviations of c_i for the Task 6 materials

Material Description	**N**	**c_1**		**c_2**		**c_3**		**c_4**	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
BB Ribbed Flooring	4	0.495	0.016	0.213	0.018	0.248	0.008	0.045	0.009
BB Blue Pigskin	4	0.146	0.025	0.496	0.027	0.344	0.002	0.013	0.001
BB High-Back Foam	3	0.213	0.013	0.116	0.008	0.671	0.007		
BB Seat Bottom Foam	3	0.313	0.003	0.064	0.003	0.623	0.001		
IC Smooth Flooring	3	0.577	0.010	0.126	0.010	0.297	0.002		
IC High-Back Foam	3	0.161	0.018	0.161	0.029	0.678	0.016		
IC Seat Bottom Foam	3	0.256	0.047	0.090	0.006	0.654	0.052		
IC Seat Back Closure	3	0.604	0.003	0.374	0.003	0.022	0.003		
MC Plywood	3	0.329	0.004	0.516	0.050	0.155	0.048		
MC Olefin Seat Cover	3	0.027	0.007	0.460	0.074	0.513	0.068		
MC Polyester Seat Cover	3	0.030	0.012	0.426	0.188	0.544	0.195		
MC FTA Foam	3	0.230	0.054	0.131	0.028	0.638	0.029		
MC Ribbed Flooring	3	0.119	0.008	0.547	0.016	0.334	0.011		

Establishing MCC Criteria of Different Stringency Levels for Buses

Two approaches were explored to develop MCC criteria of different stringency levels for bus interior materials. These approaches are discussed in the subsections below.

MCC Criteria Based on Predicting Higher Levels of Performance in FMVSS No. 302

The first approach consists of two steps.

1. Define different levels of performance in the FMVSS No. 302 test.
2. Determine whether a higher FMVSS No. 302 performance level can be correlated to one or a combination of MCC test parameters.

To develop MCC criteria of different stringency levels, the following increasing levels of FMVSS No. 302 performance are defined.

- P1: flame does not reach first mark
- P2: flame goes out in < 60 seconds and spreads ≤ 51 mm beyond first mark
- P3: flame does not reach second mark and burn rate ≤ 102 mm/min
- P4: flame spreads beyond second mark and burn rate ≤ 102 mm/min
- F1: flame does not reach second mark but burn rate > 102 mm/min
- F2: flame spreads beyond second mark and burn rate > 102 mm/min

The initial thought was to perform a multinomial logistic regression analysis to determine the best combinations of MCC test parameters and physical properties to predict whether the material's FMVSS No. 302 performance level is P1, P2, P3, or P4 (prediction of performance levels F1 and F2 is not feasible because of the lack of data for materials that fail FMVSS No. 302). A diagram of the process is shown in Figure 12.

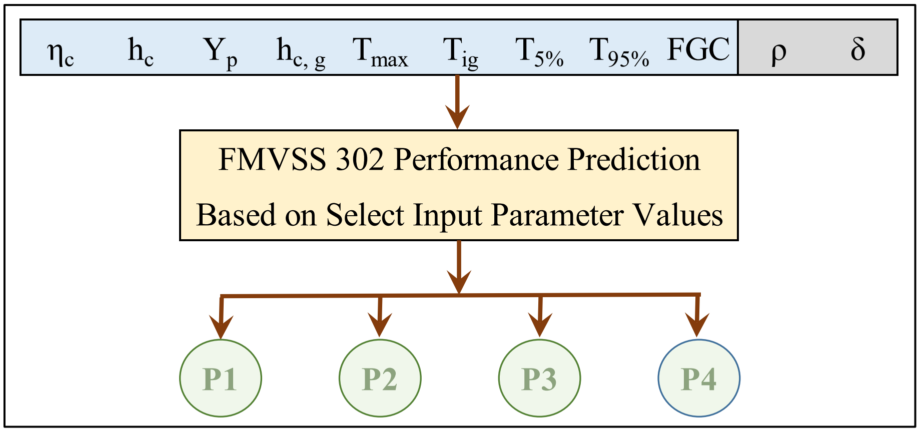

Figure 12. Multinomial logistic regression analysis to predict FMVSS No. 302 performance level

Unfortunately, the all-encompassing multinomial logistic regression analysis turned out to be too ambitious and did not provide a useful statistical model. We then decided to use a more modest approach and performed a bimodal logistic regression analysis to predict a P1 pass or fail based on the values for η_c, ρ, δ, and T_{ig}. This combination of independent variables was identified as the preferred choice to obtain the best fit.

A comparison between the predicted P1 probability versus the observed probability for the Task 2 and Task 3 materials is shown in Figure 13. The observed probability is equal to the fraction of the five FMVSS No. 302 tests in which a P1 pass was achieved. The figure shows that the model predicts some false negatives (observed probability > 0.5 but predicted probability < 0.5) but no false positives, which is acceptable.

To independently validate the model, it was used to predict FMVSS No. 302 P1 probability for the materials that were tested in the previous project (Huczek et al, 2021). In this case, however, there are a large number of false positives (see Figure 14), which shows that the binomial regression model is not a useful tool to predict a higher level of performance in the FMVSS No. 302 test based on MCC data, although all false positives are plastic foam materials.

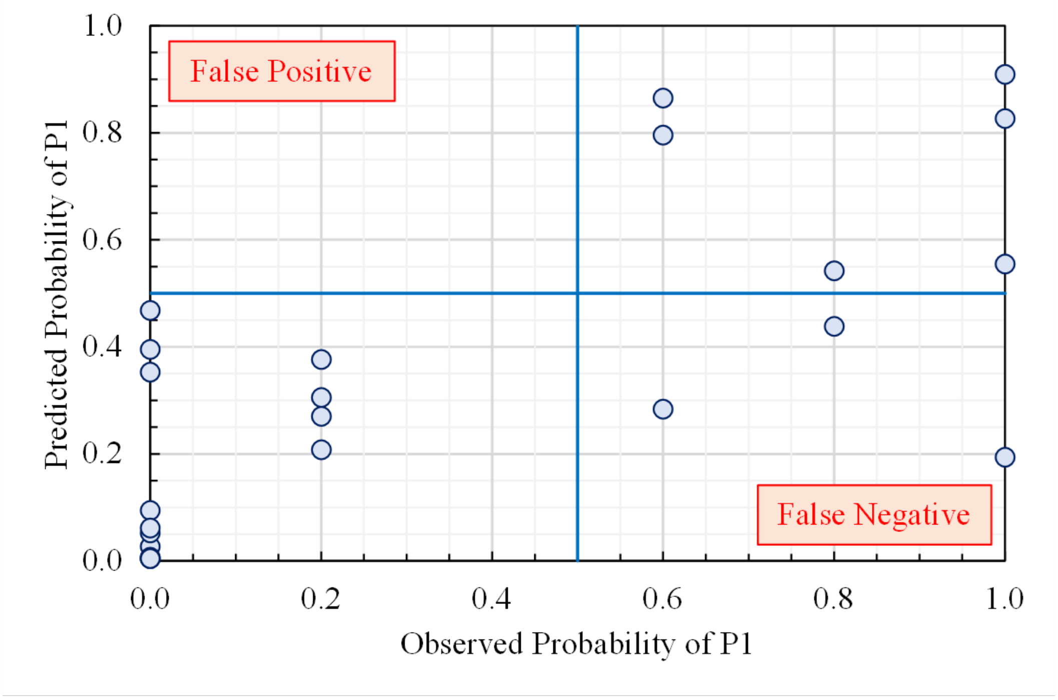

Figure 13. Predicted versus observed P1 pass probability for Task 2 and 3 materials

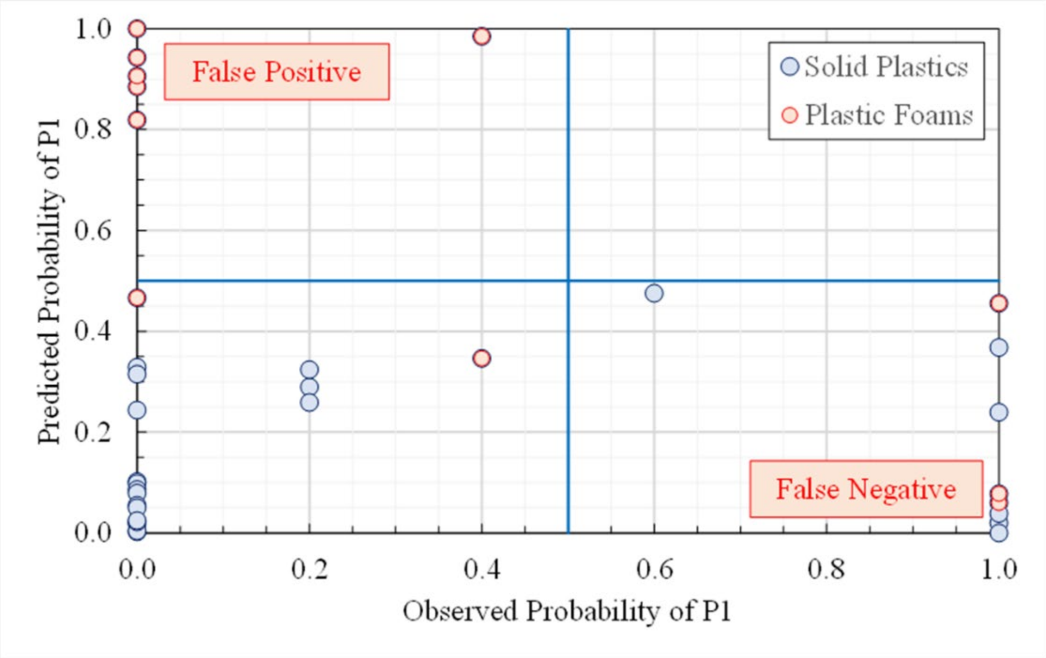

Figure 14. Predicted versus observed P1 pass probability for previous project materials

MCC Criteria Based on Predictions of Qualification Test Performance

The second explored approach to develop MCC performance criteria of different stringency levels involves establishing a relationship between the results that can be obtained through the MCC alternative method and performance in fire test methods that are used to qualify interior materials for use in other transportation vehicles. Recently, this approach was used with success by the FAA in the development of FGC. The FGC combines the ignitability and heat release of the material into a single parameter that can be measured in the MCC. The FGC successfully ranks materials according to their performance in various fire and flammability tests that are used to qualify aircraft cabin materials (Lyon et al., 2020; Safronava & Lyon, 2020, 2022).

Use of the MARHE as the Qualification Test Metric

As mentioned in the data analysis section for Task 4, a recent proposal of flammability requirements for bus interior materials (El Houssami et al., 2023), which is based on the European standard EN 45545-2 for interior materials used in passenger railcars, specifies acceptance criteria that are based on the MARHE for wall and ceiling panels. The MARHE acceptance limit in the proposal by El Houssami et al. (2023) is 90 kW/m^2.

The MARHE is usually calculated from the HRR curve measured in the cone calorimeter at a heat flux of 50 kW/m^2. However, the MARHE can also be estimated from the HRR curve measured in the MLC, as was done for eight Task 2 materials in Task 4. The results are shown in Table 33. It is clear from the table that only one material (Camry Seat Cover) would meet the MARHE requirement for wall and ceiling materials, although the proposal by El Houssami et al. (2023) specifies acceptance criteria for seating materials that are based HRR measurements for an entire seat assembly.

Table 33. MARHE values for Task 4 materials tested in the MLC

Material	**MARHE From MLC Data (kW/m^2)**		
	Test 1	**Test 2**	**Mean**
Honda Civic Carpet	186	217	201
Dodge Grand Caravan Carpet	209	211	210
Chevy Equinox Headliner	96	106	101
Honda Civic Headliner	105	112	109
Chevy Equinox Seat Cover	122	127	124
Toyota Camry Seat Cover	58	59	58
Ford F150 Seat Padding	163	174	169
Toyota Camry Seat Padding	289	264	276

The question now is whether the MARHE can be predicted from MCC data. Figure 15 shows that materials with $\eta_c \leq 300$ J/g·K, which is the η_c limit to predict a pass in FMVSS No. 302 for materials with a thickness greater than 3.2 mm, have a MARHE below 140 kW/m^2. The two data points that are colored in orange are for the Chevy Equinox seat cover, which is the only material tested in the MLC that has a thickness smaller than 3.2 mm (2.8 mm).

Surprisingly, Figure 16 shows that the ignition temperature, T_{ig}, does not appear to be a good indicator of the MARHE. Materials with $T_{ig} \geq 290$°C, which is the T_{ig} limit to predict a pass in FMVSS No. 302 for materials with a thickness greater than 3.2 mm, have a MARHE below 220 kW/m^2. Moreover, for materials with $T_{ig} < 290$°C the MARHE varies approximately between 50 and 300 kW/m^2.

Figure 17 shows that materials with $\rho\delta\Delta T_{ig} \geq 105$ kg ·K/m^2, which is slightly higher than the limit of 85 kg ·K/m^2 to predict a pass in FMVSS No. 302, have a MARHE below 140 kW/m^2.

Figure 18 shows that materials with an FGC ≥ 240 J/g·K have a MARHE below 140 kW/m^2. This is above the limit of approximately 160 J/g·K to obtain a UL 94 V0 rating, and well above the limit of approximately 80 J/g·K to pass the 65 kW/m^2 FAA Ohio State University (OSU) peak HRR requirements for large surface area materials. The OSU and UL 94 V0 limits in Figure 18 (80 and 160 J/g·K) are estimated from Figures 3 and 4 in FAA report DOT/FAA/TC-20/30 (Safronava & Lyon, 2020) that show the probability of a pass in the OSU and of achieving a UL 94 V0 rating based on the value of the FGC.

Based on Figure 18 and the research conducted by the FAA, the use of the FGC as a predictor appears to be the most promising approach to determine from MCC data whether the MARHE is below a specified threshold. However, more work is needed to determine what this MARHE threshold for large surface area materials in buses should be. A low MARHE threshold leads to a slower growing fire and more time for occupants to safely escape. In addition, MCC and cone calorimeter or MLC test data will be needed for a relatively large number of bus interior materials so that a reliable corresponding FGC threshold can be established.

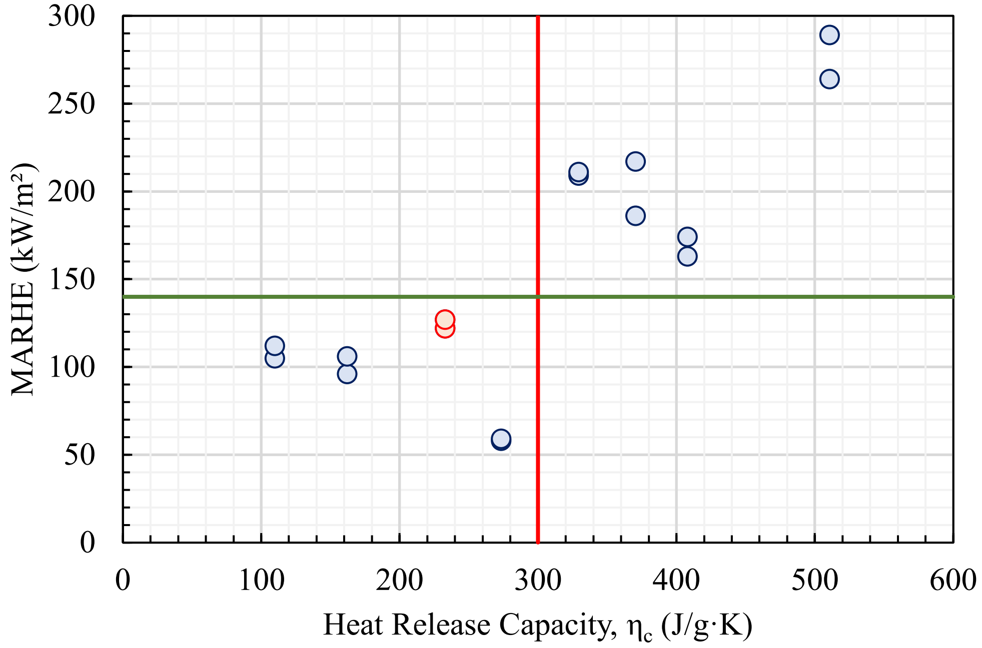

Figure 15. MARHE versus heat release capacity, η_c, *for Task 4 materials*

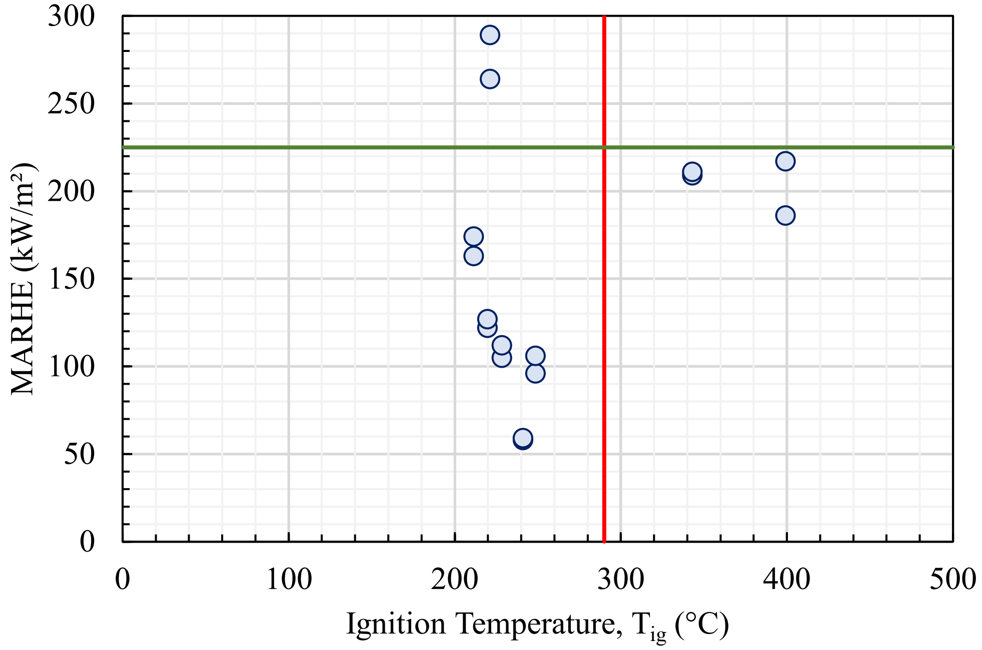

Figure 16. MARHE versus ignition temperature, T_{ig}, *for Task 4 materials*

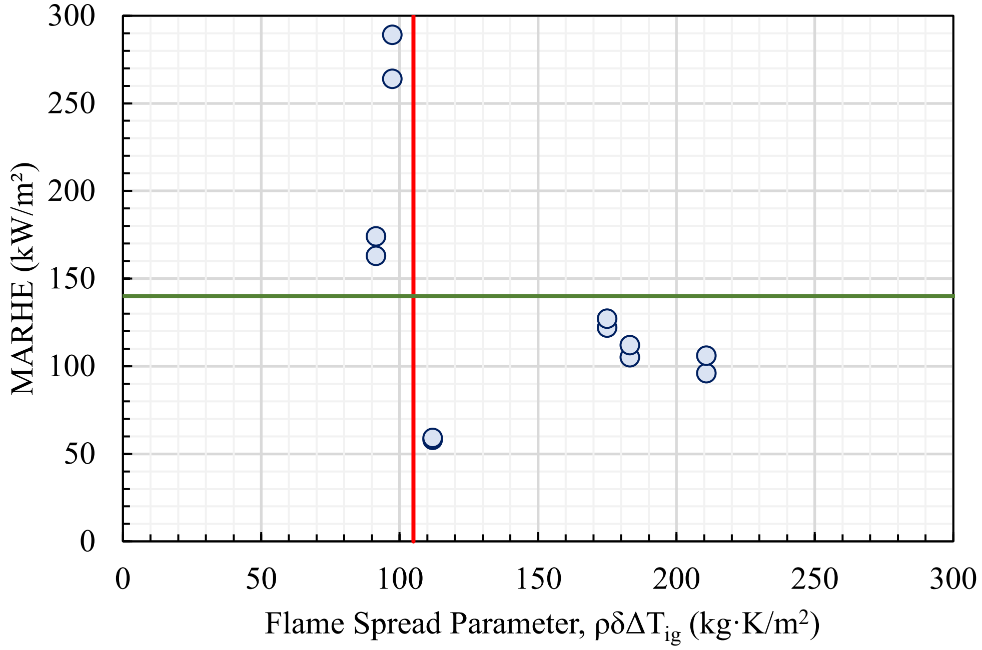

Figure 17. MARHE versus flame spread parameter, $\rho\delta\Delta T_{ig}$, for Task 4 materials

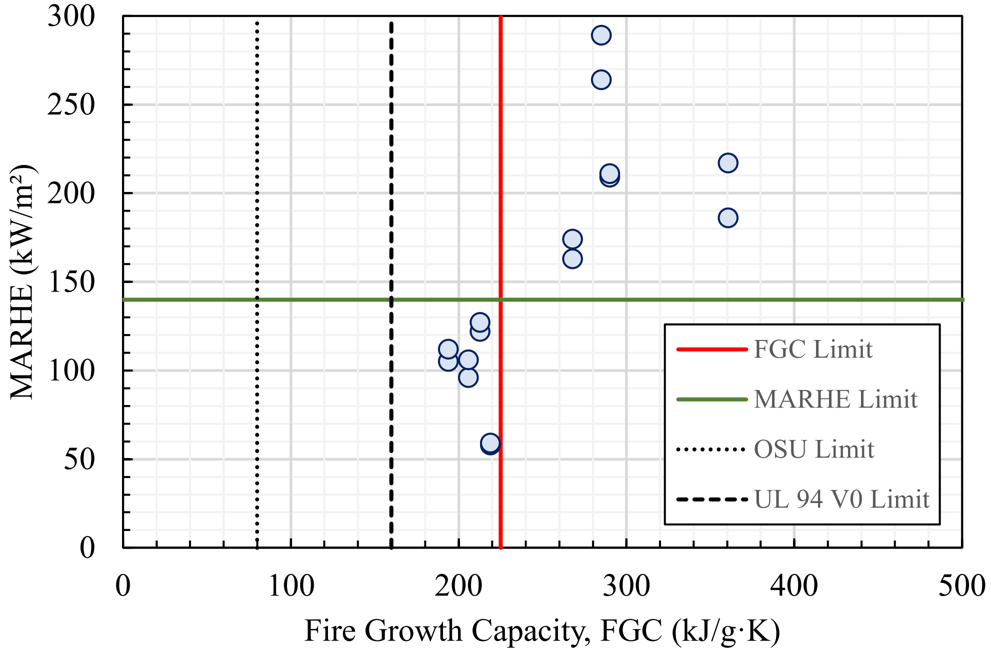

Figure 18. MARHE versus FGC for Task 4 materials

Approach to Establish the MARHE Threshold for Large Surface Area Bus Materials

This subsection presents the results of a series of zone fire model calculations using CFAST 7.7.4 to illustrate, conceptually, how the MARHE threshold for a relatively simple fire growth scenario could be established. The objective is to limit the fire growth rate so that occupants have sufficient time to safely evacuate the bus. The bus is assumed to be 12 m long, 2.25 m wide, and 2.1 m high (interior dimensions). There is a single open door at the front end of the bus, measuring 0.68 m wide and 2 m high. The thermal properties of the floor, wall, and ceiling materials are assumed to be identical to the properties used in the FDS simulation performed by Hammarström et al. (2008) and reviewed in Task 5. Additional assumptions are as follows.

- The material is assumed to burn like a circular pool fire located in the back of the bus.
    - The HRR per unit area is assumed equal to the MARHE.
    - The fire is ignited at the center and spreads at a fast or medium t-squared fire growth rate to a specified radius (R_{max} = 0.75 m or 0.5 m). Ultrafast, fast, medium, and slow t-squared fires are widely used in fire safety engineering design (see Figure 19). For example, the second step in a quantitative fire hazard analysis of passenger railcars performed by NIST (Peacock et al., 2002) determines the ASET for these four t-squared fires.
    - The HRR remains constant after R_{max} is reached, i.e., it is assumed that the fire continues to burn at the maximum rate.
- Tenability criteria: Hot gas layer temperature ≥ 95°C (corresponds to a heat flux of 1 kW/m^2, or a hot gas layer temperature ≥ 65°C **and** interface height ≤ 1.5 m. Visibility and toxicity-based criteria could not be considered.

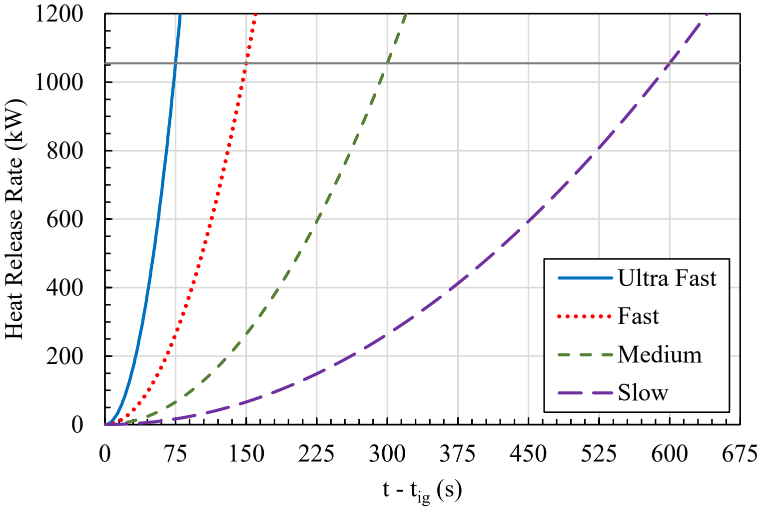

Figure 19. Ultrafast, fast, medium, and slow t-squared fire growth rates

CFAST simulations were performed for hypothetical materials with MARHE values equal to 50, 100, 150, 200, and 300 kW/m^2. The simulations were conducted for 300 seconds with the objective of determining whether the ASET exceeds an RSET of 5 minutes. The results of the simulations are shown in Figures 20 to 24 and Tables 44 to 48.

Figure 20 and Table 44 show the HRR profiles and corresponding results of the tenability calculations, assuming fast t-squared fire growth and R_{max} = 0.75 m. Only the material with a MARHE of 50 kW/m^2 has an ASET that exceeds the RSET of 5 minutes. For materials with a MARHE of 100 kW/m^2 the ASET is 86 seconds, for materials with a higher MARHE the ASET is 76 seconds because conditions become untenable before the fire has spread to the perimeter and the maximum HRR has been reached.

The assumption for the first set of CFAST simulations that a fire for a material with a MARHE of 50 kW/m² spreads much faster to the perimeter than a fire with a higher MARHE (see columns 2 in Table 44) is not realistic because materials with a lower MARHE are generally more difficult to ignite and therefore spread flare at a slower rate. To improve the realism, Figure 21 and Table 45 show revised HRR profiles and corresponding results of the tenability calculations assuming R_{max} = 0.75 m and a constant fire spread rate of 7.1 mm/s, regardless of the MARHE of the material. The 7.1 mm/s is equal to the fire spread rate for a fast t-squared fire involving the material with a MARHE equal to 300 kW/m^2 (see Table 44). The slower fire growth rate of 7.1 mm/s for all MARHE values increases the ASET for materials with a MARHE lower than 300 kW/m^2.

Figure 22 and Table 46 show the HRR profiles and corresponding results of the tenability calculations assuming medium t-squared fire growth and R_{max} = 0.75 m. Figure 23 and Table 47 show HRR profiles and corresponding results of the tenability calculations assuming R_{max} = 0.75 m and a constant fire spread rate equal to the fire spread rate for the material with a MARHE equal to 300 kW/m^2 in the first medium t-squared growth rate case (3.5 mm/s). Finally, Figure 23 and Table 47 show HRR profiles and corresponding results of the tenability calculations with R_{max} reduced to 0.5 m. Limiting the area reduces the peak HRR of the fire to the point that the ASET now exceeds 5 minutes for materials with a MARHE of 100 kW/m^2.

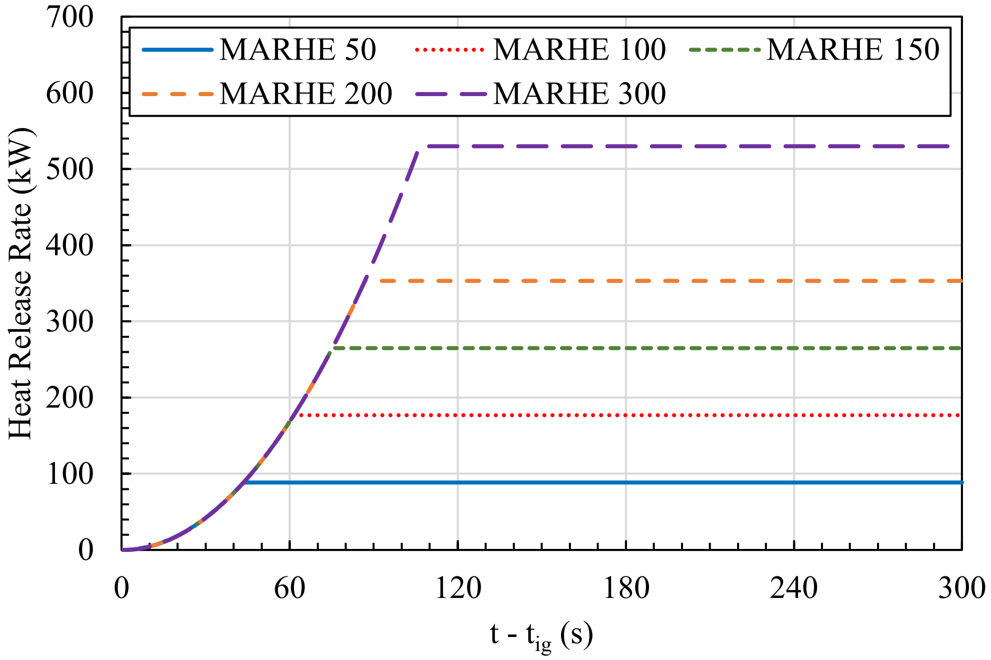

Figure 20. HRRs for fast t-squared fire growth and R_{max} = 0.75 m

Table 44. ASET for fast t-squared fire growth and R_{max} = 0.75 m

MARHE	**FSR**	**$t_{ULT=95°C}$**	**$t_{ULT=65°C}$**	**$t_{ULH=1.5\ m}$**	**Max ($t_{ULT=65°C}$, $t_{ULH=1.5\ m}$)**	**ASET**
(kW/m²)	**(mm/s)**	**(s)**	**(s)**	**(s)**	**(s)**	**(s)**
50	17.3	NA	NA	34	NA	>300
100	12.2	NA	86	34	86	86
150	10.0	108	76	34	76	76
200	8.6	94	76	34	76	76
300	7.1	93	76	34	76	76

$t_{ULT=XX°C}$ = Time to upper layer temperature reaching XX°C
$t_{ULH=1.5\ m}$ = Time to upper layer interface height reaching 1.5 m

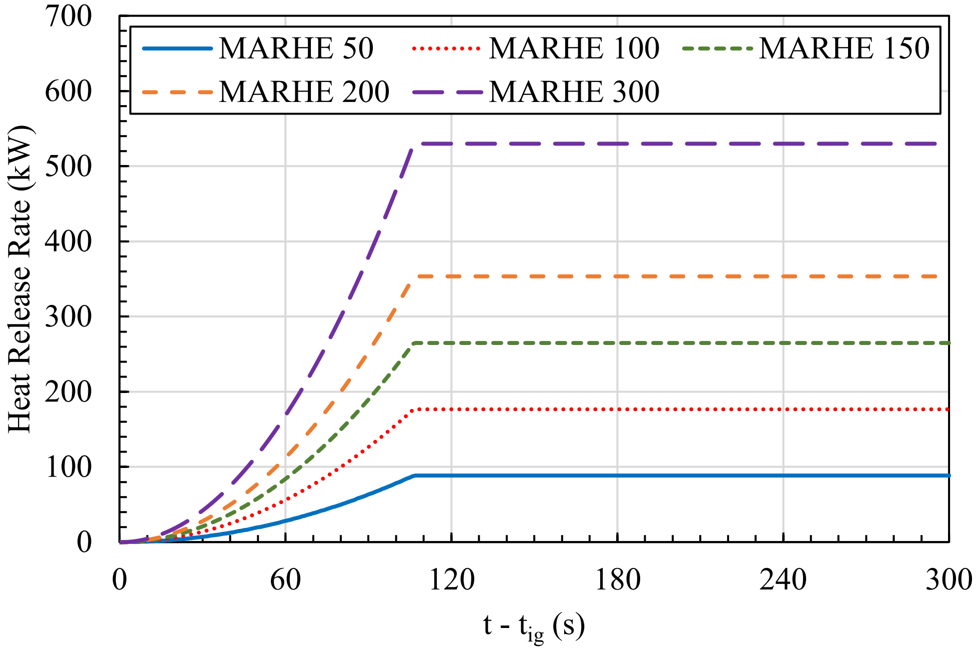

Figure 21. HRRs for fast constant spread rate fire growth and R_{max} = 0.75 m

Table 45. ASET for fast CSR fire growth and R_{max} = 0.75 m

MARHE	**CSR**	**$t_{ULT=95°C}$**	**$t_{ULT=65°C}$**	**$t_{ULH=1.5\ m}$**	**Max ($t_{ULT=65°C}$, tULH$_{=1.5\ m}$)**	**ASET**
(kW/m²)	**(mm/s)**	**(s)**	**(s)**	**(s)**	**(s)**	**(s)**
50	7.1	NA	NA	56	NA	>300
100	7.1	NA	117	51	117	117
150	7.1	132	94	48	94	94
200	7.1	107	81	46	81	81
300	7.1	93	76	34	76	76

$t_{ULT=XX°C}$ = Time to upper layer temperature reaching XX°C
$t_{ULH=1.5\ m}$ = Time to upper layer interface height reaching 1.5 m

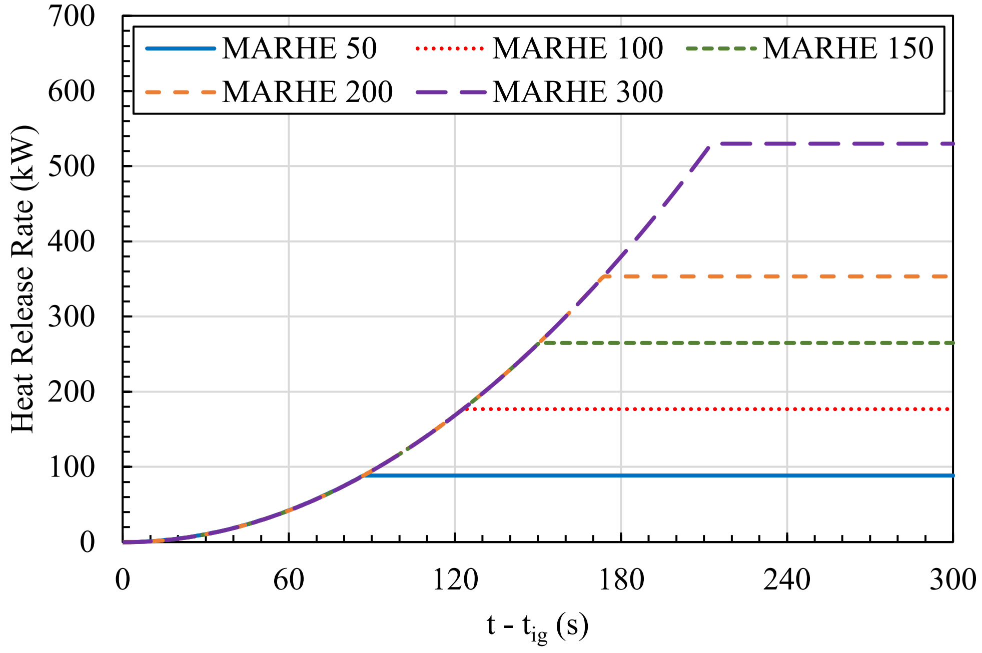

Figure 22. HRRs for medium t-squared fire growth and R_{max} = 0.75 m

Table 46. ASET for medium t-squared fire growth and R_{max} = 0.75 m

MARHE	**FSR**	**$t_{ULT=95°C}$**	**$t_{ULT=65°C}$**	**$t_{ULH=1.5\ m}$**	**Max ($t_{ULT=65°C}$, $t_{ULH=1.5\ m}$)**	**ASET**
(kW/m²)	**(mm/s)**	**(s)**	**(s)**	**(s)**	**(s)**	**(s)**
50	8.6	NA	NA	51	NA	>300
100	6.1	NA	130	55	130	130
150	5.0	166	123	57	123	123
200	4.3	158	119	58	119	119
300	3.5	152	114	60	114	114
$t_{ULT=XX°C}$ = Time to upper layer temperature reaching XX°C $t_{ULH=1.5\ m}$ = Time to upper layer interface height reaching 1.5 m						

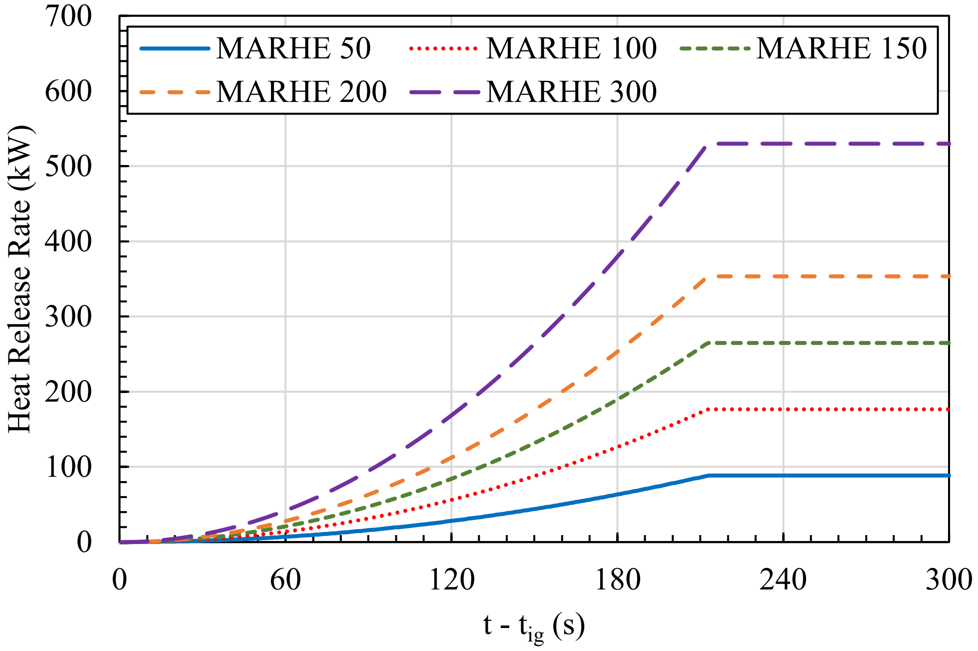

Figure 23. HRRs for medium CSR fire growth and R_{max} = 0.75 m

Table 47. ASET for medium CSR fire growth and R_{max} = 0.75 m

MARHE	**CSR**	**$t_{ULT=95°C}$**	**$t_{ULT=65°C}$**	**$t_{ULH=1.5\ m}$**	**Max ($t_{ULT=65°C}$, $t_{ULH=1.5\ m}$)**	**ASET**
(kW/m²)	**(mm/s)**	**(s)**	**(s)**	**(s)**	**(s)**	**(s)**
50	3.5	NA	NA	81	NA	>300
100	3.5	NA	198	72	198	198
150	3.5	218	161	68	161	161
200	3.5	187	139	65	139	139
300	3.5	152	114	60	114	114

$t_{ULT=XX°C}$ = Time to upper layer temperature reaching XX°C
$t_{ULH=1.5\ m}$ = Time to upper layer interface height reaching 1.5 m

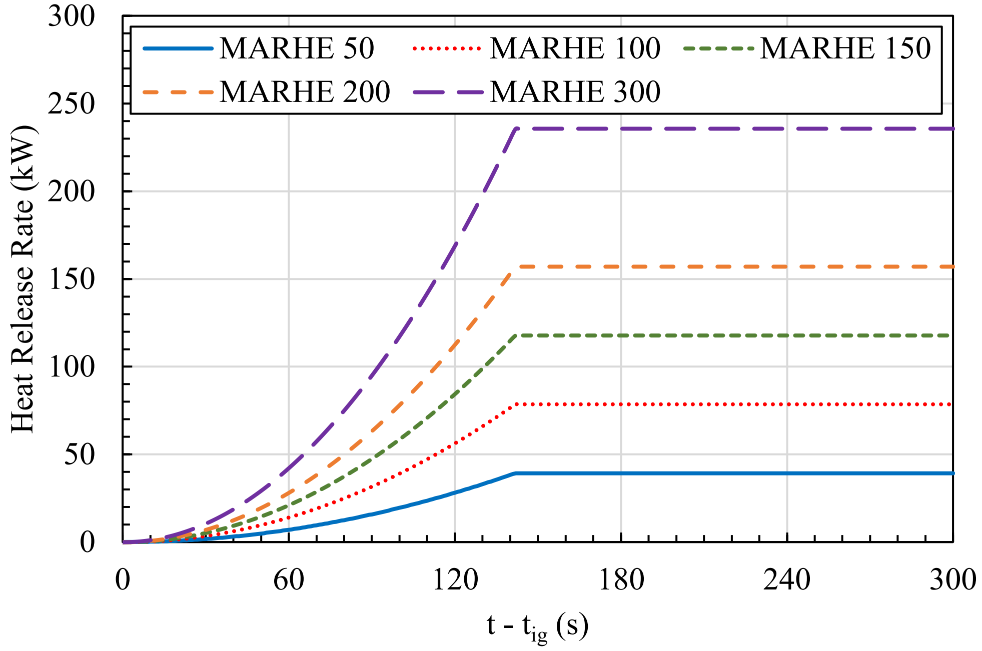

Figure 24. HRRs for medium CSR fire growth and R_{max} = 0.5 m

Table 48. ASET for medium CSR fire growth and R_{max} = 0.5 m

MARHE	**CSR**	**$t_{ULT=95°C}$**	**$t_{ULT=65°C}$**	**$t_{ULH=1.5\ m}$**	**Max ($t_{ULT=65°C}$, $t_{ULH=1.5\ m}$)**	**ASET**
(kW/m^2)	**(mm/s)**	**(s)**	**(s)**	**(s)**	**(s)**	**(s)**
50	3.5	NA	NA	81	NA	>300
100	3.5	NA	NA	72	NA	>300
150	3.5	NA	169	68	169	169
200	3.5	NA	139	65	139	139
300	3.5	155	114	60	114	114

$t_{ULT=XX°C}$ = Time to upper layer temperature reaching XX°C
$t_{ULH=1.5\ m}$ = Time to upper layer interface height reaching 1.5 m

The CFAST simulations illustrate various approaches that can be used to increase ASET and achieve a fire-safe design, e.g., delay the fire growth rate, reduce the HRR per unit, limit the burning area, etc. The objective of Task 6 is to determine which fire and flammability performance requirements to impose on large surface areas and seating materials to make sure, with reasonable probability, that ASET will exceed RSET in specified bus fire scenarios. The CFAST study shows that fire modeling is a useful tool in achieving this objective. However, modeling fire growth in a bus fire is very challenging because of the complex geometry, multitude of ignition scenarios that need to be considered, and mixture of materials that contribute to fire growth. For future work the following could be helpful for furthering MARHE-based performance criteria.

1. Based on a review of bus fire statistics, identify the ignition scenarios that need to be considered.
2. Develop models in FDS for each of the ignition scenarios. The current version of FDS (6.8.0) has many advanced features that the versions used 15 years ago by Hammarström et al. (2008) and Capote et al. (2008) did not have and is much more suitable to simulate bus fire growth.
3. Design and conduct a full-scale experiment in a bus mockup for each of the ignition scenarios that will give the validation basis for the models. In addition to full-scale testing, validation will also require small-scale testing (primarily in the cone calorimeter) to obtain input data for the FDS model.
4. For each of the ignition scenarios use FDS to perform a sensitivity analysis to determine how the fire performance of various bus interior materials and assemblies affect ASET.
5. Based on the results of the sensitivity study, recommend fire performance levels for the large surface areas and seating materials in buses.
6. Determine how the MCC can be used as a qualification test or screening tool for surface materials and seat assembly components that meet or exceed the recommended performance requirements.

Conclusions

The validity of the alternative method developed in the previous project (Huczek et al., 2021) was confirmed based on new FMVSS No. 302 and MCC data for 24 motor vehicle interior materials (only two false negatives). In the present project, equivalent criteria were developed to predict FMVSS No. 302 pass/fail performance based on $T_{5\%}$ instead of T_{ig}. The equivalent criteria are as follows.

1. MCC parameter-based criteria:
    a. Materials 3.2 mm or less in thickness are expected to pass FMVSS No. 302 when at least one of the following criteria is met: $\eta_c \leq 200$ J/g·K **or** $T_{5\%} \geq 332$°C.
    b. Materials that are more than 3.2 mm thick are expected to pass FMVSS No. 302 when at least one of the following, less stringent, criteria is met: $\eta_c \leq 300$ J/g·K **or** $T_{5\%} \geq 312$°C.
2. Physics-based criterion:
    a. Materials are expected to pass the FMVSS No. 302 if the following criterion is met: $\rho\delta(T_{5\%} - T_0) \geq 91.5$ kg·K/m^2.

A new method was developed to assess the effect of variability in the composition (in terms of contributions to the HRR) of the sample on the repeatability of the MCC test results. The effect of this variability was found to be relatively small, although there were some outliers.

The effect on the average MCC test parameter values of performing six replicate MCC tests compared to three is very small. The main benefit of performing six instead three replicate MCC tests is a higher confidence that the average composition is representative of the actual composition of a test article (e.g., layered materials).

The MLC proved to be a useful test method to measure the MARHE of interior materials used in motor vehicles. However, the underlying reasons for the discrepancies between MLC and MCC derived ignition properties are unknown.

A review of five studies that document the results of evacuation trials in school buses and motorcoaches was carried out. Conservative egress rates in fire safety engineering analyses are 27 ppm for evacuations in normal conditions and 13 ppm under more challenging circumstances (e.g., when visibility is poor).

An attempt to develop logistic regression models that can be used to predict different levels of performance in FMVSS No. 302 (e.g., no sustained ignition versus burn rate less than 102 mm/min) was not successful.

Based on limited available data, it seems that the FGC can be used to determine whether the MARHE for a material exceeds a specified threshold (if confirmed by additional data). Pending confirmation, this would provide a mechanism to develop performance criteria for use with the MCC test method for interior materials in motorcoaches and other large buses for different evacuation times.

CFAST simulations of a simple bus fire scenario were used to illustrate how a MARHE threshold to achieve a specified ASET could be determined. These simulations represent an initial examination of the scenario. More realistic bus fire scenarios are better examined using FDS, which is beyond the scope of this project.

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Appendix A: FMVSS No. 302 Test Results for Task 2 Materials

Results Description	Appendix A Table Number
FMVSS No. 302 Results for Chevrolet Equinox Materials	A-1
FMVSS No. 302 Results for Dodge Grand Caravan Materials	A-2
FMVSS No. 302 Results for Ford F150 Materials	A-3
FMVSS No. 302 Results for Honda Civic Materials	A-4
FMVSS No. 302 Results for Toyota Camry Materials	A-5

Table A-1. FMVSS No. 302 results for Chevrolet Equinox materials

Test	**Material Description**	$t_{mark\ 1}$	$t_{mark\ 2}$	t_{fo}	D_{max}	t_{Dmax}	**Burn**	m_i	m_f	**P/F**
No.		**(s)**	**(s)**	**(s)**	**(mm)**	**(s)**	**Rate**	**(g)**	**(g)**	
1	Equinox Carpet	NA	NA	15	15	15	NA	101.4	101.3	Pass
2	Equinox Carpet	NA	NA	15	15	15	NA	101.8	101.5	Pass
3	Equinox Carpet	NA	NA	15	16	15	NA	102.1	101.9	Pass
4	Equinox Carpet	NA	NA	15	20	15	NA	98.3	98.1	Pass
5	Equinox Carpet	NA	NA	15	18	15	NA	98.0	97.8	Pass
Average:		NA	NA	15	17	15	NA	100.3	100.1	**Pass**
Standard Deviation:		NA	NA	0	2.2	0	NA	2.0	2.0	
1	Equinox Headliner	78	NA	590	185	590	17	33.6	30.4	Pass
2	Equinox Headliner	86	NA	479	150	479	17	33.6	31.2	Pass
3	Equinox Headliner	NA	NA	101	38	101	NA	33.3	32.8	Pass
4	Equinox Headliner	85	NA	149	54	149	15	34.0	33.2	Pass
5	Equinox Headliner	80	837	961	325	961	20	35.3	29.0	Pass
Average:		82	837	456	150	456	17	34.0	31.3	**Pass**
Standard Deviation:		4	NA	351	115.8	351	2.1	0.8	1.7	
1	Equinox Seat Cover	53	NA	137	50	115	12	33.7	32.2	Pass
2	Equinox Seat Cover	NA	NA	38	35	30	NA	28.5	28.1	Pass
3	Equinox Seat Cover	36	NA	84	71	84	41	32.3	30.6	Pass
4	Equinox Seat Cover	35	NA	91	50	91	13	33.7	32.7	Pass
5	Equinox Seat Cover	53	NA	135	57	78	46	33.7	32.2	Pass
Average:		44	NA	97	53	80	28	32.4	31.1	**Pass**
Standard Deviation:		10	NA	41	13.0	31	18	2.2	1.9	
1	Equinox Seat Padding	NA	NA	15	15	15	NA	23.4	23.3	Pass
2	Equinox Seat Padding	NA	NA	14	15	14	NA	23.6	23.6	Pass
3	Equinox Seat Padding	NA	NA	10	14	10	NA	18.9	18.3	Pass
4	Equinox Seat Padding	NA	NA	15	15	15	NA	24.1	24.1	Pass
5	Equinox Seat Padding	NA	NA	10	15	10	NA	20.8	20.8	Pass
Average:		NA	NA	13	15	13	NA	22.2	22.0	**Pass**
Standard Deviation:		NA	NA	3	0.4	2.6	NA	2.2	2.5	

Table A-2. FMVSS No. 302 results for Dodge Grand Caravan materials

Test	**Material Description**	$t_{\text{mark 1}}$	$t_{\text{mark 2}}$	t_{fo}	D_{max}	$t_{D\text{max}}$	**Burn**	m_i	m_f	**P/F**
No.		**(s)**	**(s)**	**(s)**	**(mm)**	**(s)**	**Rate**	**(g)**	**(g)**	
1	Caravan Carpet	60	429	543	325	514	41	57.7	46.5	Pass
2	Caravan Carpet	56	345	595	325	595	53	64.9	56.0	Pass
3	Caravan Carpet	52	476	619	325	523	36	57.3	46.6	Pass
4	Caravan Carpet	39	348	505	325	505	49	59.3	47.2	Pass
5	Caravan Carpet	39	360	504	325	492	47	54.9	42.5	Pass
	Average:	49	392	553	325	526	45	58.8	47.8	**Pass**
	Standard Deviation:	10	58	52	0.0	40	6.7	3.7	5.0	
1	Caravan Headliner	82	NA	637	206	637	18	31.1	27.8	Pass
2	Caravan Headliner	82	NA	746	248	746	19	31.6	27.4	Pass
3	Caravan Headliner	83	896	943	305	943	19	31.3	26.7	Pass
4	Caravan Headliner	85	NA	150	55	150	16	32.4	31.5	Pass
5	Caravan Headliner	85	NA	131	50	131	16	31.8	31.0	Pass
	Average:	83	896	521	173	521	17	31.6	28.9	**Pass**
	Standard Deviation:	2	NA	365	115.3	365	1.6	0.5	2.2	
1	Caravan Seat Cover	38	NA	58	53	58	NA	21.1	20.3	Pass
2	Caravan Seat Cover	37	NA	53	53	53	NA	20.8	20.2	Pass
3	Caravan Seat Cover	NA	NA	43	33	43	NA	20.9	20.6	Pass
4	Caravan Seat Cover	37	NA	41	40	41	NA	20.2	19.8	Pass
5	Caravan Seat Cover	37	NA	123	115	123	54	20.5	18.8	Pass
	Average:	37	NA	64	59	64	54	20.7	19.9	**Pass**
	Standard Deviation:	1	NA	34	32.6	34	NA	0.3	0.7	
1	Caravan Padding	NA	NA	15	28	15	NA	16.6	16.5	Pass
2	Caravan Padding	NA	NA	12	30	12	NA	17.7	17.6	Pass
3	Caravan Padding	NA	NA	15	25	15	NA	20.0	20.0	Pass
4	Caravan Padding	NA	NA	12	20	12	NA	18.4	18.4	Pass
5	Caravan Padding	32	NA	40	45	40	NA	17.3	17.1	Pass
	Average:	32	NA	19	30	19	NA	18.0	17.9	**Pass**
	Standard Deviation:	NA	NA	12	9.4	12	NA	1.3	1.4	

Table A-3. FMVSS No. 302 results for Ford F150 materials

Test	Material Description	$t_{mark\ 1}$	$t_{mark\ 2}$	t_{fo}	D_{max}	t_{Dmax}	Burn	m_i	m_f	P/F
No.		(s)	(s)	(s)	(mm)	(s)	Rate	(g)	(g)	
1	Ford F150 Carpet	78	783	1,237	325	1,237	22	104.7	96.5	Pass
2	Ford F150 Carpet	67	630	1,034	325	1,034	27	104.5	90.8	Pass
3	Ford F150 Carpet	65	620	958	325	958	27	100.6	88.6	Pass
4	Ford F150 Carpet	65	760	1,082	325	1,082	22	111.4	99.9	Pass
5	Ford F150 Carpet	60	1,018	1,281	325	1,281	16	110.4	94.6	Pass
	Average:	67	762	1,118	325	1,118	23	106.3	94.1	**Pass**
	Standard Deviation:	7	161	137	0.0	137	4.7	4.5	4.5	
1	Ford F150 Headliner	NA	NA	60	30	60	NA	40.8	40.5	Pass
2	Ford F150 Headliner	NA	NA	48	30	48	NA	39.1	38.9	Pass
3	Ford F150 Headliner	NA	NA	46	30	46	NA	39.7	39.4	Pass
4	Ford F150 Headliner	NA	NA	46	30	46	NA	40.0	39.8	Pass
5	Ford F150 Headliner	NA	NA	59	33	59	NA	41.0	40.7	Pass
	Average:	NA	NA	52	31	52	NA	40.1	39.8	**Pass**
	Standard Deviation:	NA	NA	7	1.3	7	NA	0.8	0.7	
1	Ford F150 Seat Cover	28	NA	68	62	68	36	26.1	25.1	Pass
2	Ford F150 Seat Cover	35	NA	44	49	44	NA	25.5	24.9	Pass
3	Ford F150 Seat Cover	32	NA	51	52	51	NA	26.3	25.5	Pass
4	Ford F150 Seat Cover	30	NA	45	49	45	NA	24.1	23.3	Pass
5	Ford F150 Seat Cover	30	NA	43	46	43	NA	28.8	28.0	Pass
	Average:	31	NA	50	52	50	36	26.2	25.4	**Pass**
	Standard Deviation:	3	NA	10	6.2	10	NA	1.7	1.7	
1	Ford F150 Seat Padding	NA	NA	15	29	15	NA	13.4	13.2	Pass
2	Ford F150 Seat Padding	46	NA	96	74	96	43	21.9	20.7	Pass
3	Ford F150 Seat Padding	NA	NA	15	26	15	NA	16.0	15.8	Pass
4	Ford F150 Seat Padding	NA	NA	15	20	15	NA	18.0	17.9	Pass
5	Ford F150 Seat Padding	26	NA	99	111	99	60	19.9	17.8	Pass
	Average:	36	NA	48	52	48	52	17.8	17.1	**Pass**
	Standard Deviation:	14	NA	45	39.4	45	11.9	3.3	2.7	

Table A-4. FMVSS No. 302 results for Honda Civic materials

Test	**Material Description**	$t_{\text{mark 1}}$	$t_{\text{mark 2}}$	t_{fo}	D_{max}	t_{Dmax}	**Burn**	m_i	m_f	**P/F**
No.		**(s)**	**(s)**	**(s)**	**(mm)**	**(s)**	**Rate**	**(g)**	**(g)**	
1	Civic Carpet	40	488	736	325	645	34	55.2	39.5	Pass
2	Civic Carpet	35	NA	485	197	477	22	58.5	50.6	Pass
3	Civic Carpet	35	NA	186	155	186	46	57.1	52.9	Pass
4	Civic Carpet	40	NA	524	240	513	26	52.0	42.6	Pass
5	Civic Carpet	40	434	565	330	565	39	51.7	36.2	Pass
Average:		38	461	499	249	477	33	54.9	44.3	**Pass**
Standard Deviation:		3	38	200	77.4	175	10	3.0	7.2	
1	Civic Headliner	NA	NA	73	36	73	NA	32.6	32.4	Pass
2	Civic Headliner	NA	NA	67	30	67	NA	33.2	33.0	Pass
3	Civic Headliner	75	NA	80	40	80	24	32.2	32.0	Pass
4	Civic Headliner	NA	NA	68	35	68	NA	32.0	31.7	Pass
5	Civic Headliner	60	NA	90	45	90	14	32.4	32.1	Pass
Average:		68	NA	76	37	76	19	32.5	32.2	**Pass**
Standard Deviation:		11	NA	10	5.6	10	7.1	0.5	0.5	
1	Civic Seat Cover	20	NA	47	61	45	NA	13.4	13.0	Pass
2	Civic Seat Cover	NA	NA	24	30	2,010	NA	13.4	13.2	Pass
3	Civic Seat Cover	NA	NA	10	27	15	NA	14.4	14.3	Pass
4	Civic Seat Cover	NA	NA	20	27	14	NA	14.7	14.6	Pass
5	Civic Seat Cover	NA	NA	16	29	78	NA	14.5	14.3	Pass
Average:		20	NA	23	35	432	NA	14.1	13.9	**Pass**
Standard Deviation:		NA	NA	14	14.7	882	NA	0.6	0.7	
1	Civic Seat Padding	NA	NA	15	23	15	NA	20.6	20.5	Pass
2	Civic Seat Padding	NA	NA	14	15	14	NA	19.3	19.2	Pass
3	Civic Seat Padding	NA	NA	12	18	12	NA	20.9	20.8	Pass
4	Civic Seat Padding	NA	NA	12	20	12	NA	23.9	23.8	Pass
5	Civic Seat Padding	NA	NA	15	23	15	NA	20.0	19.9	Pass
Average:		NA	NA	14	20	14	NA	20.9	20.8	**Pass**
Standard Deviation:		NA	NA	2	3.4	2	NA	1.8	1.8	

Table A-5. FMVSS No. 302 results for Toyota Camry materials

Test No.	**Material Description**	$t_{mark\ 1}$ **(s)**	$t_{mark\ 2}$ **(s)**	t_{fo} **(s)**	D_{max} **(mm)**	t_{Dmax} **(s)**	**Burn Rate**	m_i **(g)**	m_f **(g)**	**P/F**
1	Camry Carpet	42	NA	297	180	265	38	31.1	26.7	Pass
2	Camry Carpet	49	NA	134	80	109	42	31.0	29.5	Pass
3	Camry Carpet	48	NA	134	90	117	45	30.5	28.7	Pass
4	Camry Carpet	47	NA	167	95	167	29	30.3	28.9	Pass
5	Camry Carpet	46	NA	186	128	186	39	30.4	27.9	Pass
Average:		46	NA	184	115	169	38	30.7	28.3	**Pass**
Standard Deviation:		3	NA	67	40.8	63	6.3	0.4	1.1	
1	Camry Headliner	41	NA	252	122	252	24	27.7	26.3	Pass
2	Camry Headliner	36	NA	423	206	423	26	27.3	24.8	Pass
3	Camry Headliner	37	582	693	321	693	28	28.0	23.8	Pass
4	Camry Headliner	45	NA	438	205	438	25	27.3	25.0	Pass
5	Camry Headliner	43	NA	409	187	409	24	28.4	26.2	Pass
Average:		40	582	443	208	443	26	27.7	25.2	**Pass**
Standard Deviation:		4	NA	159	71.8	159	1.6	0.5	1.0	
1	Camry Seat Cover	28	NA	138	142	138	57	19.5	17.1	Pass
2	Camry Seat Cover	27	NA	85	105	85	69	19.5	17.7	Pass
3	Camry Seat Cover	27	NA	224	240	224	62	19.4	14.9	Pass
4	Camry Seat Cover	NA	NA	32	30	32	NA	17.3	17.1	Pass
5	Camry Seat Cover	26	NA	33	40	33	NA	17.3	16.9	Pass
Average:		27	NA	102	111	102	63	18.6	16.7	**Pass**
Standard Deviation:		1	NA	81	85.5	81	6.4	1.2	1.1	
1	Camry Seat Padding	37	NA	105	80	102	39	18.3	16.0	Pass
2	Camry Seat Padding	NA	NA	22	25	22	NA	21.7	21.5	Pass
3	Camry Seat Padding	NA	NA	21	30	21	NA	15.3	15.1	Pass
4	Camry Seat Padding	NA	NA	16	27	16	NA	15.5	15.3	Pass
5	Camry Seat Padding	27	NA	68	69	63	52	19.1	17.8	Pass
Average:		32	NA	46	46	45	45	18.0	17.1	**Pass**
Standard Deviation:		7	NA	39	26.2	37	9.1	2.7	2.6	

Appendix B: MCC Test Results for Task 2 Materials

Results Description	Appendix B Table Number
MCC Results for Chevrolet Equinox Materials	B-1
MCC Results for Dodge Grand Caravan Materials	B-2
MCC Results for Ford F150 Materials	B-3
MCC Results for Honda Civic Materials	B-4
MCC Results for Toyota Camry Materials	B-5

Table B-1. MCC results for Chevrolet Equinox materials

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Equinox Carpet	4.07	0.96	255	253	465	25.7	0.236	33.6
2	Equinox Carpet	4.08	0.91	221	219	468	24.2	0.223	31.1
3	Equinox Carpet	4.03	0.86	367	363	450	26.2	0.213	33.3
Average:		4.06	0.91	281	278	461	25.35	0.22	32.7
Standard Deviation:		0.03	0.05	76.4	75.6	9.2	1.05	0.01	1.38
1	Equinox Headliner	4.05	0.77	186	184	391	19.5	0.190	24.1
2	Equinox Headliner	4.01	1.30	147	146	429	14.8	0.324	21.9
3	Equinox Headliner	4.04	1.59	152	151	434	12.9	0.394	21.3
Average:		4.03	1.22	162	161	418	15.8	0.30	22.5
Standard Deviation:		0.02	0.42	21.3	20.3	23.6	3.40	0.10	1.47
1	Equinox Seat Cover	3.00	0.11	210	209	402	22.7	0.037	23.6
2	Equinox Seat Cover	3.07	0.16	237	236	443	21.0	0.052	22.1
3	Equinox Seat Cover	3.03	0.12	246	244	442	22.3	0.040	23.2
Average:		3.03	0.13	231	229	429	21.98	0.04	23.0
Standard Deviation:		0.04	0.03	18.8	18.4	23.0	0.90	0.01	0.75
1	Equinox Seat Padding	3.01	0.10	514	511	404	25.0	0.033	25.8
2	Equinox Seat Padding	3.01	0.04	510	502	401	28.3	0.013	28.7
3	Equinox Seat Padding	3.02	0.04	523	520	405	27.4	0.013	27.7
Average:		3.01	0.06	516	511	403	26.9	0.02	27.4
Standard Deviation:		0.01	0.03	6.2	9.0	2.2	1.71	0.01	1.45

Table B-2. MCC results for Dodge Grand Caravan materials

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Grand Caravan Carpet	4.03	0.18	322	318	482	26.4	0.045	27.6
2	Grand Caravan Carpet	4.06	0.45	252	250	421	22.2	0.111	25.0
3	Grand Caravan Carpet	4.00	0.33	414	413	485	26.5	0.083	28.9
	Average:	4.03	0.32	329	327	463	25.1	0.08	27.2
	Standard Deviation:	0.03	0.14	81.5	82.2	36.1	2.43	0.03	1.98
1	Grand Caravan Headliner	4.07	0.28	214	213	395	20.4	0.069	22.0
2	Grand Caravan Headliner	4.07	0.25	210	208	430	20.3	0.061	21.6
3	Grand Caravan Headliner	4.00	0.24	221	218	395	20.9	0.060	22.3
	Average:	4.05	0.26	215	213	406	20.5	0.06	21.9
	Standard Deviation:	0.04	0.02	5.5	5.2	20.2	0.35	0.00	0.34
1	Grand Caravan Seat Cover	4.08	0.12	316	314	424	22.9	0.029	23.5
2	Grand Caravan Seat Cover	4.06	0.56	320	319	425	22.3	0.138	25.9
3	Grand Caravan Seat Cover	4.03	0.21	295	292	421	21.8	0.052	23.0
	Average:	4.06	0.30	310	308	423	22.31	0.07	24.1
	Standard Deviation:	0.03	0.23	13.4	14.1	2.1	0.53	0.06	1.52
1	Grand Caravan Padding	4.04	0.21	504	499	411	23.4	0.052	24.7
2	Grand Caravan Padding	4.00	0.14	511	506	406	23.9	0.035	24.7
3	Grand Caravan Padding	4.00	0.14	525	520	410	23.2	0.035	24.0
	Average:	4.01	0.16	513	508	409	23.5	0.04	24.5
	Standard Deviation:	0.02	0.04	10.5	10.9	2.5	0.36	0.01	0.41

Note: Padding refers to seat padding.

Table B-3. MCC results for Ford F150 materials

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	F150 Carpet	4.05	0.42	176	173	431	18.5	0.104	20.7
2	F150 Carpet	4.04	0.48	143	142	431	15.2	0.119	17.3
3	F150 Carpet	4.07	0.49	166	164	428	19.3	0.120	22.0
Average:		4.05	0.46	162	160	430	17.71	0.11	20.0
Standard Deviation:		0.02	0.04	16.8	16.1	1.5	2.17	0.01	2.42
1	F150 Headliner	3.02	0.23	290	285	394	23.4	0.076	25.3
2	F150 Headliner	3.03	0.42	262	259	396	21.9	0.139	25.4
3	F150 Headliner	3.06	0.49	210	208	436	19.3	0.160	23.0
Average:		3.04	0.38	254	251	409	21.5	0.12	24.6
Standard Deviation:		0.02	0.13	40.4	39.0	23.6	2.06	0.04	1.36
1	F150 Seat Cover	4.01	0.25	220	218	394	21.7	0.062	23.2
2	F150 Seat Cover	4.02	0.25	250	246	389	22.3	0.062	23.8
3	F150 Seat Cover	4.06	0.21	322	320	392	23.3	0.052	24.6
Average:		4.03	0.24	264	261	392	22.46	0.06	23.9
Standard Deviation:		0.03	0.02	52.2	52.5	2.7	0.82	0.01	0.73
1	F150 Seat Padding	3.02	0.23	427	423	405	26.1	0.076	28.2
2	F150 Seat Padding	3.04	0.14	400	394	400	26.0	0.046	27.3
3	F150 Seat Padding	3.07	0.20	398	396	407	25.9	0.065	27.7
Average:		3.04	0.19	408	404	404	26.0	0.06	27.7
Standard Deviation:		0.03	0.05	16.5	15.9	3.3	0.10	0.02	0.45

Table B-4. MCC results for Honda Civic materials

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Civic Carpet	4.09	0.44	371	365	448	18.3	0.108	20.5
2	Civic Carpet	4.07	0.49	373	369	457	19.2	0.120	21.8
3	Civic Carpet	4.08	0.56	351	346	440	17.2	0.137	20.0
Average:		4.08	0.50	365	360	448	18.2	0.12	20.8
Standard Deviation:		0.01	0.06	12.3	12.3	8.4	0.95	0.01	0.91
1	Civic Headliner	3.01	1.07	104	104	399	14.5	0.355	22.4
2	Civic Headliner	3.02	0.52	127	125	395	18.7	0.172	22.6
3	Civic Headliner	3.06	0.61	98	96	425	15.3	0.199	19.1
Average:		3.03	0.73	110	108	406	16.2	0.24	21.4
Standard Deviation:		0.03	0.30	15.3	14.9	16.2	2.25	0.10	1.97
1	Civic Seat Cover	3.02	0.31	286	282	361	20.5	0.103	22.9
2	Civic Seat Cover	3.03	0.22	289	286	367	22.7	0.073	24.5
3	Civic Seat Cover	3.00	0.35	292	289	363	21.5	0.117	24.4
Average:		3.02	0.29	289	286	364	21.59	0.10	23.9
Standard Deviation:		0.02	0.07	3.0	3.2	3.1	1.08	0.02	0.89
1	Civic Padding	3.01	0.07	589	584	406	27.7	0.023	28.4
2	Civic Padding	3.06	0.01	592	587	407	28.6	0.004	28.8
3	Civic Padding	3.02	0.07	578	573	407	27.7	0.023	28.4
Average:		3.03	0.05	586	581	407	28.0	0.02	28.5
Standard Deviation:		0.03	0.03	7.2	7.1	0.3	0.54	0.01	0.22

Note: Padding refers to seat padding.

Table B-5. MCC results for Toyota Camry materials

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Camry Carpet	5.02	0.31	562	558	482	32.0	0.062	34.1
2	Camry Carpet	5.00	0.23	576	572	474	32.7	0.046	34.3
3	Camry Carpet	5.08	0.28	415	412	460	25.9	0.055	27.4
Average:		5.03	0.27	518	514	472	30.21	0.05	31.9
Standard Deviation:		0.04	0.04	89.3	88.5	10.8	3.75	0.01	3.93
1	Camry Headliner	4.08	1.56	142	141	427	13.4	0.382	21.7
2	Camry Headliner	4.08	1.56	61	61	423	8.9	0.382	14.4
3	Camry Headliner	4.02	1.18	144	143	418	15.9	0.294	22.5
Average:		4.06	1.43	116	115	423	12.7	0.35	19.5
Standard Deviation:		0.03	0.22	47.1	46.9	4.4	3.56	0.05	4.47
1	Camry Seat Cover	4.05	0.23	273	271	441	22.5	0.057	23.9
2	Camry Seat Cover	4.08	0.21	284	282	446	23.2	0.051	24.5
3	Camry Seat Cover	4.08	0.28	256	253	400	22.6	0.069	24.2
Average:		4.07	0.24	271	269	429	22.76	0.06	24.2
Standard Deviation:		0.02	0.04	14.2	14.7	25.5	0.38	0.01	0.29
1	Camry Seat Padding	4.05	0.23	537	532	403	29.3	0.057	31.1
2	Camry Seat Padding	4.08	0.21	526	521	404	27.7	0.051	29.2
3	Camry Seat Padding	4.08	0.28	526	522	405	27.7	0.069	29.7
Average:		4.07	0.24	530	525	404	28.2	0.06	30.0
Standard Deviation:		0.02	0.04	6.4	6.2	0.8	0.95	0.01	0.99

Appendix C: FMVSS No. 302 Test Results for Additional Task 3 Materials

Results Description	Appendix C Table Number
FMVSS No. 302 Results for Additional Task 3 Materials	C-1

Table C-1. FMVSS 302 Results for Additional Task 3 Materials

Test No.	**Material Description**	**$t_{mark\ 1}$ (s)**	**$t_{mark\ 2}$ (s)**	**t_{fo} (s)**	**D_{max} (mm)**	**t_{Dmax} (s)**	**Burn Rate**	**m_i (g)**	**m_f (g)**	**P/F**
1	Caravan Seat Upholstery	NA	NA	34	33	34	NA	39.1	38.7	Pass
2	Caravan Seat Upholstery	28	NA	544	257	544	25	41.7	31.4	Pass
3	Caravan Seat Upholstery	40	NA	323	122	256	23	44.9	39.7	Pass
4	Caravan Seat Upholstery	31	NA	91	63	81	30	35.1	33.7	Pass
5	Caravan Seat Upholstery	31	502	646	328	646	32	36.5	24.8	Pass
Average:		33	502	328	161	312	28	39.5	33.6	**Pass**
Standard Deviation:		5	NA	269	127.1	273	4.1	4.0	6.0	
1	Caravan Visor	21	NA	24	43	24	NA	33.4	24.7	Pass
2	Caravan Visor	48	NA	215	88	215	18	35.2	31.1	Pass
3	Caravan Visor	56	NA	220	115	220	28	36.0	26.9	Pass
4	Caravan Visor	54	NA	107	101	107	71	34.6	25.5	Pass
5	Caravan Visor	21	NA	23	65	23	NA	35.9	26.5	Pass
Average:		40	NA	118	82	118	39	35.0	26.9	**Pass**
Standard Deviation:		18	NA	97	28.7	97	28.3	1.1	2.5	
1	Malibu Door Trim Panel	105	NA	227	128	227	44	78.3	72.6	Pass
2	Malibu Door Trim Panel	89	NA	260	152	260	40	78.4	72.0	Pass
3	Malibu Door Trim Panel	120	NA	205	108	205	49	78.9	74.0	Pass
4	Malibu Door Trim Panel	110	NA	251	155	251	50	79.2	72.0	Pass
5	Malibu Door Trim Panel	106	NA	216	118	216	44	80.7	75.4	Pass
Average:		106	NA	232	132	232	45	79.1	73.2	**Pass**
Standard Deviation:		11	NA	23	20.7	23	4.2	1.0	1.4	
1	Malibu Instrument Panel	231	NA	1061	260	800	23	122.0	97.1	Pass
2	Malibu Instrument Panel	183	677	1165	325	821	31	105.5	74.9	Pass
3	Malibu Instrument Panel	182	695	1104	325	844	30	102.3	71.9	Pass
4	Malibu Instrument Panel	182	705	1110	328	819	29	105.2	76.0	Pass
5	Malibu Instrument Panel	183	726	1248	325	884	28	106.4	77.6	Pass
Average:		192	701	1138	313	834	28	108.3	79.5	**Pass**
Standard Deviation:		22	20	72	29.4	32	2.9	7.8	10.1	
1	Civic Carpet By The Yard	71	582	688	325	668	30	33.4	24.7	Pass
2	Civic Carpet By The Yard	85	NA	308	150	308	30	35.2	31.1	Pass
3	Civic Carpet By The Yard	84	604	696	325	680	29	36.0	26.9	Pass
4	Civic Carpet By The Yard	83	551	646	325	626	33	34.6	25.5	Pass
5	Civic Carpet By The Yard	78	653	751	325	751	27	35.9	26.5	Pass
Average:		80	598	618	290	607	30	35.0	26.9	**Pass**
Standard Deviation:		6	43	177	78.3	173	2.2	1.1	2.5	
1	Civic Molded Carpet	63	538	660	325	623	32	33.4	24.2	Pass
2	Civic Molded Carpet	54	460	559	325	540	38	32.5	23.7	Pass
3	Civic Molded Carpet	68	467	619	330	558	38	33.8	24.4	Pass
4	Civic Molded Carpet	66	517	645	330	610	34	34.3	24.7	Pass
5	Civic Molded Carpet	65	445	536	325	536	40	31.9	23.0	Pass
Average:		63	485	604	327	573	36	33.2	24.0	**Pass**
Standard Deviation:		5	40	54	2.7	40	3.3	1.0	0.6	

Appendix D: MCC Test Results for All Task 3 Materials

Results Description	Appendix D Table Number
Task 3 MCC Results for Equinox, F150, and Civic Materials	D-1
Task 3 MCC Results for Camry and Grand Caravan Materials	D-2
Task 3 MCC Results for Malibu and Aftermarket Materials	D-3

Table D-1. Task 3 ASTM D7309 Results for Equinox, F150 and Civic Materials (Tests 1-6)

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Equinox Seat Cover	3.00	0.11	210	209	402	22.7	0.037	23.6
2	Equinox Seat Cover	3.07	0.16	237	236	443	21.0	0.052	22.1
3	Equinox Seat Cover	3.03	0.12	246	244	442	22.3	0.040	23.2
4	Equinox Seat Cover	3.01	0.17	255	254	450	22.0	0.056	23.3
5	Equinox Seat Cover	3.03	0.07	245	243	404	24.7	0.023	25.3
6	Equinox Seat Cover	3.04	0.10	204	202	429	23.1	0.033	23.9
	Average:	3.03	0.12	233	231	428	22.6	0.040	23.6
	Standard Deviation:	0.02	0.04	21	21	20	1.26	0.012	1.05
1	F150 Seat Padding	3.02	0.23	427	423	405	26.1	0.076	28.2
2	F150 Seat Padding	3.04	0.14	400	394	400	26.0	0.046	27.3
3	F150 Seat Padding	3.07	0.20	398	396	407	25.9	0.065	27.7
4	F150 Seat Padding	3.05	0.07	409	402	406	27.2	0.023	27.8
5	F150 Seat Padding	3.05	0.08	409	399	405	26.6	0.026	27.3
6	F150 Seat Padding	3.08	0.12	405	405	410	26.0	0.039	27.0
	Average:	3.05	0.14	408	403	406	26.3	0.046	27.5
	Standard Deviation:	0.02	0.06	11	10	3	0.49	0.021	0.43
1	Civic Carpet	4.09	0.44	371	365	448	18.3	0.108	20.5
2	Civic Carpet	4.07	0.49	373	369	457	19.2	0.120	21.8
3	Civic Carpet	4.08	0.56	351	346	440	17.2	0.137	20.0
4	Civic Carpet	4.07	0.47	359	355	442	18.6	0.115	21.0
5	Civic Carpet	4.08	0.42	372	370	457	21.6	0.103	24.0
6	Civic Carpet	4.05	0.36	396	392	452	21.9	0.089	24.1
	Average:	4.07	0.46	370	366	449	19.5	0.112	21.9
	Standard Deviation:	0.01	0.07	15	16	7	1.87	0.016	1.76
1	Civic Seat Cover	3.02	0.31	286	282	361	20.5	0.103	22.9
2	Civic Seat Cover	3.03	0.22	289	286	367	22.7	0.073	24.5
3	Civic Seat Cover	3.00	0.35	292	289	363	21.5	0.117	24.4
4	Civic Seat Cover	4.04	0.22	250	248	365	21.6	0.054	22.9
5	Civic Seat Cover	4.06	0.20	338	331	364	20.0	0.049	21.1
6	Civic Seat Cover	4.04	0.19	343	341	364	19.8	0.047	20.7
	Average:	3.53	0.25	300	296	364	21.0	0.074	22.7
	Standard Deviation:	0.56	0.07	35	34	2	1.12	0.030	1.59

Table D-2. Task 3 ASTM D7309 Results for Camry and Grand Caravan Materials (Tests 1-6)

Test No.	**Material Description**	m_i **(mg)**	m_f **(mg)**	η_c **(J/g·K)**	Q_{max} **(W/g)**	T_{max} **(°C)**	h_c **(kJ/g)**	Y_p **(g/g)**	$h_{c,gas}$ **(kJ/g)**
1	Camry Seat Cover	4.05	0.23	273	271	441	22.5	0.057	23.9
2	Camry Seat Cover	4.08	0.21	284	282	446	23.2	0.051	24.5
3	Camry Seat Cover	4.08	0.28	256	253	400	22.6	0.069	24.2
4	Camry Seat Cover	4.04	0.22	297	296	444	21.6	0.054	22.8
5	Camry Seat Cover	4.06	0.20	253	252	405	23.0	0.049	24.1
6	Camry Seat Cover	4.04	0.19	277	276	404	23.0	0.047	24.1
Average:		4.06	0.22	273	272	423	22.6	0.055	23.9
Standard Deviation:		0.02	0.03	17	17	22	0.58	0.008	0.59
1	Camry Seat Padding	4.05	0.23	537	532	403	29.3	0.057	31.1
2	Camry Seat Padding	4.08	0.21	526	521	404	27.7	0.051	29.2
3	Camry Seat Padding	4.08	0.28	526	522	405	27.7	0.069	29.7
4	Camry Seat Padding	4.00	0.08	493	488	398	27.0	0.020	27.5
5	Camry Seat Padding	4.06	0.04	493	489	400	27.4	0.010	27.7
6	Camry Seat Padding	4.06	0.05	489	483	401	26.9	0.012	27.3
Average:		4.06	0.15	511	506	402	27.7	0.037	28.8
Standard Deviation:		0.03	0.10	21	22	3	0.87	0.025	1.50
1	Grand Caravan Visor Foam	4.07	0.28	214	213	395	20.4	0.069	22.0
2	Grand Caravan Visor Foam	4.07	0.25	210	208	430	20.3	0.061	21.6
3	Grand Caravan Visor Foam	4.00	0.24	221	218	395	20.9	0.060	22.3
4	Grand Caravan Visor Foam	4.06	0.29	224	223	430	20.0	0.071	21.6
5	Grand Caravan Visor Foam	4.03	0.24	208	207	392	20.6	0.060	21.9
6	Grand Caravan Visor Foam	4.04	0.13	246	244	401	22.0	0.032	22.7
Average:		4.05	0.24	220	219	407	20.7	0.059	22.0
Standard Deviation:		0.03	0.06	14	14	18	0.69	0.014	0.43
1	Gr. Caravan Visor Plastic	4.01	0.00	1141	1132	470	43.1	0.000	43.1
2	Gr. Caravan Visor Plastic	4.02	0.00	1116	1107	468	42.6	0.000	42.6
3	Gr. Caravan Visor Plastic	4.08	0.00	1091	1082	470	43.0	0.000	43.0
4	Gr. Caravan Visor Plastic	4.06	0.00	1107	1095	468	43.5	0.000	43.5
5	Gr. Caravan Visor Plastic	4.03	0.03	1116	1108	470	42.7	0.007	43.0
6	Gr. Caravan Visor Plastic	4.07	0.00	1197	1192	480	44.0	0.000	44.0
Average:		4.05	0.01	1128	1119	471	43.1	0.001	43.2
Standard Deviation:		0.03	0.01	38	39	5	0.54	0.003	0.49

Table D-3. Task 3 ASTM D7309 Results for Malibu and Civic Aftermarket Materials (Tests 1-6)

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	Malibu Door Trim Panel	4.08	0.54	1012	1006	480	36.3	0.132	41.8
2	Malibu Door Trim Panel	4.09	0.55	1012	1003	476	35.9	0.134	41.5
3	Malibu Door Trim Panel	4.03	0.55	1013	1002	475	36.2	0.136	41.9
4	Malibu Door Trim Panel	4.07	0.56	1048	1037	479	36.2	0.138	42.0
5	Malibu Door Trim Panel	4.02	0.50	1046	1037	480	36.3	0.124	41.4
6	Malibu Door Trim Panel	4.03	0.59	1055	1049	484	36.7	0.146	43.0
Average:		4.05	0.55	1031	1022	479	36.3	0.135	41.9
Standard Deviation:		0.03	0.03	21	21	3	0.26	0.007	0.57
1	Malibu Instrument Panel	4.01	0.72	881	874	476	33.2	0.180	40.5
2	Malibu Instrument Panel	4.02	0.77	943	933	474	33.2	0.192	41.0
3	Malibu Instrument Panel	4.00	0.77	1013	1002	475	36.2	0.193	44.8
4	Malibu Instrument Panel	4.07	0.74	901	890	475	33.8	0.182	41.4
5	Malibu Instrument Panel	4.04	0.78	939	931	475	33.3	0.193	41.3
6	Malibu Instrument Panel	4.06	0.82	952	935	478	34.5	0.202	43.3
Average:		4.03	0.77	938	927	476	34.0	0.190	42.0
Standard Deviation:		0.03	0.03	46	45	1	1.16	0.008	1.64
1	Aftermarket Carpet BTY	4.01	0.02	440	434	479	33.6	0.005	33.8
2	Aftermarket Carpet BTY	4.07	0.03	407	404	423	28.1	0.007	28.3
3	Aftermarket Carpet BTY	4.02	0.02	433	428	474	34.2	0.005	34.4
4	Aftermarket Carpet BTY	4.01	0.03	394	391	473	30.7	0.007	31.0
5	Aftermarket Carpet BTY	4.05	0.03	341	336	483	31.5	0.007	31.8
6	Aftermarket Carpet BTY	4.07	0.00	406	403	424	30.1	0.000	30.1
Average:		4.04	0.02	403	399	459	31.4	0.005	31.6
Standard Deviation:		0.03	0.01	35	35	28	2.25	0.003	2.26
1	Aftermarket Molded Carpet	4.00	0.00	405	401	479	34.1	0.000	34.1
2	Aftermarket Molded Carpet	4.08	0.00	517	512	487	35.6	0.000	35.6
3	Aftermarket Molded Carpet	4.07	0.02	472	466	476	34.2	0.005	34.4
4	Aftermarket Molded Carpet	4.04	0.00	539	536	479	34.1	0.000	34.1
5	Aftermarket Molded Carpet	4.05	0.00	365	362	484	32.8	0.000	32.8
6	Aftermarket Molded Carpet	4.04	0.00	550	546	474	35.1	0.000	35.1
Average:		4.05	0.00	475	470	480	34.3	0.001	34.3
Standard Deviation:		0.03	0.01	76	75	5	0.98	0.002	0.98

Appendix E: MLC Test Results for Task 4 Materials

Results Description	Appendix E Table Number
MLC Results for Dodge Grand Caravan Carpet	E-1
MLC Results for Honda Civic Carpet	E-2
MLC Results for Chevrolet Equinox Headliner	E-3
MLC Results for Honda Civic Headliner	E-4
MLC Results for Chevrolet Equinox Seat Cover	E-5
MLC Results for Toyota Camry Seat Cover	E-6
MLC Results for Ford F150 Seat Padding	E-7
MLC Results for Toyota Camry Seat Padding	E-8

Table E-1. MLC Task 4 results for Dodge Grand Caravan carpet

Make, Model, Article	Heat Flux (kW/m²)	Test No.	m_i (g)	ML_{total} (g)	t_{ig} (s)	MLR_{avg} (g/m²s)	MLR_{max} (g/m²s)	HRR_{180s} (kW/m²)	HRR_{max} (kW/m²)	THR (MJ/m²)
Dodge Grand Caravan Carpet	25	1	15.50	14.80	73	7.38	21.28	126.4	198.8	24.84
		2	16.07	15.33	52	8.26	22.11	128.8	189.7	24.93
	Average:		15.79	15.07	63	7.82	21.70	127.6	194.3	24.89
	Standard Dev:		0.40	0.37	15	0.62	0.59	1.7	6.4	0.06
	35	1	16.25	15.56	35	5.95	24.48	143.0	220.1	30.70
		2	16.48	15.87	31	8.23	23.92	151.3	237.4	29.12
	Average:		16.37	15.72	33	7.09	24.20	147.2	228.8	29.91
	Standard Dev:		0.16	0.22	3	1.61	0.40	5.9	12.2	1.12
	50	1	16.43	16.43	27	12.79	28.10	178.5	361.5	30.37
		2	17.49	16.97	25	10.54	29.75	196.8	356.7	35.61
	Average:		16.96	16.70	26	11.67	28.93	187.7	359.1	32.99
	Standard Dev:		0.75	0.38	1	1.59	1.17	12.9	3.4	3.71

Table E-2. MLC Task 4 results for Honda Civic carpet

Make, Model, Article	Heat Flux (kW/m²)	Test No.	m_i (g)	ML_{total} (g)	t_{ig} (s)	MLR_{avg} (g/m²s)	MLR_{max} (g/m²s)	HRR_{180s} (kW/m²)	HRR_{max} (kW/m²)	THR (MJ/m²)
Honda Civic Carpet	25	1	18.20	16.68	224	9.11	24.74	99.3	175.7	18.73
		2	16.59	15.08	77	6.69	23.14	96.8	165.0	19.14
	Average:		17.40	15.88	151	7.90	23.94	98.1	170.4	18.94
	Standard Dev:		1.14	1.13	104	1.71	1.13	1.8	7.6	0.29
	35	1	14.42	14.26	41	6.46	23.35	99.7	182.3	20.33
		2	13.38	13.32	30	5.54	27.32	91.6	163.5	19.24
	Average:		13.90	13.79	36	6.00	25.34	95.7	172.9	19.79
	Standard Dev:		0.74	0.66	8	0.65	2.81	5.7	13.3	0.77
	50	1	14.49	14.49	29	12.29	35.74	143.6	378.7	23.45
		2	17.86	17.86	24	13.71	45.66	166.2	367.5	28.08
	Average:		16.18	16.18	27	13.00	40.70	154.9	373.1	25.77
	Standard Dev:		2.38	2.38	4	1.00	7.01	16.0	7.9	3.27

Table E-3. MLC Task 4 results for Chevrolet Equinox headliner

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m$_i$ (g)**	**ML$_{total}$ (g)**	**t$_{ig}$ (s)**	**MLR$_{avg}$ (g/m^{2}s)**	**MLR$_{max}$ (g/m^{2}s)**	**HRR$_{180s}$ (kW/m^2)**	**HRR$_{max}$ (kW/m^2)**	**THR (MJ/m^2)**
Chevrolet Equinox Headliner	35	1	8.76	4.78	45	11.56	21.18	N/A	87.8	3.07
		2	9.12	5.12	27	9.38	33.83	26.9	100.4	4.35
	Average:		8.94	4.95	36	10.47	27.51	26.9	94.1	3.71
	Standard Dev:		0.25	0.24	13	1.54	8.94	N/A	8.9	0.91
	50	1	9.77	7.13	14	6.23	33.11	49.4	163.8	8.56
		2	9.20	6.61	13	7.36	29.96	61.0	177.7	9.45
	Average:		9.49	6.87	14	6.80	31.54	55.2	170.8	9.01
	Standard Dev:		0.40	0.37	1	0.80	2.23	8.2	9.8	0.63

Table E-4. MLC Task 4 results for Honda Civic headliner

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m$_i$ (g)**	**ML$_{total}$ (g)**	**t$_{ig}$ (s)**	**MLR$_{avg}$ (g/m^{2}s)**	**MLR$_{max}$ (g/m^{2}s)**	**HRR$_{180s}$ (kW/m^2)**	**HRR$_{max}$ (kW/m^2)**	**THR (MJ/m^2)**
Honda Civic Headliner	25	1	9.43	3.58	56	7.68	11.57	N/A	65.5	2.50
		2	9.19	4.07	40	8.26	11.73	24.2	70.3	2.94
	Average:		9.31	3.83	48	7.97	11.65	24.2	67.9	2.72
	Standard Dev:		0.17	0.35	11	0.41	0.11	N/A	3.4	0.31
	35	1	9.09	4.94	21	10.40	23.14	N/A	103.8	4.22
		2	9.20	4.98	20	9.43	23.14	38.3	100.1	4.59
	Average:		9.15	4.96	21	9.92	23.14	38.3	102.0	4.41
	Standard Dev:		0.08	0.03	1	0.69	0.00	N/A	2.6	0.26
	50	1	9.09	6.09	11	6.24	29.49	64.1	160.2	9.61
		2	9.36	6.13	8	3.02	30.37	63.7	166.2	12.42
	Average:		9.23	6.11	10	4.63	29.93	63.9	163.2	11.02
	Standard Dev:		0.19	0.03	2	2.28	0.62	0.3	4.2	1.99

Table E-5. MLC Task 4 results for Chevrolet Equinox seat cover

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m_i (g)**	**ML_{total} (g)**	**t_{ig} (s)**	**MLR_{avg} (g/m^{2}s)**	**MLR_{max} (g/m^{2}s)**	**HRR_{180s} (kW/m^2)**	**HRR_{max} (kW/m^2)**	**THR (MJ/m^2)**
Chevrolet Equinox Seat Cover	25	1	5.87	4.52	100	6.67	14.93	15.4	55.3	2.75
		2	5.82	4.98	95	5.39	15.24	19.7	48.2	3.40
	Average:		5.85	4.75	98	6.03	15.09	17.6	51.8	3.08
	Standard Dev:		0.04	0.33	4	0.91	0.22	3.0	5.0	0.46
	35	1	7.48	6.78	63	6.26	31.87	40.1	98.6	6.68
		2	7.34	6.71	56	8.03	20.87	40.1	106.7	6.33
	Average:		7.41	6.75	60	7.15	26.37	40.1	102.7	6.51
	Standard Dev:		0.10	0.05	5	1.25	7.78	0.0	5.7	0.25
	50	1	7.40	7.03	2	6.19	48.09	72.3	205.3	11.50
		2	7.13	6.84	5	6.94	71.07	70.3	213.3	10.82
	Average:		7.27	6.94	4	6.57	59.58	71.3	209.3	11.16
	Standard Dev:		0.19	0.13	2	0.53	16.25	1.4	5.7	0.48

Table E-6. MLC Task 4 results for Toyota Camry seat cover

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m_i (g)**	**ML_{total} (g)**	**t_{ig} (s)**	**MLR_{avg} (g/m^{2}s)**	**MLR_{max} (g/m^{2}s)**	**HRR_{180s} (kW/m^2)**	**HRR_{max} (kW/m^2)**	**THR (MJ/m^2)**
Toyota Camry Seat Cover	25	1	5.59	5.03	88	5.55	15.34	21.3	60.1	3.77
		2	5.45	4.64	110	5.02	12.97	17.3	52.1	3.15
	Average:		5.52	4.84	99	5.29	14.16	19.3	56.1	3.46
	Standard Dev:		0.10	0.28	16	0.37	1.68	2.8	5.7	0.44
	35	1	5.53	5.04	51	6.16	22.93	31.2	87.5	4.86
		2	5.56	4.70	49	4.95	16.89	23.8	74.8	3.97
	Average:		5.55	4.87	50	5.56	19.91	27.5	81.2	4.42
	Standard Dev:		0.02	0.24	1	0.86	4.27	5.2	9.0	0.63
	50	1	5.77	5.63	24	5.20	21.75	42.6	116.6	6.97
		2	5.62	5.50	24	5.73	22.57	43.4	110.9	6.81
	Average:		5.70	5.57	24	5.47	22.16	43.0	113.8	6.89
	Standard Dev:		0.11	0.09	0	0.37	0.58	0.6	4.0	0.11

Table E-7. MLC Task 4 results for Ford F150 seat padding

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m_i (g)**	**ML_{total} (g)**	**t_{ig} (s)**	**MLR_{avg} (g/m^{2}s)**	**MLR_{max} (g/m^{2}s)**	**HRR_{180s} (kW/m^2)**	**HRR_{max} (kW/m^2)**	**THR (MJ/m^2)**
Ford F150 Seat Padding	25	1	18.49	16.75	61	4.30	16.84	85.2	119.8	25.04
		2	No Ignition							
	Average:		18.49	16.75	61	4.30	16.84	85.2	119.8	25.04
	Standard Dev:		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	35	1	20.64	18.80	47	7.63	21.54	123.5	155.4	30.38
		2	22.41	20.91	53	6.17	15.65	116.1	149.2	33.36
	Average:		21.53	19.86	50	6.90	18.60	119.8	152.3	31.87
	Standard Dev:		1.25	1.49	4	1.03	4.16	5.2	4.4	2.11
	50	1	21.45	21.33	7	9.22	24.85	159.2	228.8	36.79
		2	24.41	23.79	3	9.32	31.20	170.0	223.7	41.35
	Average:		22.93	22.56	5	9.27	28.03	164.6	226.3	39.07
	Standard Dev:		2.09	1.74	3	0.07	4.49	7.6	3.6	3.22

Table E-8. MLC Task 4 results for Toyota Camry seat padding

Make, Model, Article	**Heat Flux (kW/m^2)**	**Test No.**	**m_i (g)**	**ML_{total} (g)**	**t_{ig} (s)**	**MLR_{avg} (g/m^{2}s)**	**MLR_{max} (g/m^{2}s)**	**HRR_{180s} (kW/m^2)**	**HRR_{max} (kW/m^2)**	**THR (MJ/m^2)**
Toyota Camry Seat Padding	25	1	24.00	22.81	28	6.50	15.91	123.8	152.9	40.65
		2	24.05	2.90	16	0.98	14.67	132.0	178.7	40.88
	Average:		24.03	12.86	22	3.74	15.29	127.9	165.8	40.77
	Standard Dev:		0.04	14.08	8	3.90	0.88	5.8	18.2	0.16
	35	1	23.62	22.66	7	9.16	22.21	177.6	242.0	43.32
		2	24.35	23.48	15	9.99	18.96	167.9	200.2	42.06
	Average:		23.99	23.07	11	9.58	20.59	172.8	221.1	42.69
	Standard Dev:		0.52	0.58	6	0.59	2.30	6.9	29.6	0.89
	50	1	22.46	21.27	8	16.67	24.90	251.0	407.5	41.83
		2	22.52	22.06	21	17.41	26.24	246.9	392.4	41.13
	Average:		22.49	21.67	15	17.04	25.57	249.0	400.0	41.48
	Standard Dev:		0.04	0.56	9	0.52	0.95	2.9	10.7	0.49

Appendix F: MCC Test Results for Task 6 Materials

Results Description	Appendix F Table Number
MCC Test Results From Bluebird School Bus Parts	F-1
MCC Test Results From IC School Bus Parts	F-2
MCC Test Results From Motorcoach Bus Parts	F-3

Table F-1. MCC results for Task 6 materials – Bluebird school bus parts

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	BB Ribbed Flooring	4.00	1.01	149	147	312	15.1	0.253	20.2
2	BB Ribbed Flooring	4.03	1.03	153	151	313	14.6	0.256	19.7
3	BB Ribbed Flooring	4.04	1.01	158	156	307	15.1	0.250	20.2
Average:		4.02	1.02	153	151	311	14.95	0.25	20.0
Standard Deviation:		0.02	0.01	4.4	4.3	3.4	0.27	0.00	0.29
1	BB Blue Pigskin	4.05	0.84	116	115	310	14.9	0.207	18.8
2	BB Blue Pigskin	4.08	0.82	119	118	309	15.2	0.201	19.1
3	BB Blue Pigskin	4.03	0.83	116	114	308	15.3	0.206	19.2
Average:		4.05	0.83	117	116	309	15.1	0.20	19.0
Standard Deviation:		0.03	0.01	1.6	1.8	0.6	0.21	0.00	0.22
1	BB High-Back Foam	4.06	0.10	428	422	404	25.5	0.025	26.2
2	BB High-Back Foam	4.00	0.03	388	385	407	25.3	0.008	25.5
3	BB High-Back Foam	4.02	0.00	402	397	412	25.8	0.000	25.8
Average:		4.03	0.04	406	401	408	25.54	0.01	25.8
Standard Deviation:		0.03	0.05	20.0	19.1	3.9	0.28	0.01	0.36
1	BB Seat Bottom Foam	4.03	0.58	368	364	406	23.0	0.144	26.8
2	BB Seat Bottom Foam	4.04	0.57	388	384	409	22.8	0.141	26.5
3	BB Seat Bottom Foam	4.02	0.56	372	365	404	22.3	0.139	25.9
Average:		4.03	0.57	376	371	407	22.7	0.14	26.4
Standard Deviation:		0.01	0.01	10.9	11.3	2.7	0.34	0.00	0.46

Table F-2. MCC results for Task 6 materials – IC school bus parts

Test No.	**Material Description**	**m_i (mg)**	**m_f (mg)**	**η_c (J/g·K)**	**Q_{max} (W/g)**	**T_{max} (°C)**	**h_c (kJ/g)**	**Y_p (g/g)**	**$h_{c,gas}$ (kJ/g)**
1	IC Smooth Flooring	4.05	1.09	144	142	317	13.1	0.269	17.9
2	IC Smooth Flooring	4.04	1.11	149	148	316	13.3	0.275	18.4
3	IC Smooth Flooring	4.02	1.10	146	143	315	13.4	0.274	18.5
	Average:	4.04	1.10	146	145	316	13.28	0.27	18.3
	Standard Deviation:	0.02	0.01	2.2	3.1	0.8	0.20	0.00	0.34
1	IC High-Back Foam	4.05	0.06	476	471	410	26.0	0.015	26.4
2	IC High-Back Foam	4.01	0.05	428	424	412	25.6	0.012	25.9
3	IC High-Back Foam	4.06	0.05	458	453	412	26.5	0.012	26.8
	Average:	4.04	0.05	454	449	411	26.0	0.01	26.4
	Standard Deviation:	0.03	0.01	24.1	23.6	1.3	0.44	0.00	0.45
1	IC Seat Bottom Foam	4.07	0.00	383	380	403	25.5	0.000	25.5
2	IC Seat Bottom Foam	4.04	0.00	438	435	413	27.9	0.000	27.9
3	IC Seat Bottom Foam	4.05	0.00	430	426	412	26.7	0.000	26.7
	Average:	4.05	0.00	417	414	409	26.69	0.00	26.7
	Standard Deviation:	0.02	0.00	29.8	29.5	5.4	1.22	0.00	1.22
1	IC Seat Back Closure	4.04	0.82	126	125	296	15.5	0.203	19.4
2	IC Seat Back Closure	4.03	0.80	129	127	294	15.7	0.199	19.6
3	IC Seat Back Closure	4.00	0.86	117	115	302	14.7	0.215	18.8
	Average:	4.02	0.83	124	123	297	15.3	0.21	19.2
	Standard Deviation:	0.02	0.03	6.3	6.4	4.2	0.50	0.01	0.42

Table F-3. MCC results for Task 6 materials – Motorcoach bus parts

Test No.	Material Description	m_i (mg)	m_f (mg)	η_c (J/g·K)	Q_{max} (W/g)	T_{max} (°C)	h_c (kJ/g)	Y_p (g/g)	$h_{c,gas}$ (kJ/g)
1	MC Plywood	4.09	0.68	153	151	381	10.2	0.166	12.2
2	MC Plywood	4.06	0.83	120	118	379	8.9	0.204	11.2
3	MC Plywood	4.08	0.86	121	119	379	9.1	0.211	11.6
Average:		4.08	0.79	131	129	380	9.40	0.19	11.6
Standard Deviation:		0.02	0.10	18.8	18.5	1.2	0.68	0.02	0.52
1	MC Olefin Seat Cover	4.00	0.57	275	268	445	16.7	0.143	19.5
2	MC Olefin Seat Cover	4.03	0.56	278	276	440	16.9	0.139	19.7
3	MC Olefin Seat Cover	4.03	0.53	288	286	443	17.1	0.132	19.7
Average:		4.02	0.55	280	277	443	16.9	0.14	19.6
Standard Deviation:		0.02	0.02	6.9	9.2	2.4	0.20	0.01	0.11
1	MC Polyester Seat Cover	4.06	0.62	255	253	453	15.9	0.153	18.8
2	MC Polyester Seat Cover	4.07	0.55	257	254	437	15.5	0.135	17.9
3	MC Polyester Seat Cover	4.08	0.50	274	272	445	16.8	0.123	19.2
Average:		4.07	0.56	262	260	445	16.08	0.14	18.6
Standard Deviation:		0.01	0.06	10.9	10.6	8.1	0.70	0.02	0.68
1	MC FTA Foam	4.02	0.27	444	438	407	26.5	0.067	28.4
2	MC FTA Foam	4.05	0.17	447	442	411	24.4	0.042	25.5
3	MC FTA Foam	4.01	0.14	458	452	410	24.4	0.035	25.3
Average:		4.03	0.19	450	444	409	25.1	0.05	26.4
Standard Deviation:		0.02	0.07	7.1	7.2	1.9	1.17	0.02	1.71
1	MC Ribbed Flooring	4.02	2.21	112	111	405	13.5	0.550	30.0
2	MC Ribbed Flooring	4.07	2.25	115	113	401	14.5	0.553	32.4
3	MC Ribbed Flooring	4.03	2.23	118	116	401	14.6	0.553	32.6
Average:		4.04	2.23	115	113	402	14.2	0.55	31.7
Standard Deviation:		0.03	0.02	2.6	2.4	2.0	0.60	0.00	1.48

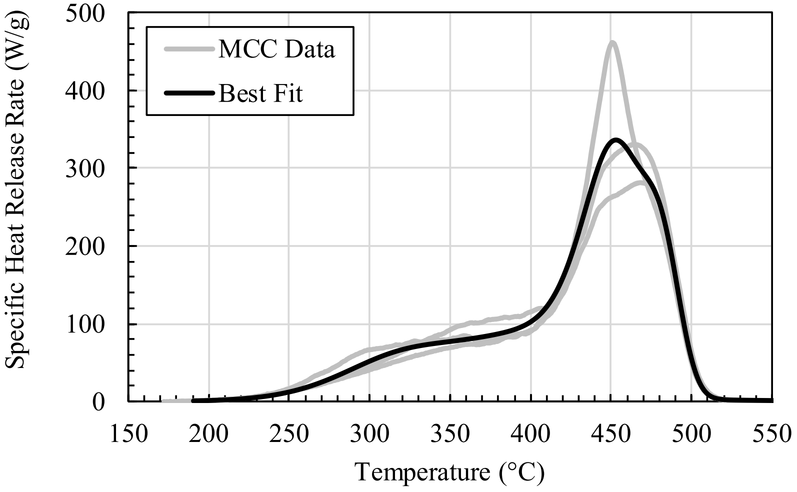
Appendix G: Arrhenius Model Parameters for Task 2 Materials

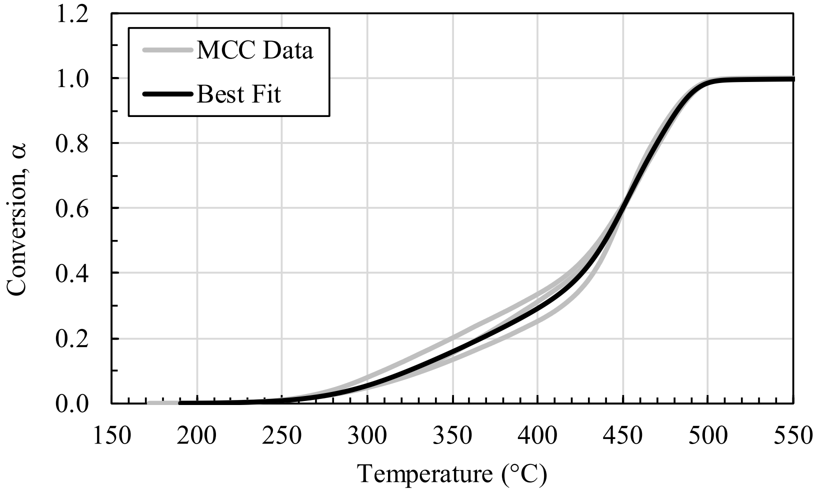
Chevy Equinox Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.07	4.08	4.03				4.06	0.026
m_f (mg)	0.96	0.91	0.86				0.91	0.050
η_c (J/g·K)	255	221	367				281	76.4
Q_{max} (W/g)	253	219	363				278	75.6
T_{max} (°C)	465	468	450				461	9.2
h_c (kJ/g)	25.7	24.2	26.2				25.3	1.05
Y_p (g/g)	0.236	0.223	0.213				0.22	0.011
$h_{c,gas}$ (kJ/g)	33.6	31.1	33.3				32.7	1.38

	c_1	c_2	c_3	c_4
Test 1	0.173	0.178	0.242	0.407
Test 2	0.202	0.169	0.264	0.365
Test 3	0.264	0.112	0.317	0.307
Test 4				
Test 5				
Test 6				
Average	0.213	0.153	0.275	0.359
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	274	300	489	0.989
Test 2	257	285	490	0.992
Test 3	275	301	487	0.990
Test 4				
Test 5				
Test 6				
Average	269	295	489	0.990

	R1	R2	R3	R4
A (1/s)	7.07E+06	1.37E+07	5.22E+17	1.10E+18
E (kJ/mol)	96	110	261	276
n	2.38	1.29	1.07	1.08

Physical Properties	
ρ (kg/m^3)	382
δ (mm)	7.26





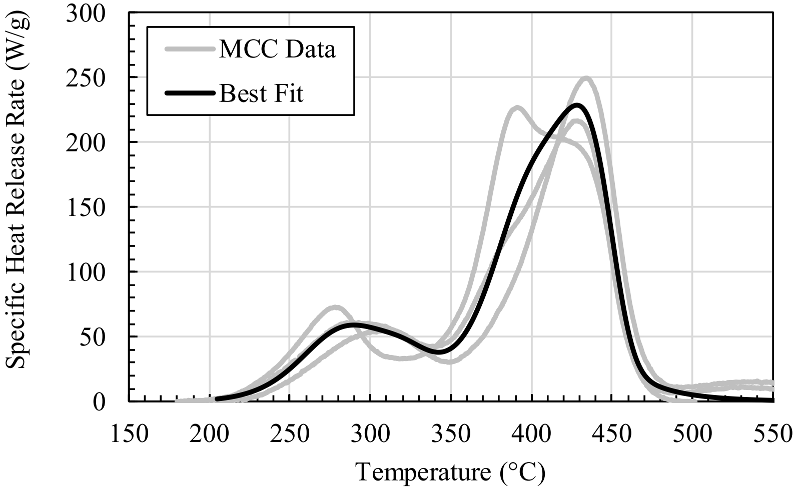
Chevy Equinox Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.01	4.04				4.03	0.021
m_f (mg)	0.77	1.30	1.59				1.22	0.416
η_c (J/g·K)	186	147	152				162	21.3
Q_{max} (W/g)	184	146	151				161	20.3
T_{max} (°C)	391	429	434				418	23.6
h_c (kJ/g)	19.5	14.8	12.9				15.8	3.40
Y_p (g/g)	0.190	0.324	0.394				0.30	0.103
$h_{c,gas}$ (kJ/g)	24.1	21.9	21.3				22.5	1.47

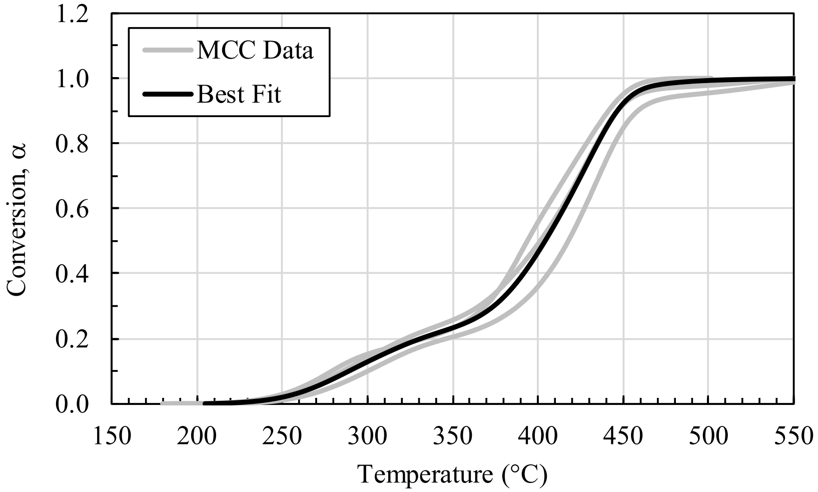
	c_1	c_2	c_3	c_4
Test 1	0.177	0.036	0.415	0.371
Test 2	0.206	0.035	0.416	0.343
Test 3	0.209	0.036	0.477	0.278
Test 4				
Test 5				
Test 6				
Average	0.197	0.036	0.436	0.331

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	238	261	450	0.987
Test 2	247	265	458	0.995
Test 3	261	278	491	0.994
Test 4				
Test 5				
Test 6				
Average	249	268	466	0.992

	R1	R2	R3	R4
A (1/s)	3.80E+10	3.74E+17	2.16E+15	2.72E+16
E (kJ/mol)	127	213	214	239
n	2.18	1.72	2.29	1.08

Physical Properties	
ρ (kg/m^3)	95
δ (mm)	9.92





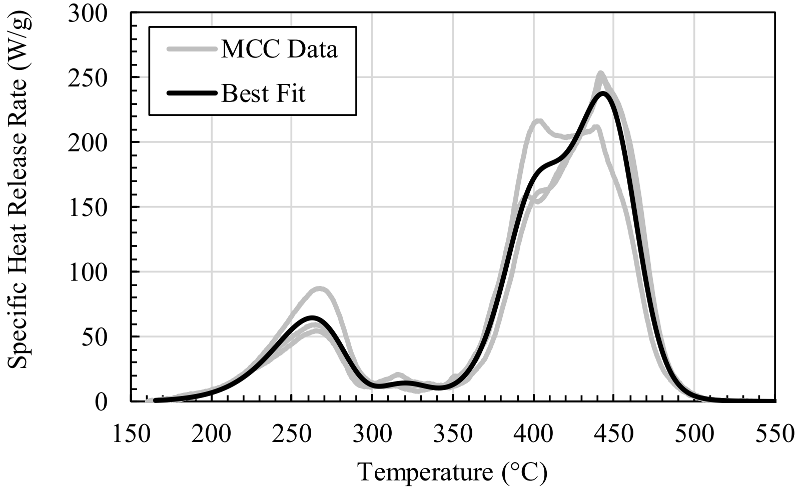
Chevy Equinox Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.00	3.07	3.03				3.03	0.035
m_f (mg)	0.11	0.16	0.12				0.13	0.026
η_c (J/g·K)	210	237	246				231	18.8
Q_{max} (W/g)	209	236	244				229	18.4
T_{max} (°C)	402	443	442				429	23.0
h_c (kJ/g)	22.7	21.0	22.3				22.0	0.90
Y_p (g/g)	0.037	0.052	0.040				0.04	0.008
$h_{c,gas}$ (kJ/g)	23.6	22.1	23.2				23.0	0.75

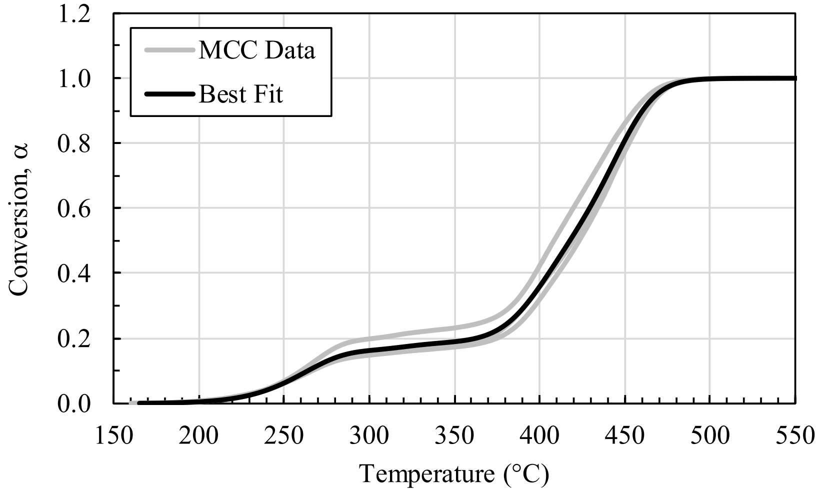
	c_1	c_2	c_3	c_4
Test 1	0.192	0.030	0.310	0.467
Test 2	0.140	0.027	0.351	0.481
Test 3	0.141	0.025	0.336	0.498
Test 4				
Test 5				
Test 6				
Average	0.158	0.027	0.333	0.482

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	220	243	464	0.993
Test 2	221	243	470	0.994
Test 3	220	244	469	0.989
Test 4				
Test 5				
Test 6				
Average	220	243	468	0.992

	R1	R2	R3	R4
A (1/s)	9.91E+08	1.99E+16	2.04E+20	9.20E+16
E (kJ/mol)	106	198	277	251
n	1.00	1.44	2.19	1.34

Physical Properties	
ρ (kg/m^3)	348
δ (mm)	2.58





Chevy Equinox Seat Padding MCC Data

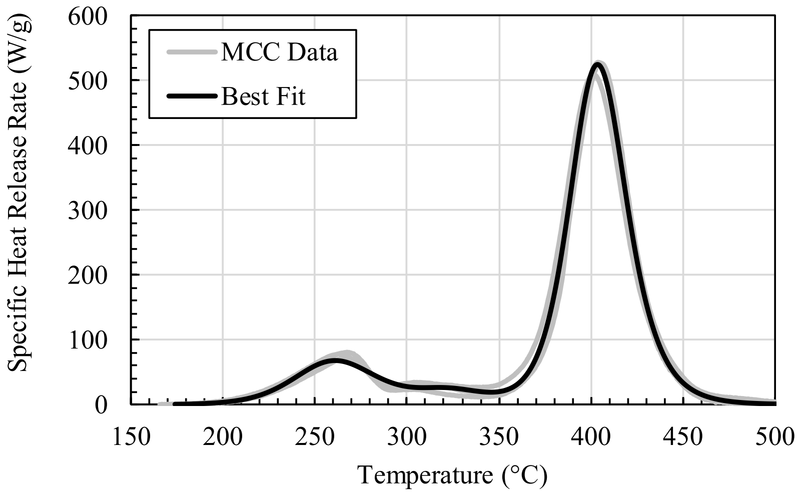
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.01	3.01	3.02				3.01	0.006
m_f (mg)	0.10	0.04	0.04				0.06	0.035
η_c (J/g·K)	514	510	523				516	6.2
Q_{max} (W/g)	511	502	520				511	9.0
T_{max} (°C)	404	401	405				403	2.2
h_c (kJ/g)	25.0	28.3	27.4				26.9	1.71
Y_p (g/g)	0.033	0.013	0.013				0.02	0.012
$h_{c,gas}$ (kJ/g)	25.8	28.7	27.7				27.4	1.45

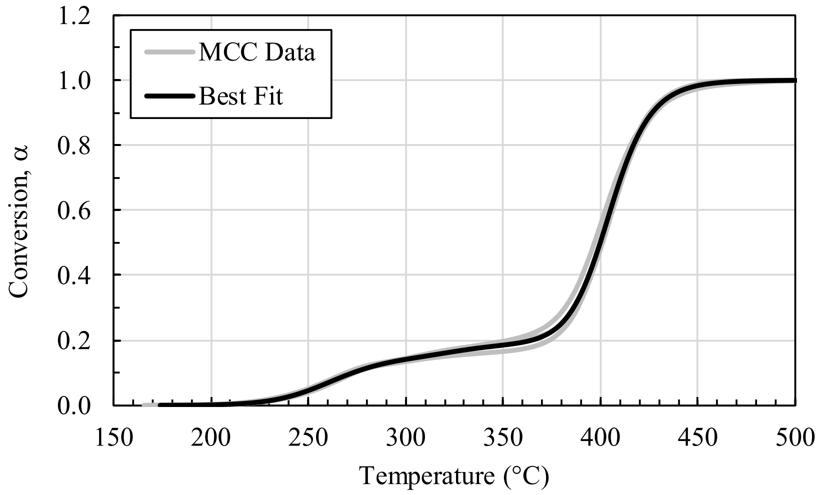
	c_1	c_2	c_3	c_4
Test 1	0.121	0.041	0.838	
Test 2	0.180	0.038	0.782	
Test 3	0.155	0.044	0.801	
Test 4				
Test 5				
Test 6				
Average	0.152	0.041	0.807	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	228	255	433	0.993
Test 2	220	249	438	0.984
Test 3	225	253	438	0.996
Test 4				
Test 5				
Test 6				
Average	224	252	437	0.991

	R1	R2	R3	R4
A (1/s)	1.21E+13	1.68E+20	7.08E+26	
E (kJ/mol)	146	244	361	
n	2.01	2.75	2.11	

Physical Properties	
ρ (kg/m^3)	59
δ (mm)	10.49





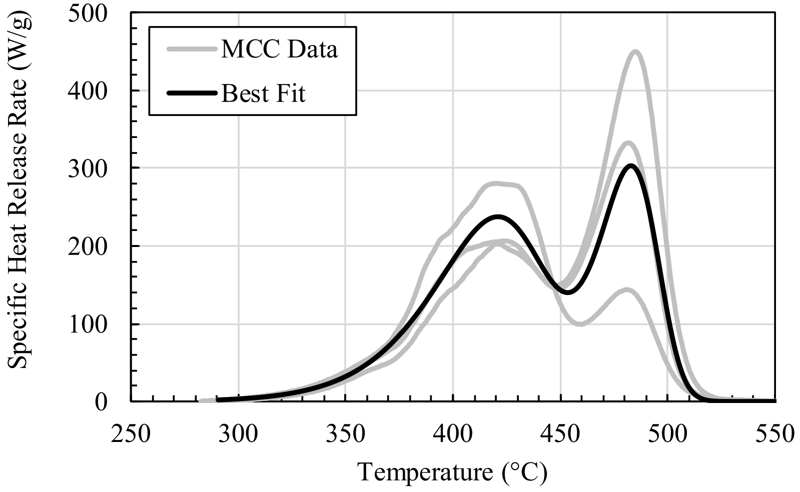
Dodge Grand Caravan Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.03	4.06	4.00				4.03	0.030
m_f (mg)	0.18	0.45	0.33				0.32	0.135
η_c (J/g·K)	322	252	414				329	81.5
Q_{max} (W/g)	318	250	413				327	82.2
T_{max} (°C)	482	421	485				463	36.1
h_c (kJ/g)	26.4	22.2	26.5				25.1	2.43
Y_p (g/g)	0.045	0.111	0.083				0.08	0.033
$h_{c,gas}$ (kJ/g)	27.6	25.0	28.9				27.2	1.98

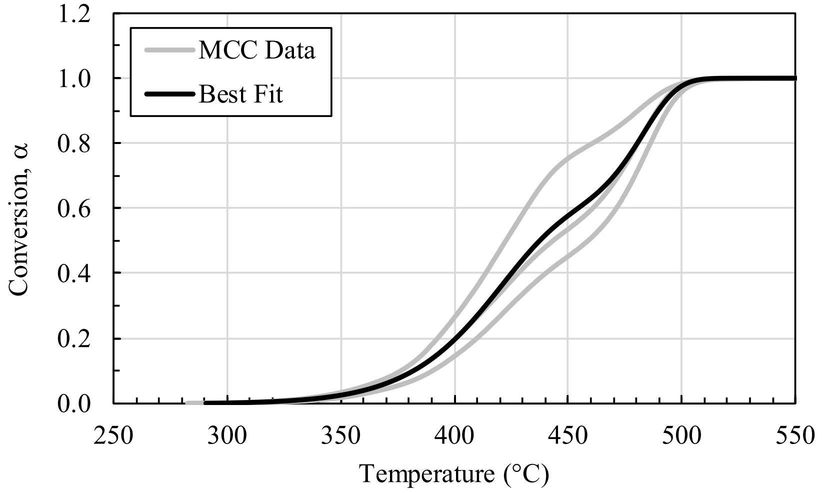
	c_1	c_2	c_3	c_4
Test 1	0.383	0.149	0.468	
Test 2	0.352	0.394	0.254	
Test 3	0.341	0.126	0.533	
Test 4				
Test 5				
Test 6				
Average	0.359	0.223	0.418	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	339	362	494	0.988
Test 2	341	359	489	0.992
Test 3	349	373	499	0.997
Test 4				
Test 5				
Test 6				
Average	343	365	494	0.992

	R1	R2	R3	R4
A (1/s)	2.08E+08	4.56E+12	2.27E+23	
E (kJ/mol)	130	186	355	
n	1.00	1.06	1.14	

Physical Properties	
ρ (kg/m^3)	139
δ (mm)	11.75





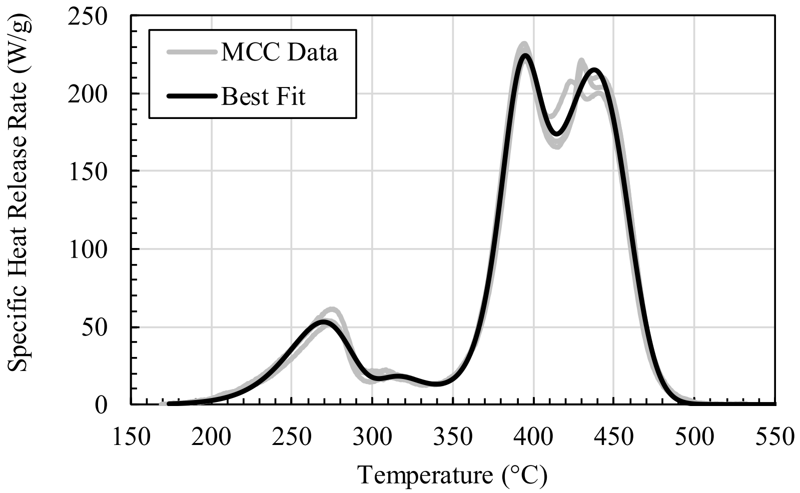
Dodge Grand Caravan Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.07	4.07	4.00				4.05	0.040
m_f (mg)	0.28	0.25	0.24				0.26	0.021
η_c (J/g·K)	214	210	221				215	5.5
Q_{max} (W/g)	213	208	218				213	5.2
T_{max} (°C)	395	430	395				406	20.2
h_c (kJ/g)	20.4	20.3	20.9				20.5	0.35
Y_p (g/g)	0.069	0.061	0.060				0.06	0.005
$h_{c,gas}$ (kJ/g)	22.0	21.6	22.3				21.9	0.34

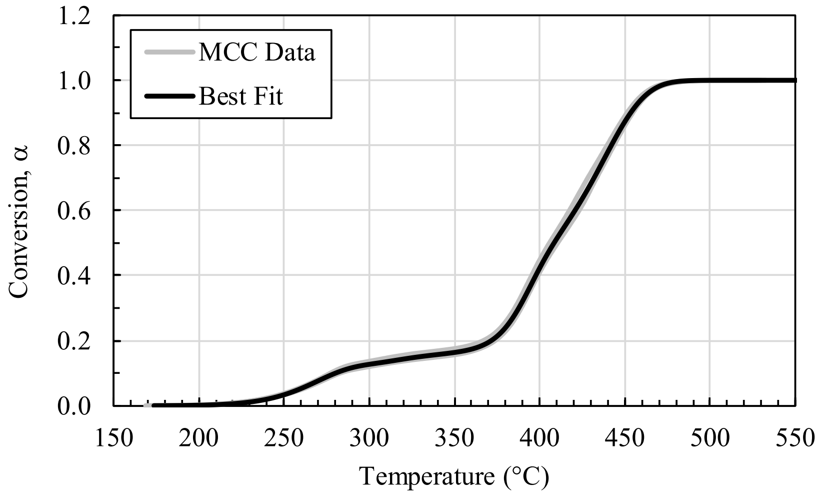
	c_1	c_2	c_3	c_4
Test 1	0.120	0.039	0.268	0.572
Test 2	0.114	0.041	0.255	0.590
Test 3	0.132	0.039	0.274	0.555
Test 4				
Test 5				
Test 6				
Average	0.122	0.040	0.266	0.572

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	234	257	462	0.993
Test 2	237	260	462	0.990
Test 3	234	257	459	0.989
Test 4				
Test 5				
Test 6				
Average	235	258	461	0.991

	R1	R2	R3	R4
A (1/s)	2.49E+10	4.73E+22	4.54E+27	1.01E+13
E (kJ/mol)	121	268	365	195
n	1.00	2.67	1.65	1.12

Physical Properties	
ρ (kg/m^3)	94
δ (mm)	9.34





Dodge Grand Caravan Seat Cover MCC

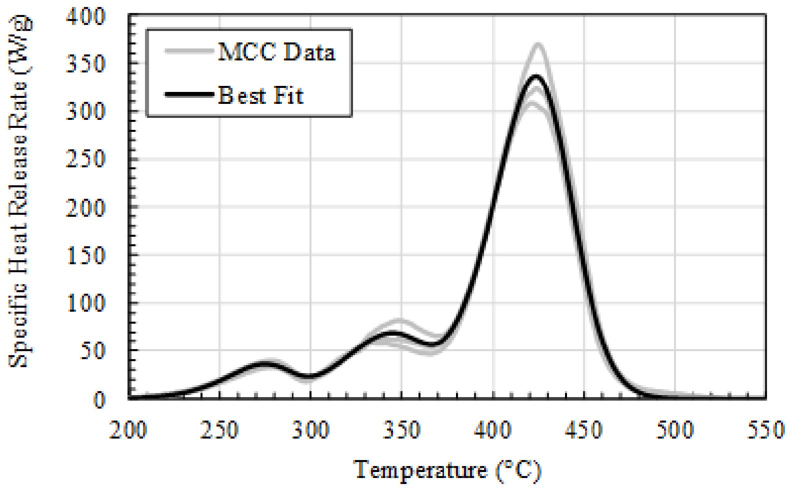
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.06	4.03				4.06	0.025
m_f (mg)	0.12	0.56	0.21				0.30	0.232
η_c (J/g·K)	316	320	295				310	13.4
Q_{max} (W/g)	314	319	292				308	14.1
T_{max} (°C)	424	425	421				423	2.1
h_c (kJ/g)	22.9	22.3	21.8				22.3	0.53
Y_p (g/g)	0.029	0.138	0.052				0.07	0.057
$h_{c,gas}$ (kJ/g)	23.5	25.9	23.0				24.1	1.52

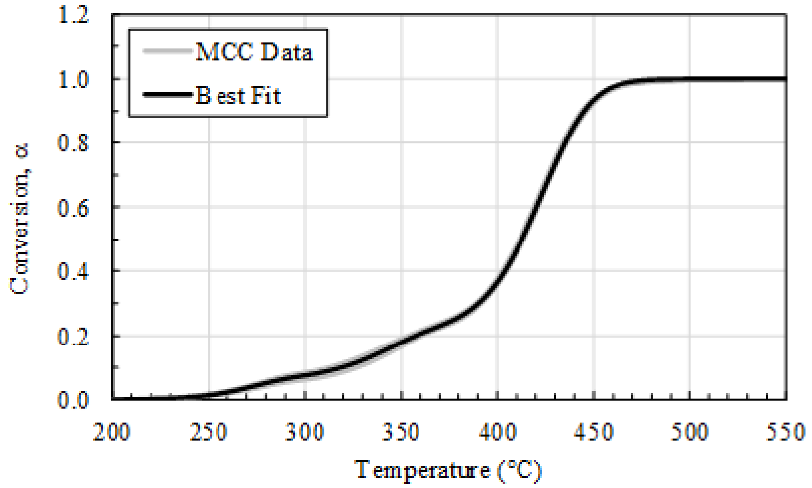
	c_1	c_2	c_3	c_4
Test 1	0.066	0.149	0.785	
Test 2	0.053	0.159	0.788	
Test 3	0.063	0.124	0.813	
Test 4				
Test 5				
Test 6				
Average	0.061	0.144	0.795	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	247	275	452	0.994
Test 2	252	285	454	0.995
Test 3	248	276	454	0.990
Test 4				
Test 5				
Test 6				
Average	249	279	453	0.993

	R1	R2	R3	R4
A (1/s)	3.69E+11	3.89E+10	4.83E+14	
E (kJ/mol)	134	140	213	
n	1.00	1.00	1.34	

Physical Properties	
ρ (kg/m³)	95
δ (mm)	6.00





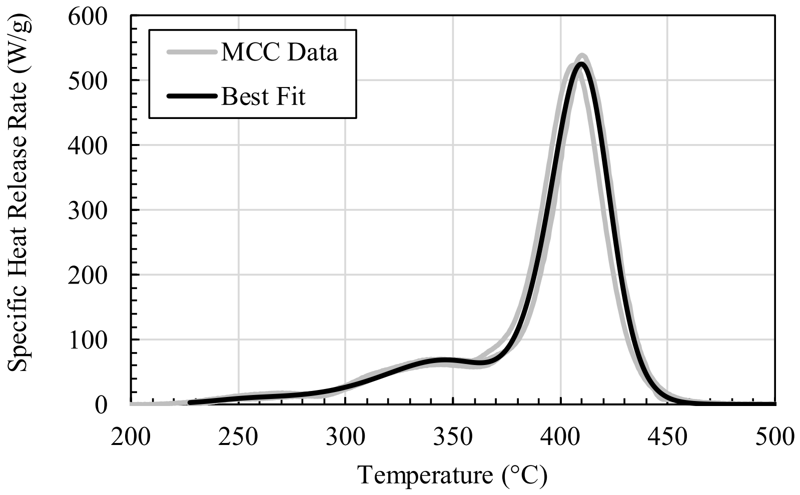
Dodge Grand Caravan Seat Padding MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.04	4.00	4.00				4.01	0.023
m_f (mg)	0.21	0.14	0.14				0.16	0.040
η_c (J/g·K)	504	511	525				513	10.5
Q_{max} (W/g)	499	506	520				508	10.9
T_{max} (°C)	411	406	410				409	2.5
h_c (kJ/g)	23.4	23.9	23.2				23.5	0.36
Y_p (g/g)	0.052	0.035	0.035				0.04	0.010
$h_{c,gas}$ (kJ/g)	24.7	24.7	24.0				24.5	0.41

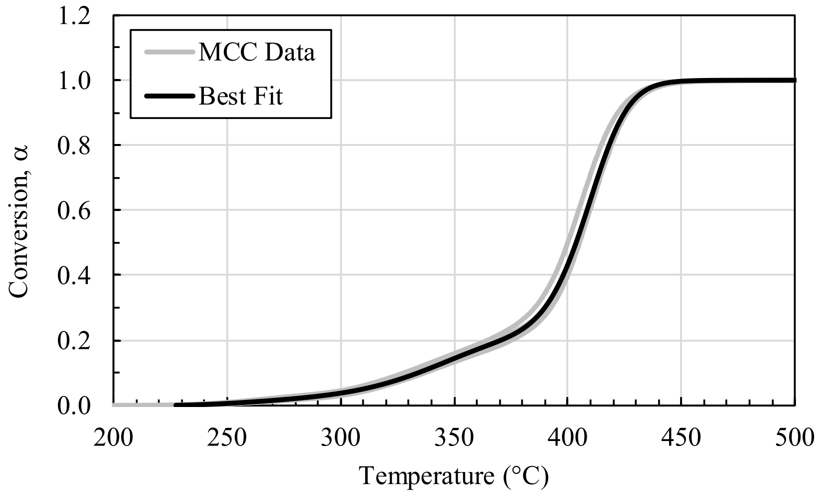
	c_1	c_2	c_3	c_4
Test 1	0.016	0.175	0.809	
Test 2	0.026	0.175	0.799	
Test 3	0.021	0.168	0.811	
Test 4				
Test 5				
Test 6				
Average	0.021	0.173	0.806	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	256	311	432	0.990
Test 2	246	303	428	0.990
Test 3	260	314	432	0.992
Test 4				
Test 5				
Test 6				
Average	254	310	431	0.991

	R1	R2	R3	R4
A (1/s)	1.75E+17	9.11E+08	4.43E+24	
E (kJ/mol)	188	122	336	
n	3.61	1.00	1.49	

Physical Properties	
ρ (kg/m^3)	62
δ (mm)	8.02



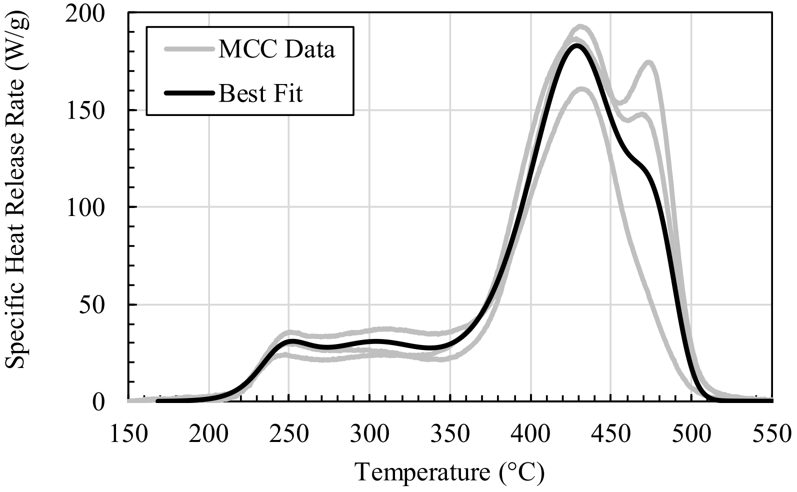


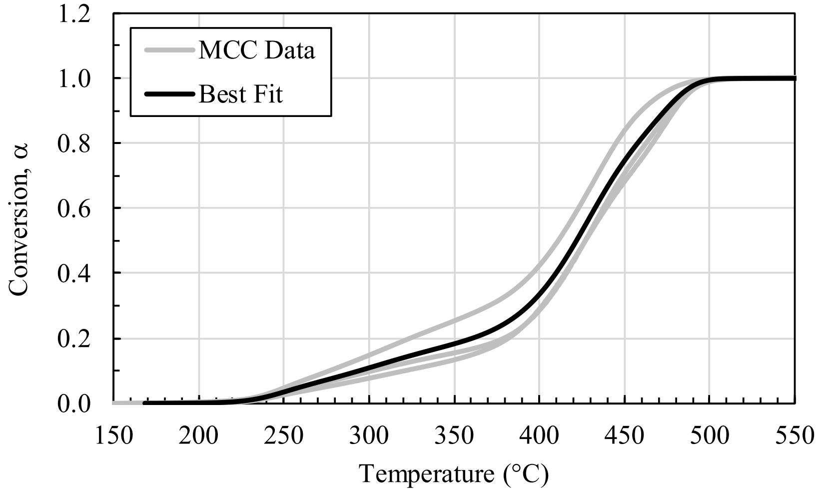
Ford F150 Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.04	4.07				4.05	0.015
m_f (mg)	0.42	0.48	0.49				0.46	0.038
η_c (J/g·K)	176	143	166				162	16.8
Q_{max} (W/g)	173	142	164				160	16.1
T_{max} (°C)	431	431	428				430	1.5
h_c (kJ/g)	18.5	15.2	19.3				17.7	2.17
Y_p (g/g)	0.104	0.119	0.120				0.11	0.009
$h_{c,gas}$ (kJ/g)	20.7	17.3	22.0				20.0	2.42

	c_1	c_2	c_3	c_4
Test 1	0.053	0.094	0.511	0.341
Test 2	0.074	0.237	0.630	0.060
Test 3	0.036	0.108	0.522	0.334
Test 4				
Test 5				
Test 6				
Average	0.055	0.146	0.554	0.245
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	234	263	485	0.984
Test 2	232	251	472	0.991
Test 3	234	274	487	0.989
Test 4				
Test 5				
Test 6				
Average	233	263	481	0.988

	R1	R2	R3	R4
A (1/s)	1.35E+20	2.40E+08	7.11E+10	5.03E+17
E (kJ/mol)	211	109	164	271
n	2.52	2.29	1.10	1.08

Physical Properties	
ρ (kg/m^3)	254
δ (mm)	11.57





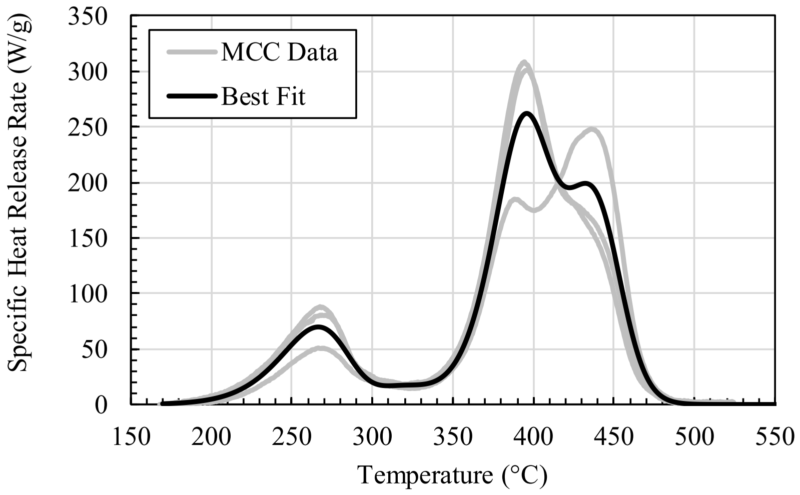
Ford F150 Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.02	3.03	3.06				3.04	0.021
m_f (mg)	0.23	0.42	0.49				0.38	0.135
η_c (J/g·K)	290	262	210				254	40.4
Q_{max} (W/g)	285	259	208				251	39.0
T_{max} (°C)	394	396	436				409	23.6
h_c (kJ/g)	23.4	21.9	19.3				21.5	2.06
Y_p (g/g)	0.076	0.139	0.160				0.12	0.044
$h_{c,gas}$ (kJ/g)	25.3	25.4	23.0				24.6	1.36

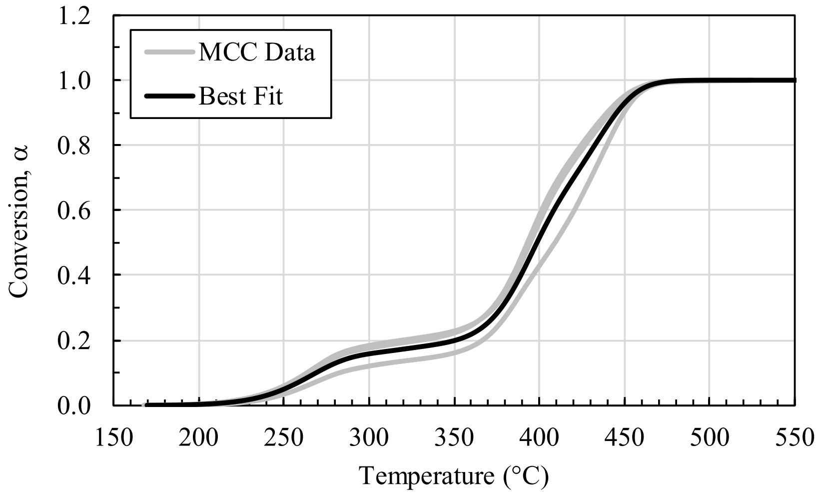
	c_1	c_2	c_3	c_4
Test 1	0.169	0.029	0.531	0.271
Test 2	0.174	0.035	0.468	0.323
Test 3	0.112	0.038	0.297	0.553
Test 4				
Test 5				
Test 6				
Average	0.152	0.034	0.432	0.382

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	222	246	449	0.984
Test 2	223	246	451	0.988
Test 3	241	258	457	0.992
Test 4				
Test 5				
Test 6				
Average	229	250	452	0.988

	R1	R2	R3	R4
A (1/s)	7.94E+09	7.19E+14	4.53E+18	6.91E+16
E (kJ/mol)	116	181	253	246
n	1.06	1.74	1.48	1.28

Physical Properties	
ρ (kg/m^3)	88
δ (mm)	12.60





Ford F150 Seat Cover MCC Data

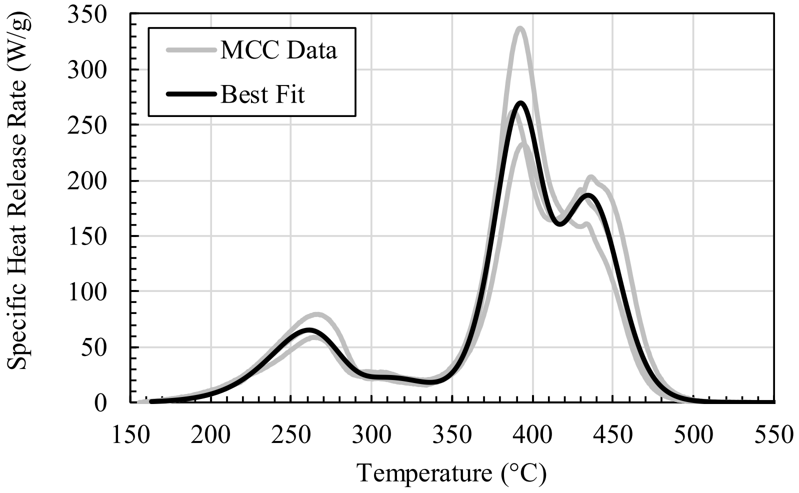
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.02	4.06				4.03	0.026
m_f (mg)	0.25	0.25	0.21				0.24	0.023
η_c (J/g·K)	220	250	322				264	52.2
Q_{max} (W/g)	218	246	320				261	52.5
T_{max} (°C)	394	389	392				392	2.7
h_c (kJ/g)	21.7	22.3	23.3				22.5	0.82
Y_p (g/g)	0.062	0.062	0.052				0.06	0.006
$h_{c,gas}$ (kJ/g)	23.2	23.8	24.6				23.9	0.73

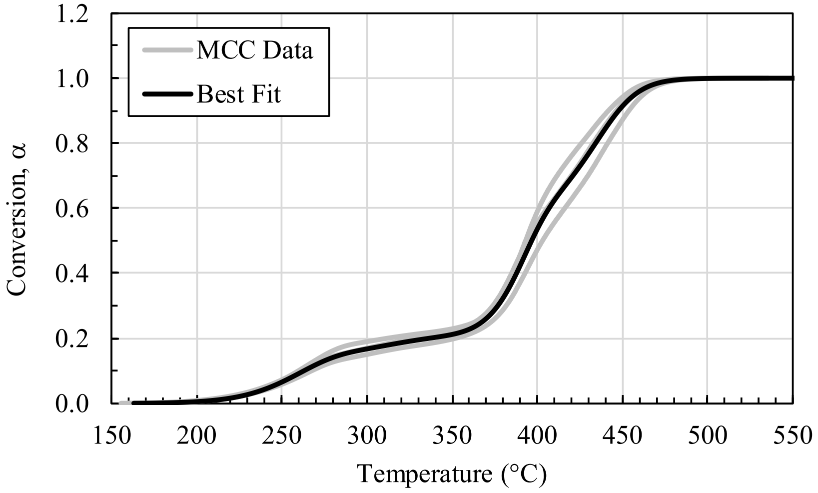
	c_1	c_2	c_3	c_4
Test 1	0.109	0.076	0.369	0.447
Test 2	0.128	0.082	0.356	0.434
Test 3	0.160	0.055	0.428	0.357
Test 4				
Test 5				
Test 6				
Average	0.132	0.071	0.384	0.412

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	224	246	462	0.990
Test 2	218	239	455	0.982
Test 3	218	241	451	0.993
Test 4				
Test 5				
Test 6				
Average	220	242	456	0.989

	R1	R2	R3	R4
A (1/s)	1.29E+09	6.23E+06	1.88E+22	2.24E+17
E (kJ/mol)	107	92	297	252
n	1.00	1.01	1.39	1.48

Physical Properties	
ρ (kg/m^3)	114
δ (mm)	6.38





Ford F150 Seat Padding MCC Data

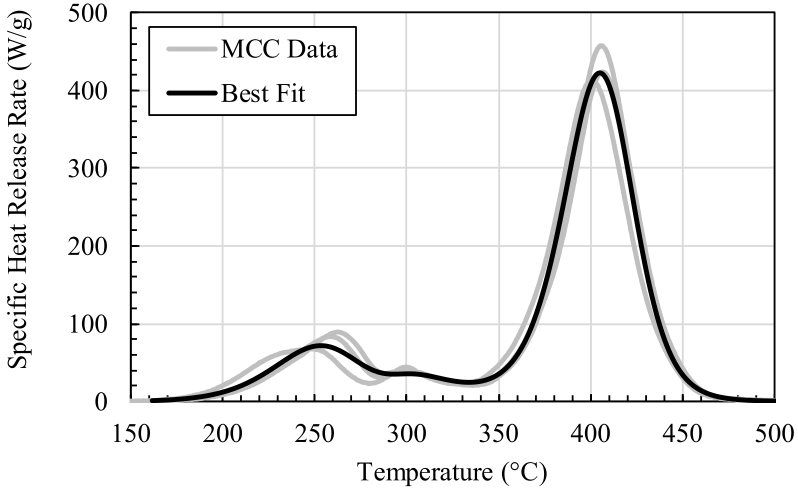
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.02	3.04	3.07				3.04	0.025
m_f (mg)	0.23	0.14	0.20				0.19	0.046
η_c (J/g·K)	427	400	398				408	16.5
Q_{max} (W/g)	423	394	396				404	15.9
T_{max} (°C)	405	400	407				404	3.3
h_c (kJ/g)	26.1	26.0	25.9				26.0	0.10
Y_p (g/g)	0.076	0.046	0.065				0.06	0.015
$h_{c,gas}$ (kJ/g)	28.2	27.3	27.7				27.7	0.45

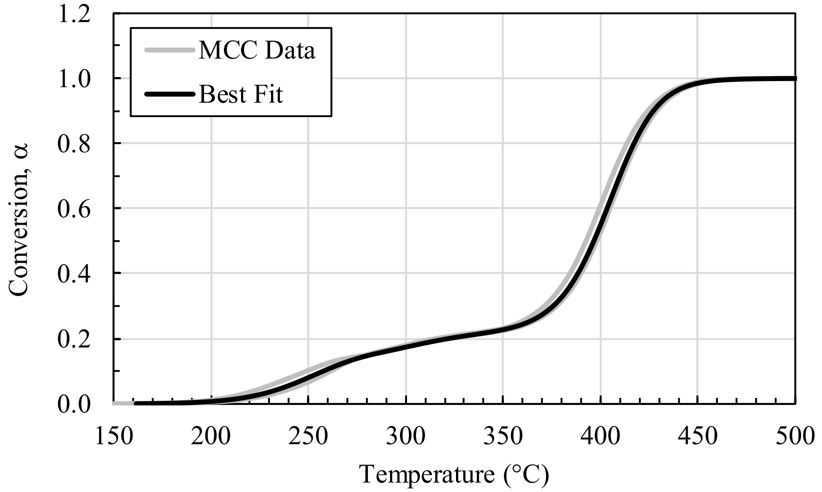
	c_1	c_2	c_3	c_4
Test 1	0.151	0.077	0.772	
Test 2	0.148	0.078	0.775	
Test 3	0.187	0.054	0.759	
Test 4				
Test 5				
Test 6				
Average	0.162	0.070	0.769	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	211	239	435	0.990
Test 2	198	227	433	0.987
Test 3	216	242	437	0.997
Test 4				
Test 5				
Test 6				
Average	208	236	435	0.991

	R1	R2	R3	R4
A (1/s)	2.64E+09	7.24E+23	3.23E+18	
E (kJ/mol)	108	277	256	
n	1.35	4.20	1.62	

Physical Properties	
ρ (kg/m^3)	49
δ (mm)	10.00





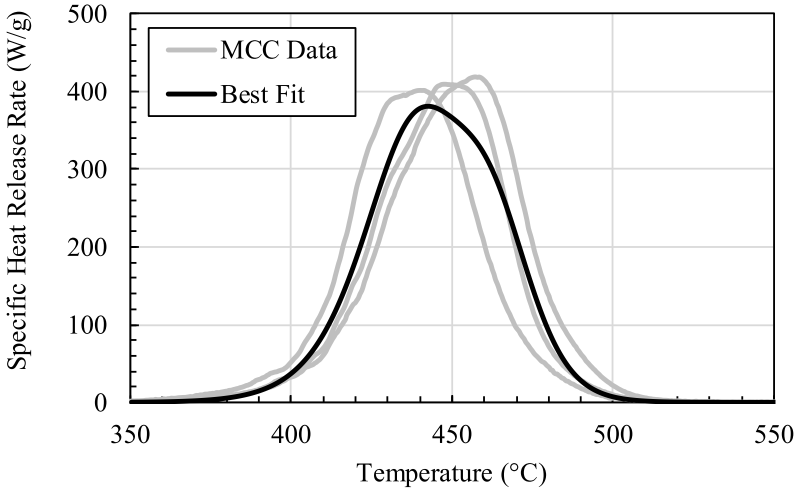
Honda Civic Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.09	4.07	4.08				4.08	0.010
m_f (mg)	0.44	0.49	0.56				0.50	0.060
η_c (J/g·K)	371	373	351				365	12.3
Q_{max} (W/g)	365	369	346				360	12.3
T_{max} (°C)	448	457	440				448	8.4
h_c (kJ/g)	18.3	19.2	17.2				18.2	0.95
Y_p (g/g)	0.108	0.120	0.137				0.12	0.015
$h_{c,gas}$ (kJ/g)	20.5	21.8	20.0				20.8	0.91

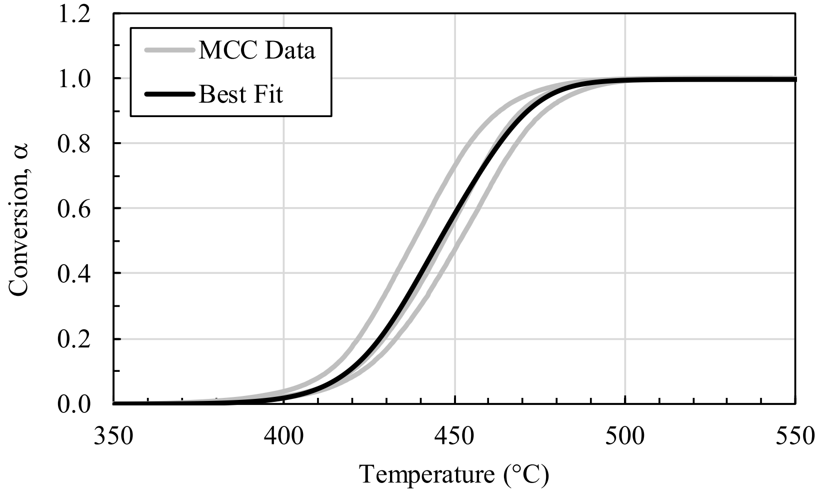
	c_1	c_2	c_3	c_4
Test 1	0.478	0.522		
Test 2	0.415	0.585		
Test 3	0.556	0.436		
Test 4				
Test 5				
Test 6				
Average	0.483	0.514		

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	399	410	476	0.984
Test 2	401	413	484	0.990
Test 3	394	403	471	0.987
Test 4				
Test 5				
Test 6				
Average	398	409	477	0.987

	R1	R2	R3	R4
A (1/s)	9.07E+24	4.16E+25		
E (kJ/mol)	353	375		
n	1.44	1.51		

Physical Properties	
ρ (kg/m^3)	127
δ (mm)	12.01





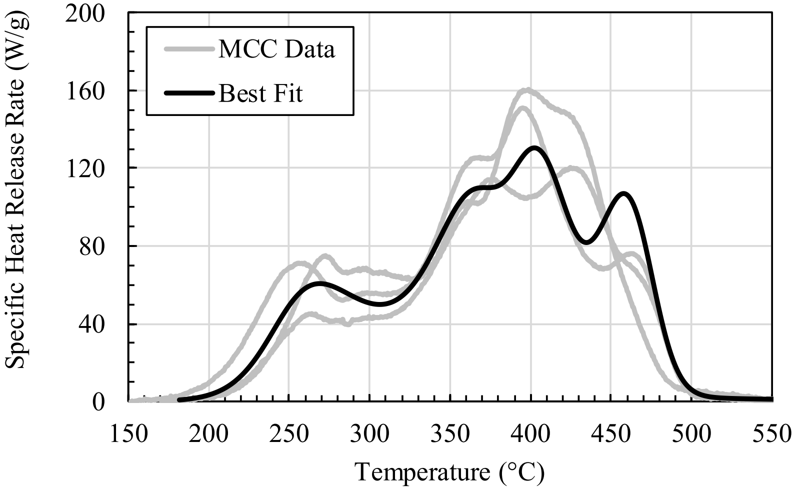
Honda Civic Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.01	3.02	3.06				3.03	0.026
m_f (mg)	1.07	0.52	0.61				0.73	0.295
η_c (J/g·K)	104	127	98				110	15.3
Q_{max} (W/g)	104	125	96				108	14.9
T_{max} (°C)	399	395	425				406	16.2
h_c (kJ/g)	14.5	18.7	15.3				16.2	2.25
Y_p (g/g)	0.355	0.172	0.199				0.24	0.099
$h_{c,gas}$ (kJ/g)	22.4	22.6	19.1				21.4	1.97

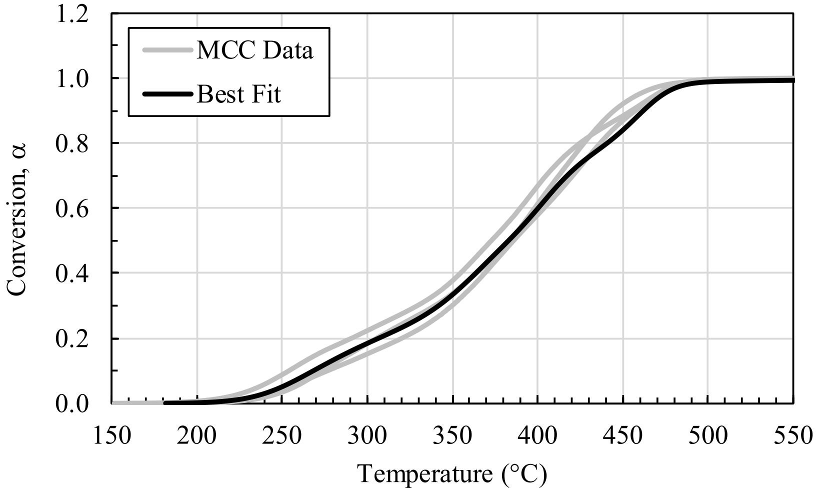
	c_1	c_2	c_3	c_4
Test 1	0.336	0.082	0.110	0.472
Test 2	0.339	0.087	0.446	0.127
Test 3	0.235	0.250	0.408	0.107
Test 4				
Test 5				
Test 6				
Average	0.304	0.140	0.321	0.235

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	239	257	459	0.993
Test 2	214	236	469	0.985
Test 3	233	254	471	0.987
Test 4				
Test 5				
Test 6				
Average	228	249	466	0.989

	R1	R2	R3	R4
A (1/s)	2.18E+12	8.76E+11	2.12E+12	9.67E+17
E (kJ/mol)	141	160	176	269
n	4.27	1.00	1.15	1.27

Physical Properties	
ρ (kg/m^3)	93
δ (mm)	9.68





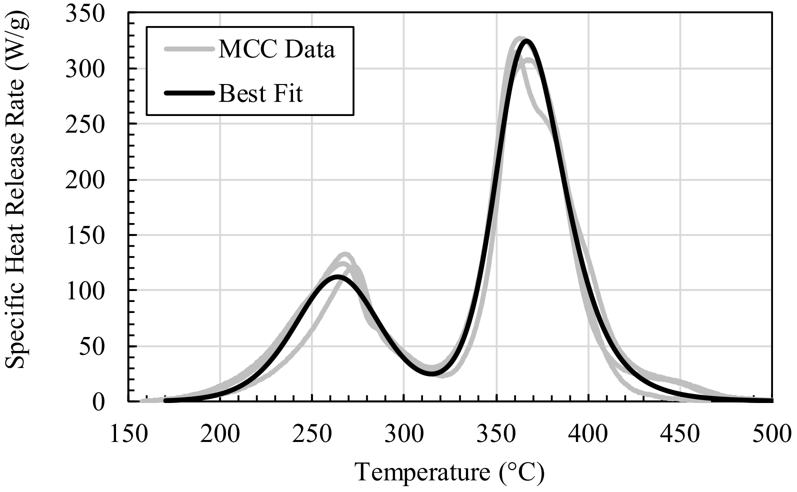
Honda Civic Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.02	3.03	3.00				3.02	0.015
m_f (mg)	0.31	0.22	0.35				0.29	0.067
η_c (J/g·K)	286	289	292				289	3.0
Q_{max} (W/g)	282	286	289				286	3.2
T_{max} (°C)	361	367	363				364	3.1
h_c (kJ/g)	20.5	22.7	21.5				21.6	1.08
Y_p (g/g)	0.103	0.073	0.117				0.10	0.023
$h_{c,gas}$ (kJ/g)	22.9	24.5	24.4				23.9	0.89

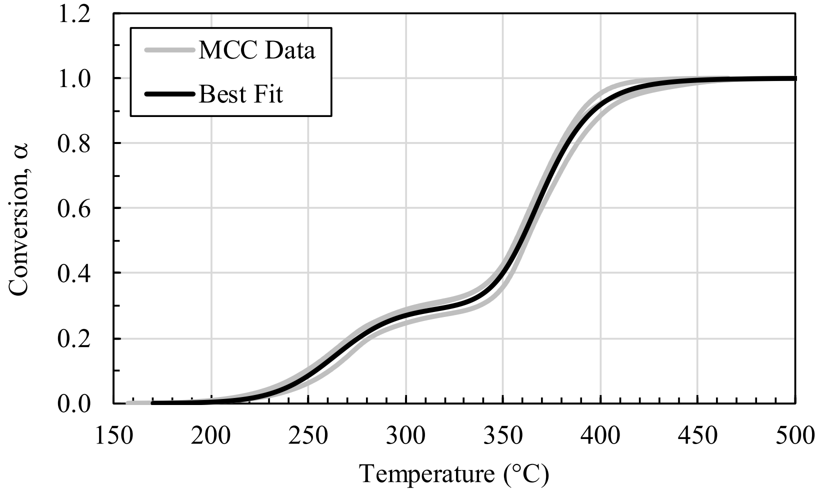
	c_1	c_2	c_3	c_4
Test 1	0.268	0.074	0.497	0.160
Test 2	0.310	0.070	0.569	0.051
Test 3	0.312	0.064	0.459	0.166
Test 4				
Test 5				
Test 6				
Average	0.296	0.069	0.508	0.126

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	226	245	418	0.989
Test 2	211	232	412	0.988
Test 3	215	235	399	0.991
Test 4				
Test 5				
Test 6				
Average	217	237	410	0.989

	R1	R2	R3	R4
A (1/s)	3.28E+11	3.02E+26	1.53E+24	1.99E+20
E (kJ/mol)	132	337	308	267
n	1.73	3.00	2.56	1.91

Physical Properties	
ρ (kg/m^3)	184
δ (mm)	2.12



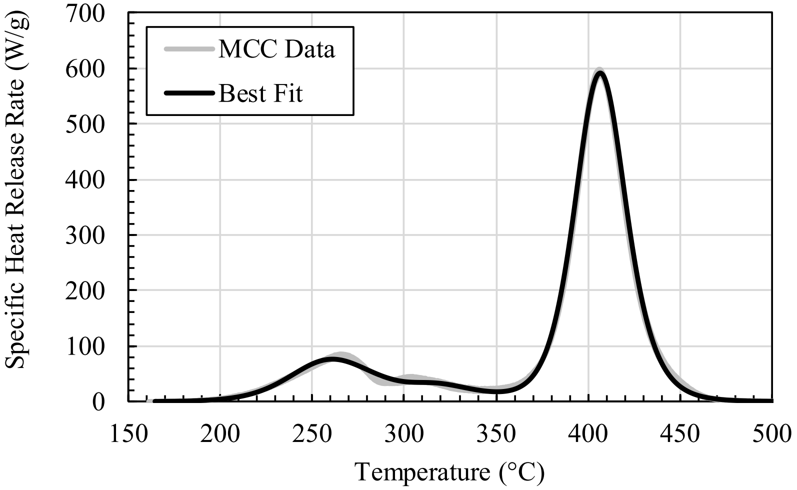


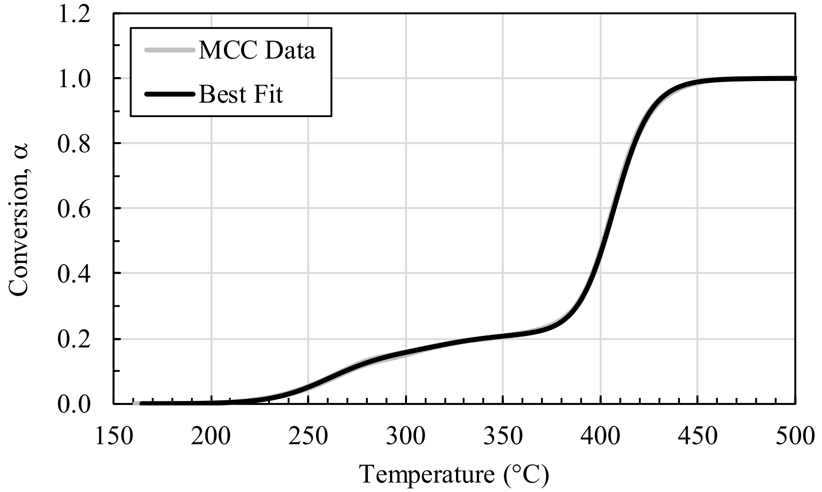
Honda Civic Seat Padding Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.01	3.06	3.02				3.03	0.026
m_f (mg)	0.07	0.01	0.07				0.05	0.033
η_c (J/g·K)	589	592	578				586	7.2
Q_{max} (W/g)	584	587	573				581	7.1
T_{max} (°C)	406	407	407				407	0.3
h_c (kJ/g)	27.7	28.6	27.7				28.0	0.54
Y_p (g/g)	0.023	0.004	0.023				0.02	0.011
$h_{c,gas}$ (kJ/g)	28.4	28.8	28.4				28.5	0.22

	c_1	c_2	c_3	c_4
Test 1	0.181	0.038	0.781	
Test 2	0.176	0.054	0.770	
Test 3	0.176	0.038	0.786	
Test 4				
Test 5				
Test 6				
Average	0.178	0.043	0.779	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	220	248	433	0.993
Test 2	222	251	434	0.990
Test 3	221	249	435	0.991
Test 4				
Test 5				
Test 6				
Average	221	249	434	0.991

	R1	R2	R3	R4
A (1/s)	1.18E+13	1.16E+25	2.38E+29	
E (kJ/mol)	146	297	395	
n	2.26	3.81	1.99	

Physical Properties	
ρ (kg/m^3)	47
δ (mm)	12.36





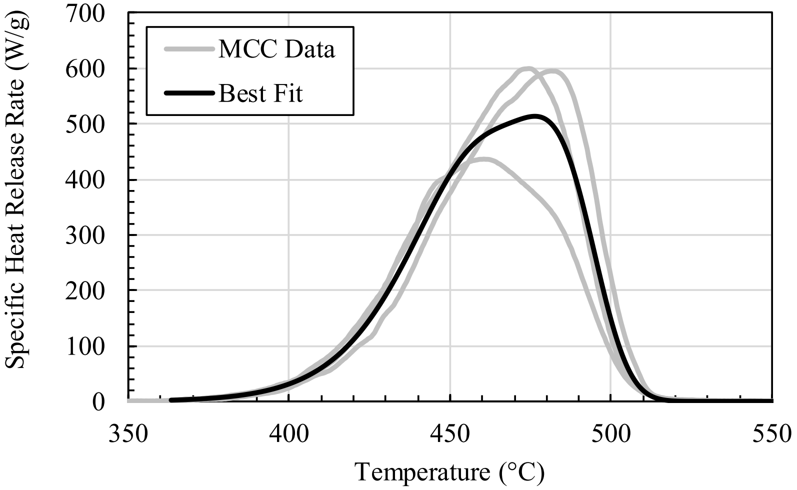
Toyota Camry Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	5.02	5.00	5.08				5.03	0.042
m_f (mg)	0.31	0.23	0.28				0.27	0.040
η_c (J/g·K)	562	576	415				518	89.3
Q_{max} (W/g)	558	572	412				514	88.5
T_{max} (°C)	482	474	460				472	10.8
h_c (kJ/g)	32.0	32.7	25.9				30.2	3.75
Y_p (g/g)	0.062	0.046	0.055				0.05	0.008
$h_{c,gas}$ (kJ/g)	34.1	34.3	27.4				31.9	3.93

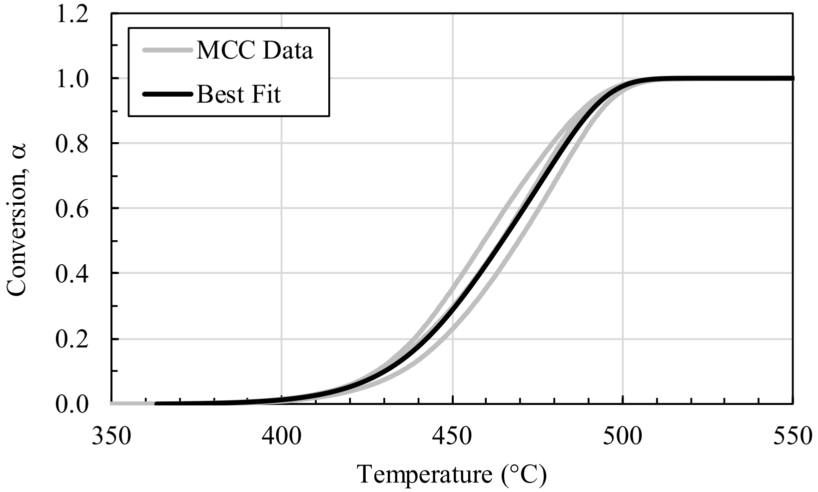
	c_1	c_2	c_3	c_4
Test 1	0.299	0.701		
Test 2	0.318	0.682		
Test 3	0.435	0.565		
Test 4				
Test 5				
Test 6				
Average	0.351	0.649		

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	399	423	498	0.992
Test 2	393	418	494	0.992
Test 3	400	417	494	0.993
Test 4				
Test 5				
Test 6				
Average	397	419	495	0.992

	R1	R2	R3	R4
A (1/s)	1.69E+17	5.72E+19		
E (kJ/mol)	256	302		
n	1.03	1.06		

Physical Properties	
ρ (kg/m^3)	340
δ (mm)	2.50





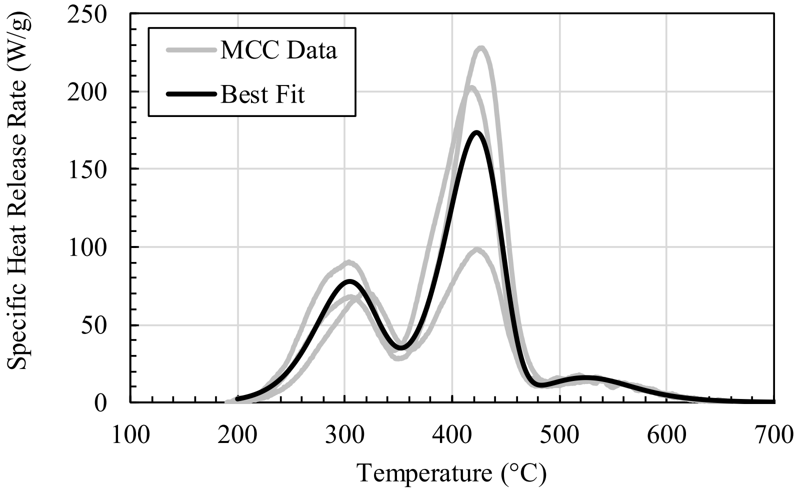
Toyota Camry Headliner MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.08	4.02				4.06	0.035
m_f (mg)	1.56	1.56	1.18				1.43	0.219
η_c (J/g·K)	142	61	144				116	47.1
Q_{max} (W/g)	141	61	143				115	46.9
T_{max} (°C)	427	423	418				423	4.4
h_c (kJ/g)	13.4	8.9	15.9				12.7	3.56
Y_p (g/g)	0.382	0.382	0.294				0.35	0.051
$h_{c,gas}$ (kJ/g)	21.7	14.4	22.5				19.5	4.47

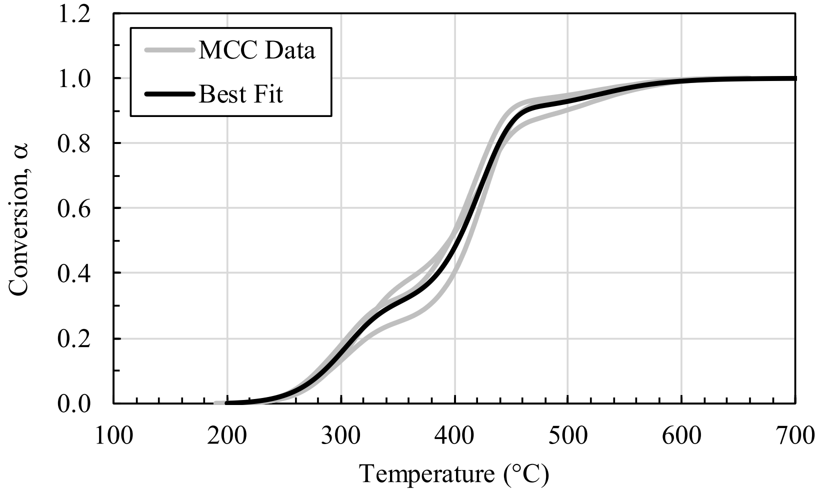
	c_1	c_2	c_3	c_4
Test 1	0.247	0.677	0.076	
Test 2	0.352	0.495	0.153	
Test 3	0.294	0.638	0.068	
Test 4				
Test 5				
Test 6				
Average	0.298	0.603	0.099	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	257	270	516	0.992
Test 2	270	272	542	0.991
Test 3	245	263	504	0.994
Test 4				
Test 5				
Test 6				
Average	257	269	520	0.992

	R1	R2	R3	R4
A (1/s)	2.73E+07	1.09E+10	4.75E+08	0.00E+00
E (kJ/mol)	98	153	156	0
n	1.19	1.04	1.85	0.00

Physical Properties	
ρ (kg/m^3)	111
δ (mm)	6.90



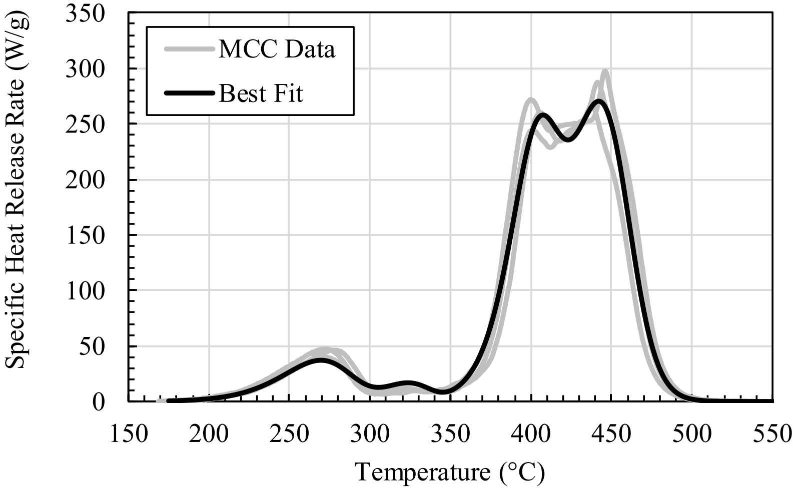


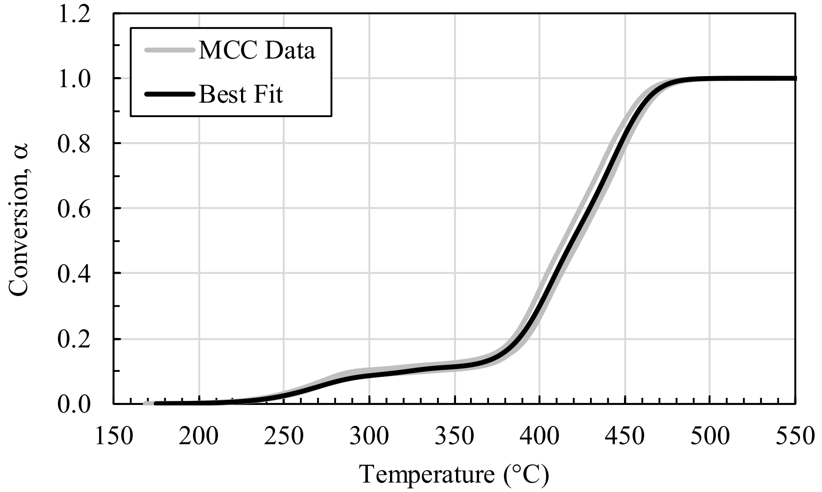
Toyota Camry Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.08	4.08				4.07	0.017
m_f (mg)	0.23	0.21	0.28				0.24	0.036
η_c (J/g·K)	273	284	256				271	14.2
Q_{max} (W/g)	271	282	253				269	14.7
T_{max} (°C)	441	446	400				429	25.5
h_c (kJ/g)	22.5	23.2	22.6				22.8	0.38
Y_p (g/g)	0.057	0.051	0.069				0.06	0.009
$h_{c,gas}$ (kJ/g)	23.9	24.5	24.2				24.2	0.29

	c_1	c_2	c_3	c_4
Test 1	0.074	0.023	0.328	0.575
Test 2	0.077	0.036	0.313	0.574
Test 3	0.097	0.022	0.393	0.489
Test 4				
Test 5				
Test 6				
Average	0.083	0.027	0.345	0.546
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	241	267	465	0.995
Test 2	245	269	468	0.995
Test 3	237	262	461	0.991
Test 4				
Test 5				
Test 6				
Average	241	266	465	0.994

	R1	R2	R3	R4
A (1/s)	2.48E+09	1.99E+15	2.04E+21	3.43E+17
E (kJ/mol)	111	188	290	257
n	1.00	1.00	1.48	1.34

Physical Properties	
ρ (kg/m^3)	75
δ (mm)	6.90





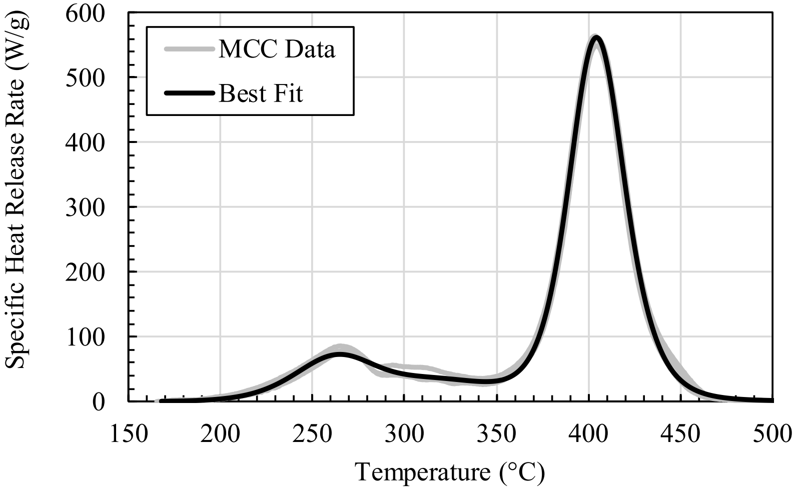
Toyota Camry Seat Padding MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.08	4.08				4.07	0.017
m_f (mg)	0.23	0.21	0.28				0.24	0.036
η_c (J/g·K)	537	526	526				530	6.4
Q_{max} (W/g)	532	521	522				525	6.2
T_{max} (°C)	403	404	405				404	0.8
h_c (kJ/g)	29.3	27.7	27.7				28.2	0.95
Y_p (g/g)	0.057	0.051	0.069				0.06	0.009
$h_{c,gas}$ (kJ/g)	31.1	29.2	29.7				30.0	0.99

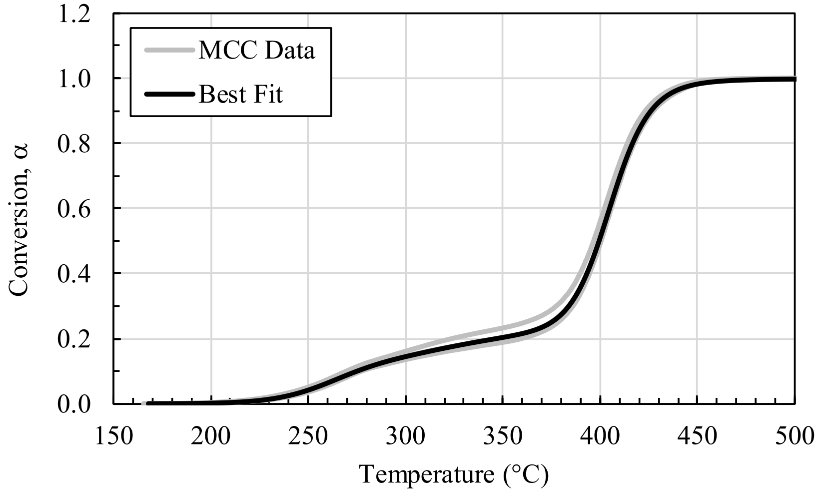
	c_1	c_2	c_3	c_4
Test 1	0.143	0.096	0.761	
Test 2	0.112	0.137	0.751	
Test 3	0.117	0.118	0.765	
Test 4				
Test 5				
Test 6				
Average	0.124	0.117	0.759	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	219	249	432	0.991
Test 2	225	252	436	0.991
Test 3	230	257	437	0.992
Test 4				
Test 5				
Test 6				
Average	225	253	435	0.991

	R1	R2	R3	R4
A (1/s)	6.77E+11	5.41E+09	7.10E+26	
E (kJ/mol)	134	126	362	
n	1.56	2.76	2.01	

Physical Properties	
ρ (kg/m^3)	40
δ (mm)	12.40





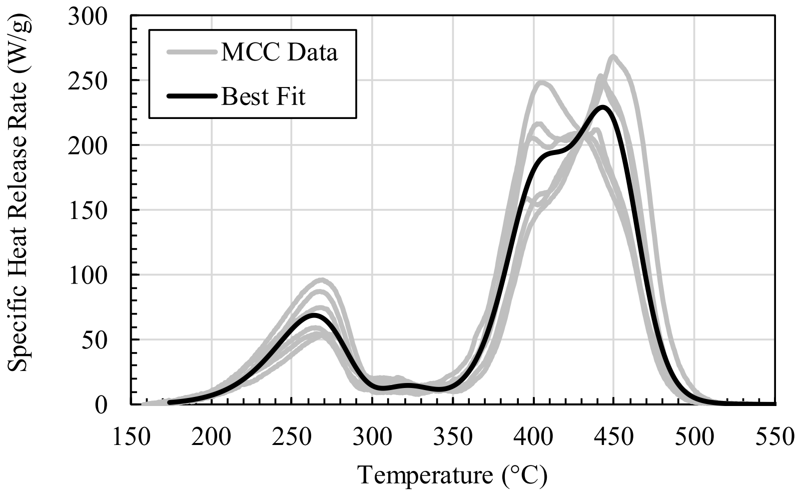
Appendix H: Arrhenius Model Parameters for Task 3 Materials

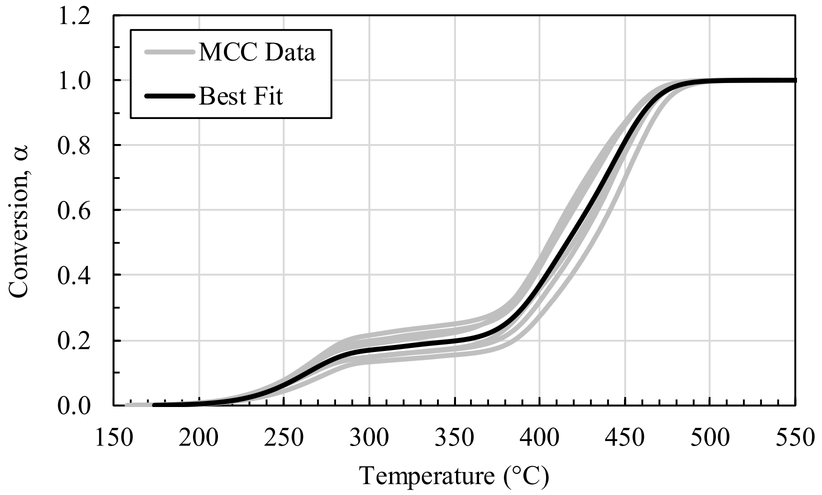
Chevy Equinox Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.00	3.07	3.03	3.01	3.03	3.04	3.03	0.024
m_f (mg)	0.11	0.16	0.12	0.17	0.07	0.10	0.12	0.038
η_c (J/g·K)	210	237	246	255	245	204	233	20.9
Q_{max} (W/g)	209	236	244	254	243	202	231	20.7
T_{max} (°C)	402	443	442	450	404	429	428	20.4
h_c (kJ/g)	22.7	21.0	22.3	22.0	24.7	23.1	22.6	1.26
Y_p (g/g)	0.037	0.052	0.040	0.056	0.023	0.033	0.04	0.012
$h_{c,gas}$ (kJ/g)	23.6	22.1	23.2	23.3	25.3	23.9	23.6	1.05

	c_1	c_2	c_3	c_4
Test 1	0.192	0.030	0.310	0.467
Test 2	0.140	0.027	0.351	0.481
Test 3	0.141	0.025	0.336	0.498
Test 4	0.130	0.018	0.311	0.541
Test 5	0.209	0.034	0.450	0.307
Test 6	0.181	0.031	0.340	0.448
Average	0.166	0.028	0.350	0.457
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	220	243	464	0.993
Test 2	221	243	470	0.994
Test 3	220	244	469	0.989
Test 4	229	253	476	0.994
Test 5	214	239	465	0.992
Test 6	214	238	463	0.993
Average	220	243	468	0.993

	R1	R2	R3	R4
A (1/s)	6.99E+08	3.25E+15	3.70E+19	4.07E+16
E (kJ/mol)	105	190	268	246
n	1.00	1.38	2.08	1.35

Physical Properties	
ρ (kg/m^3)	348
δ (mm)	2.58





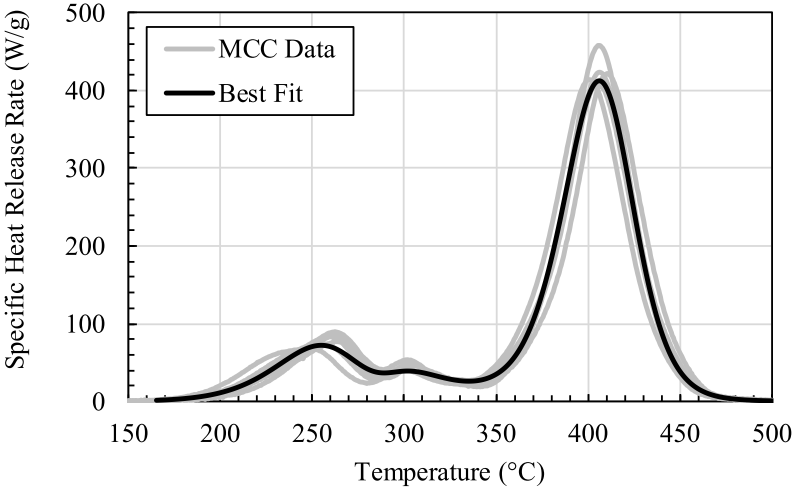
Ford F150 Seat Padding MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.02	3.04	3.07	3.05	3.05	3.08	3.05	0.021
m_f (mg)	0.23	0.14	0.20	0.07	0.08	0.12	0.14	0.064
η_c (J/g·K)	427	400	398	409	409	405	408	10.5
Q_{max} (W/g)	423	394	396	402	399	405	403	10.3
T_{max} (°C)	405	400	407	406	405	410	406	3.2
h_c (kJ/g)	26.1	26.0	25.9	27.2	26.6	26.0	26.3	0.49
Y_p (g/g)	0.076	0.046	0.065	0.023	0.026	0.039	0.05	0.021
$h_{c,gas}$ (kJ/g)	28.2	27.3	27.7	27.8	27.3	27.0	27.5	0.43

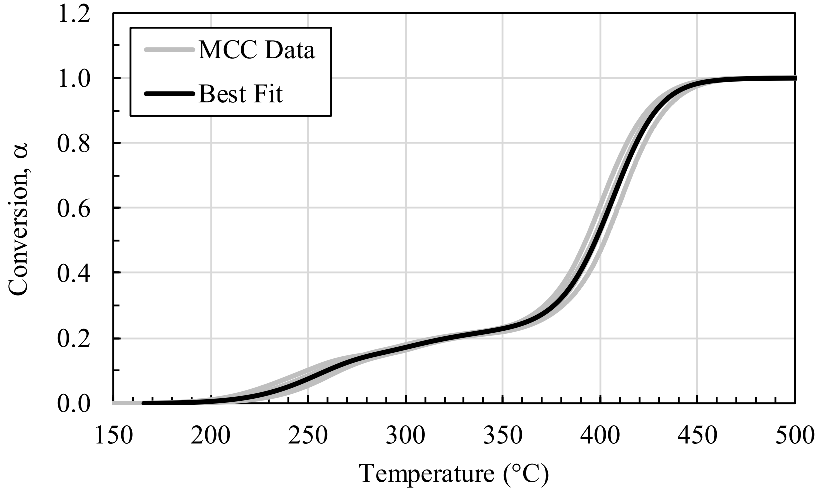
	c_1	c_2	c_3	c_4
Test 1	0.151	0.077	0.772	
Test 2	0.148	0.078	0.775	
Test 3	0.187	0.054	0.759	
Test 4	0.132	0.111	0.757	
Test 5	0.147	0.098	0.755	
Test 6	0.143	0.092	0.765	
Average	0.151	0.085	0.764	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	211	239	435	0.990
Test 2	198	227	433	0.987
Test 3	216	242	437	0.997
Test 4	221	248	438	0.983
Test 5	207	235	436	0.975
Test 6	216	243	441	0.999
Average	211	239	437	0.988

	R1	R2	R3	R4
A (1/s)	1.54E+09	6.60E+24	2.12E+18	
E (kJ/mol)	106	286	254	
n	1.12	4.33	1.62	

Physical Properties	
ρ (kg/m^3)	49
δ (mm)	10.00





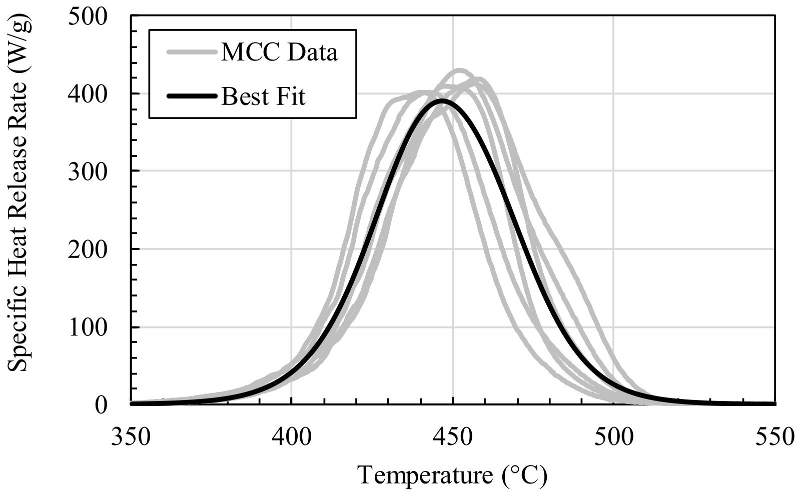
Honda Civic Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.09	4.07	4.08	4.07	4.08	4.05	4.07	0.014
m_f (mg)	0.44	0.49	0.56	0.47	0.42	0.36	0.46	0.068
η_c (J/g·K)	371	373	351	359	372	396	370	15.2
Q_{max} (W/g)	365	369	346	355	370	392	366	15.6
T_{max} (°C)	448	457	440	442	457	452	449	7.3
h_c (kJ/g)	18.3	19.2	17.2	18.6	21.6	21.9	19.5	1.87
Y_p (g/g)	0.108	0.120	0.137	0.115	0.103	0.089	0.11	0.016
$h_{c,gas}$ (kJ/g)	20.5	21.8	20.0	21.0	24.0	24.1	21.9	1.76

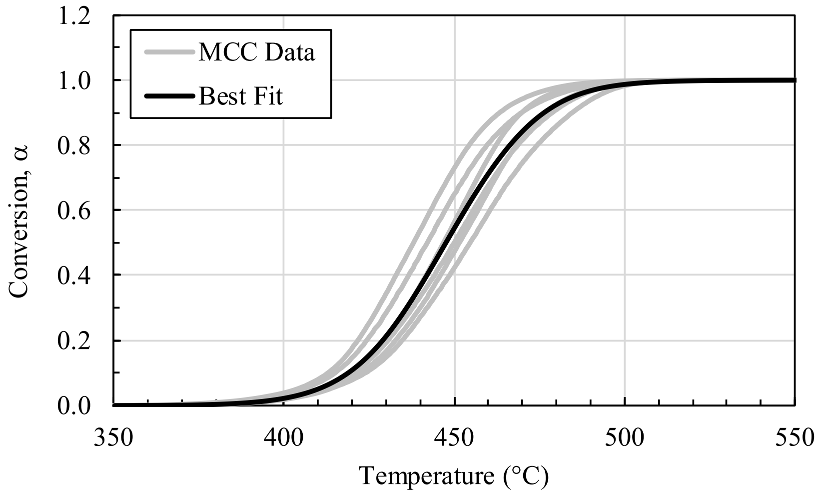
	c_1	c_2	c_3	c_4
Test 1	0.478	0.522		
Test 2	0.415	0.585		
Test 3	0.556	0.436		
Test 4	0.343	0.657		
Test 5	0.455	0.545		
Test 6	0.272	0.728		
Average	0.420	0.579		

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	399	410	476	0.984
Test 2	401	413	484	0.990
Test 3	394	403	471	0.987
Test 4	397	405	478	0.987
Test 5	401	412	491	0.995
Test 6	403	411	486	0.990
Average	399	409	481	0.989

	R1	R2	R3	R4
A (1/s)	2.35E+23	1.03E+19		
E (kJ/mol)	334	282		
n	1.82	1.57		

Physical Properties	
ρ (kg/m^3)	127
δ (mm)	12.01





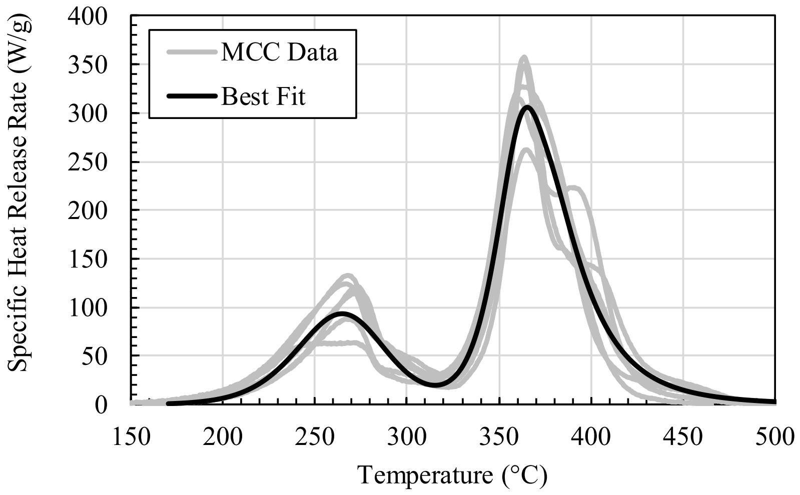
Honda Civic Seat Cover MCC Data

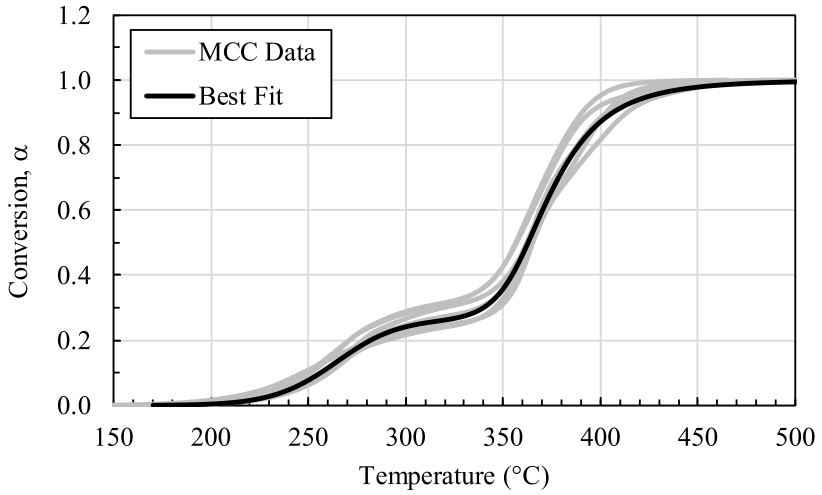
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	3.02	3.03	3.00	4.04	4.06	4.04	3.53	0.564
m_f (mg)	0.31	0.22	0.35	0.22	0.20	0.19	0.25	0.066
η_c (J/g·K)	286	289	292	250	338	343	300	35.1
Q_{max} (W/g)	282	286	289	248	331	341	296	34.4
T_{max} (°C)	361	367	363	365	364	364	364	2.1
h_c (kJ/g)	20.5	22.7	21.5	21.6	20.0	19.8	21.0	1.12
Y_p (g/g)	0.103	0.073	0.117	0.054	0.049	0.047	0.07	0.030
$h_{c,gas}$ (kJ/g)	22.9	24.5	24.4	22.9	21.1	20.7	22.7	1.59

	c_1	c_2	c_3	c_4
Test 1	0.268	0.074	0.497	0.160
Test 2	0.310	0.070	0.569	0.051
Test 3	0.312	0.064	0.459	0.166
Test 4	0.252	0.047	0.519	0.182
Test 5	0.244	0.036	0.332	0.389
Test 6	0.193	0.036	0.500	0.272
Average	0.263	0.055	0.479	0.203
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	226	245	418	0.989
Test 2	211	232	412	0.988
Test 3	215	235	399	0.991
Test 4	219	240	412	0.990
Test 5	206	228	429	0.979
Test 6	224	243	417	0.994
Average	217	237	414	0.988

	R1	R2	R3	R4
A (1/s)	4.45E+10	2.68E+26	7.91E+23	2.50E+23
E (kJ/mol)	123	332	307	302
n	1.58	1.00	2.66	3.79

Physical Properties	
ρ (kg/m^3)	184
δ (mm)	2.12





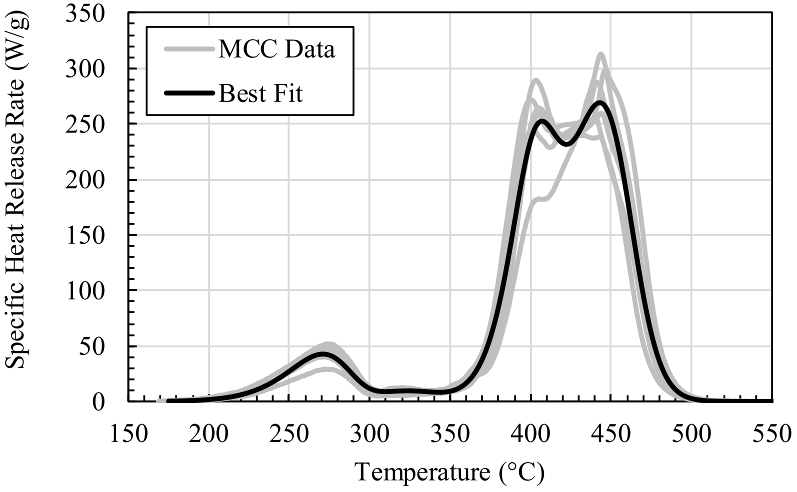
Toyota Camry Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.08	4.08	4.04	4.06	4.04	4.06	0.018
m_f (mg)	0.23	0.21	0.28	0.22	0.20	0.19	0.22	0.032
η_c (J/g·K)	273	284	256	297	253	277	273	16.7
Q_{max} (W/g)	271	282	253	296	252	276	272	17.1
T_{max} (°C)	441	446	400	444	405	404	423	22.5
h_c (kJ/g)	22.5	23.2	22.6	21.6	23.0	23.0	22.6	0.58
Y_p (g/g)	0.057	0.051	0.069	0.054	0.049	0.047	0.05	0.008
$h_{c,gas}$ (kJ/g)	23.9	24.5	24.2	22.8	24.1	24.1	23.9	0.59

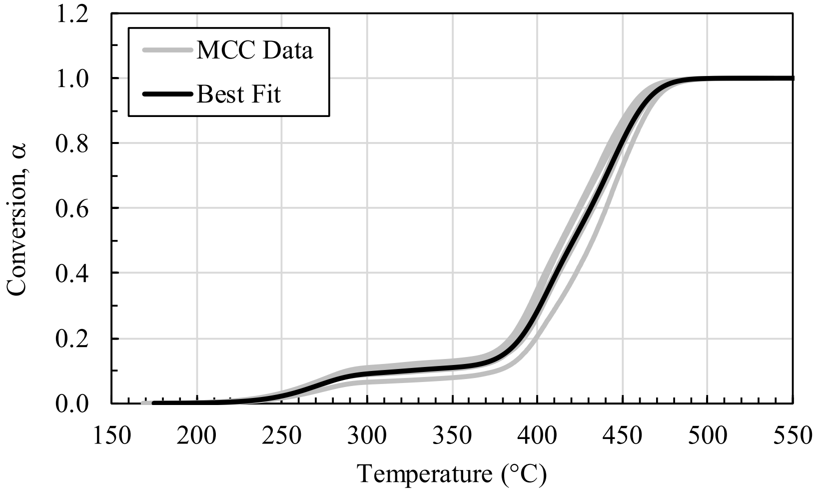
	c_1	c_2	c_3	c_4
Test 1	0.074	0.023	0.328	0.575
Test 2	0.077	0.036	0.313	0.574
Test 3	0.097	0.022	0.393	0.489
Test 4	0.060	0.019	0.244	0.677
Test 5	0.094	0.023	0.331	0.553
Test 6	0.106	0.020	0.333	0.541
Average	0.084	0.024	0.324	0.568

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	241	267	465	0.995
Test 2	245	269	468	0.995
Test 3	237	262	461	0.991
Test 4	248	280	471	0.996
Test 5	239	265	467	0.993
Test 6	237	263	464	0.995
Average	241	268	466	0.994

	R1	R2	R3	R4
A (1/s)	5.02E+10	1.46E+09	2.15E+24	2.58E+16
E (kJ/mol)	125	120	329	243
n	1.00	1.00	1.72	1.30

Physical Properties	
ρ (kg/m^3)	75
δ (mm)	6.90





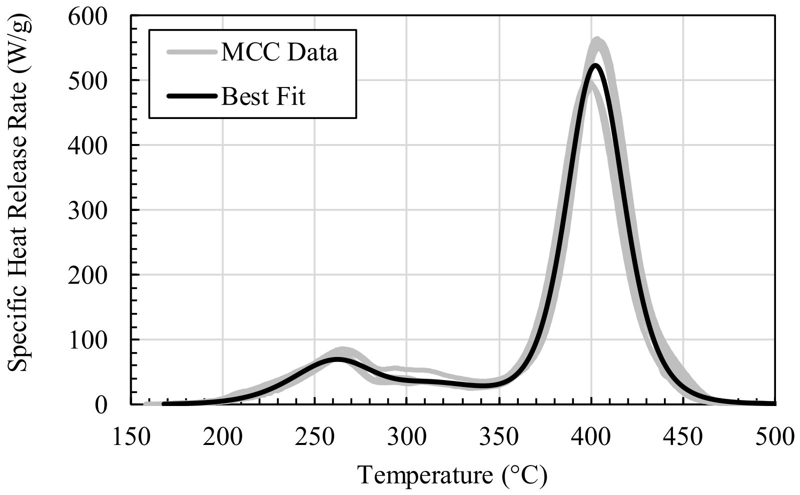
Toyota Camry Seat Padding MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.08	4.08	4.00	4.06	4.06	4.06	0.029
m_f (mg)	0.23	0.21	0.28	0.08	0.04	0.05	0.15	0.104
η_c (J/g·K)	537	526	526	493	493	489	511	21.4
Q_{max} (W/g)	532	521	522	488	489	483	506	21.6
T_{max} (°C)	403	404	405	398	400	401	402	2.6
h_c (kJ/g)	29.3	27.7	27.7	27.0	27.4	26.9	27.7	0.87
Y_p (g/g)	0.057	0.051	0.069	0.020	0.010	0.012	0.04	0.025
$h_{c,gas}$ (kJ/g)	31.1	29.2	29.7	27.5	27.7	27.3	28.8	1.50

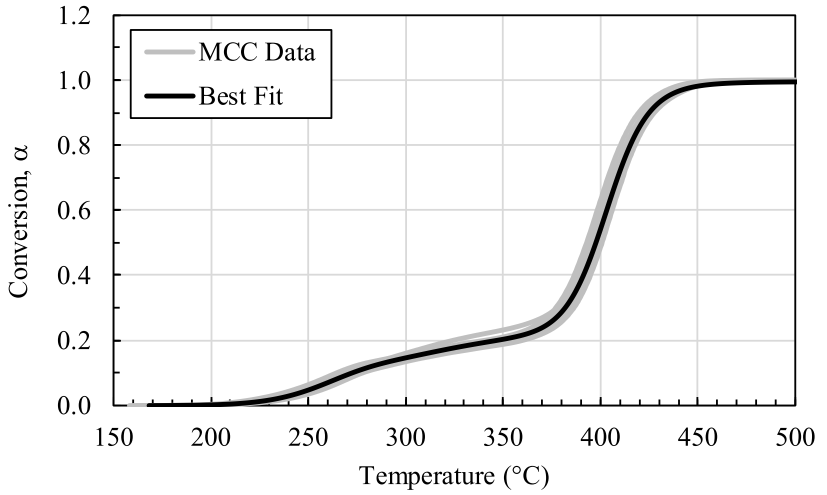
	c_1	c_2	c_3	c_4
Test 1	0.144	0.088	0.766	
Test 2	0.111	0.124	0.766	
Test 3	0.130	0.108	0.766	
Test 4	0.134	0.093	0.766	
Test 5	0.128	0.098	0.766	
Test 6	0.127	0.103	0.766	
Average	0.129	0.102	0.766	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	220	249	432	0.991
Test 2	225	252	436	0.991
Test 3	229	257	437	0.992
Test 4	213	243	428	0.991
Test 5	220	249	433	0.991
Test 6	220	250	431	0.989
Average	221	250	433	0.991

	R1	R2	R3	R4
A (1/s)	8.51E+10	1.50E+13	1.79E+25	
E (kJ/mol)	125	163	340	
n	1.37	3.16	1.94	

Physical Properties	
ρ (kg/m^3)	40
δ (mm)	12.40





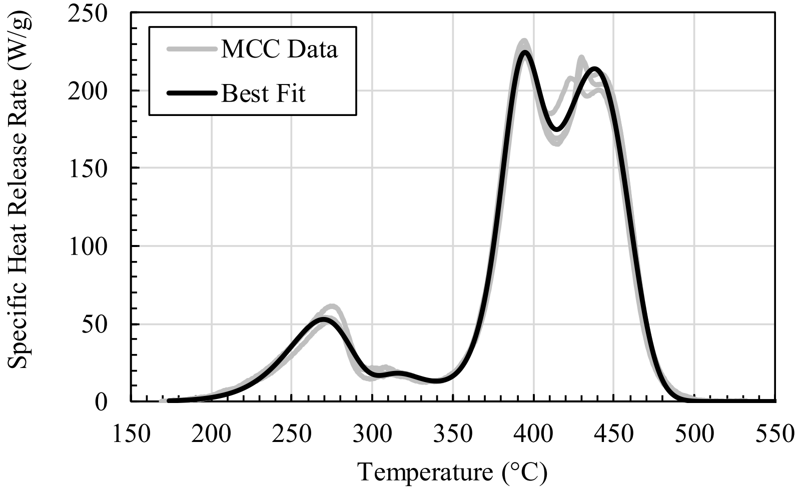
Dodge Grand Caravan Visor Foam MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.07	4.07	4.00				4.05	0.040
m_f (mg)	0.28	0.25	0.24				0.26	0.021
η_c (J/g·K)	214	210	221				215	5.5
Q_{max} (W/g)	213	208	218				213	5.2
T_{max} (°C)	395	430	395				406	20.2
h_c (kJ/g)	20.4	20.3	20.9				20.5	0.35
Y_p (g/g)	0.069	0.061	0.060				0.06	0.005
$h_{c,gas}$ (kJ/g)	22.0	21.6	22.3				21.9	0.34

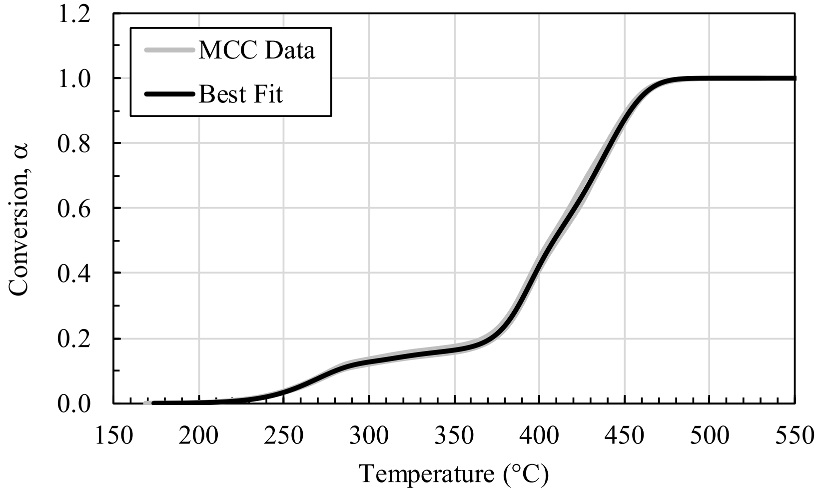
	c_1	c_2	c_3	c_4
Test 1	0.120	0.039	0.268	0.572
Test 2	0.114	0.041	0.255	0.590
Test 3	0.132	0.039	0.274	0.555
Test 4				
Test 5				
Test 6				
Average	0.122	0.040	0.266	0.572

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	234	257	462	0.993
Test 2	237	260	462	0.990
Test 3	234	257	459	0.989
Test 4				
Test 5				
Test 6				
Average	235	258	461	0.991

	R1	R2	R3	R4
A (1/s)	2.17E+10	1.27E+23	3.73E+28	4.09E+12
E (kJ/mol)	121	272	377	190
n	1.00	2.77	1.75	1.08

Physical Properties	
ρ (kg/m^3)	67
δ (mm)	2.77





Dodge Grand Caravan Visor Foam MCC Data

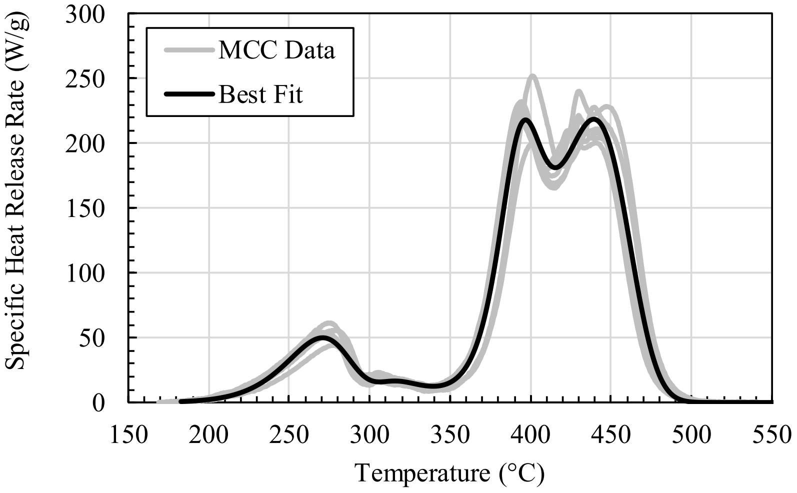
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.07	4.07	4.00	4.06	4.03	4.04	4.05	0.027
m_f (mg)	0.28	0.25	0.24	0.29	0.24	0.13	0.24	0.057
η_c (J/g·K)	214	210	221	224	208	246	220	13.9
Q_{max} (W/g)	213	208	218	223	207	244	219	13.8
T_{max} (°C)	395	430	395	430	392	401	407	18.0
h_c (kJ/g)	20.4	20.3	20.9	20.0	20.6	22.0	20.7	0.69
Y_p (g/g)	0.069	0.061	0.060	0.071	0.060	0.032	0.06	0.014
$h_{c,gas}$ (kJ/g)	22.0	21.6	22.3	21.6	21.9	22.7	22.0	0.43

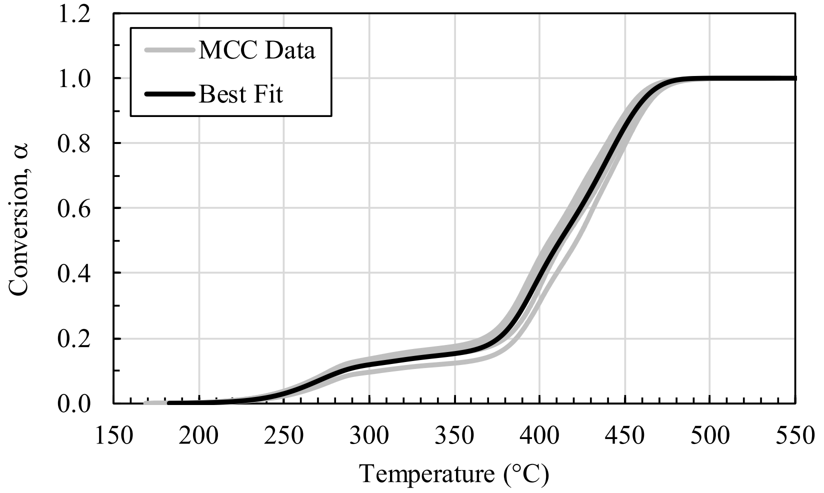
	c_1	c_2	c_3	c_4
Test 1	0.120	0.039	0.268	0.572
Test 2	0.114	0.041	0.255	0.590
Test 3	0.132	0.039	0.274	0.555
Test 4	0.090	0.025	0.193	0.691
Test 5	0.112	0.042	0.269	0.577
Test 6	0.117	0.034	0.244	0.605
Average	0.114	0.037	0.251	0.598

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	234	257	462	0.993
Test 2	237	260	462	0.990
Test 3	234	257	459	0.989
Test 4	245	269	468	0.997
Test 5	237	259	460	0.992
Test 6	238	263	466	0.992
Average	237	261	463	0.992

	R1	R2	R3	R4
A (1/s)	2.46E+10	2.91E+22	3.63E+28	1.43E+12
E (kJ/mol)	122	265	378	185
n	1.00	2.77	1.80	1.07

Physical Properties	
ρ (kg/m^3)	67
δ (mm)	2.77





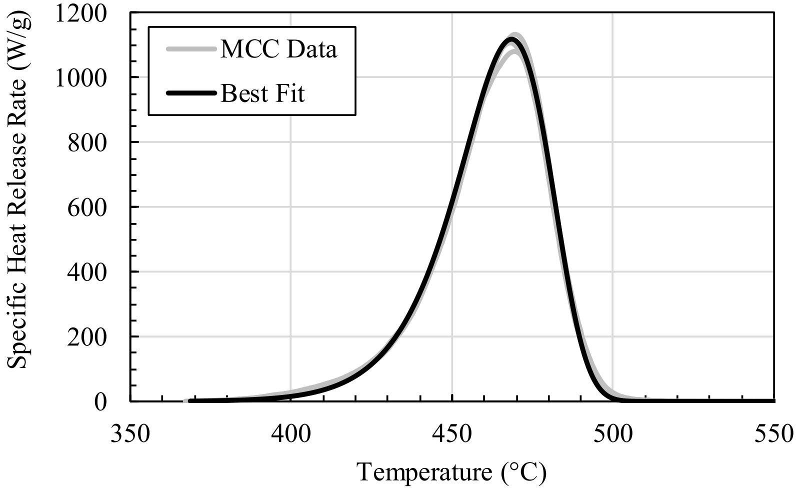
Dodge Grand Caravan Visor Plastic MCC Data

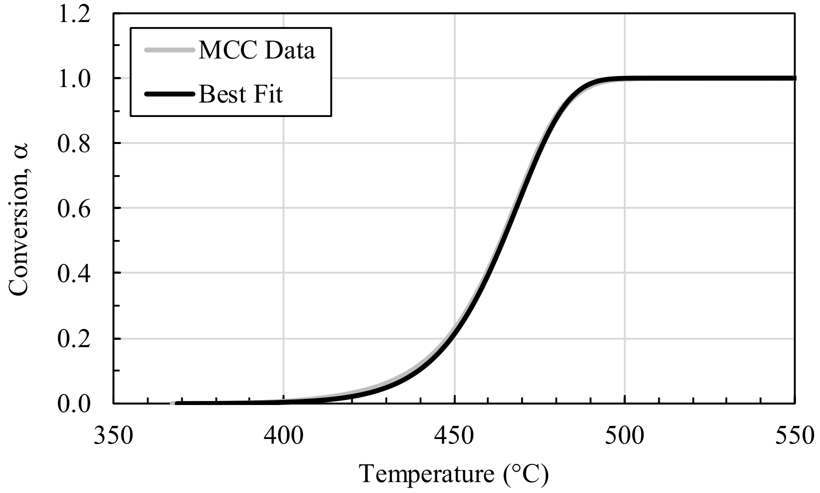
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.02	4.08				4.04	0.038
m_f (mg)	0.00	0.00	0.00				0.00	0.000
η_c (J/g·K)	1141	1116	1091				1116	25.1
Q_{max} (W/g)	1132	1107	1082				1107	25.1
T_{max} (°C)	470	468	470				469	0.9
h_c (kJ/g)	43.1	42.6	43.0				42.9	0.26
Y_p (g/g)	0.000	0.000	0.000				0.00	0.000
$h_{c,gas}$ (kJ/g)	43.1	42.6	43.0				42.9	0.26

	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4				
Test 5				
Test 6				
Average	1.000			
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	403	428	485	0.992
Test 2	404	428	485	0.992
Test 3	402	427	486	0.991
Test 4				
Test 5				
Test 6				
Average	403	427	485	0.992

	R1	R2	R3	R4
A (1/s)	1.89E+21			
E (kJ/mol)	319			
n	1.04			

Physical Properties	
ρ (kg/m^3)	881
δ (mm)	1.86





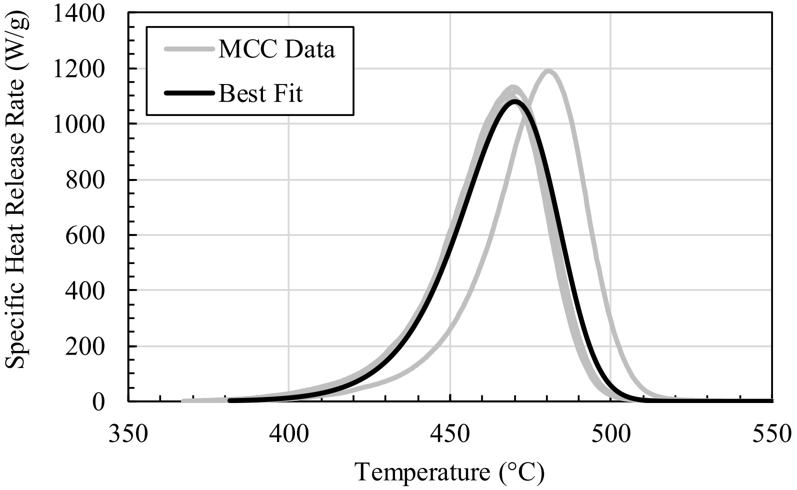
Dodge Grand Caravan Visor Plastic MCC Data	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.02	4.08	4.06	4.03	4.07	4.05	0.029
m_f (mg)	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.012
η_c (J/g·K)	1141	1116	1091	1107	1116	1197	1128	37.7
Q_{max} (W/g)	1132	1107	1082	1095	1108	1192	1119	39.3
T_{max} (°C)	470	468	470	468	470	480	471	4.7
h_c (kJ/g)	43.1	42.6	43.0	43.5	42.7	44.0	43.1	0.54
Y_p (g/g)	0.000	0.000	0.000	0.000	0.007	0.000	0.00	0.003
$h_{c,gas}$ (kJ/g)	43.1	42.6	43.0	43.5	43.0	44.0	43.2	0.49

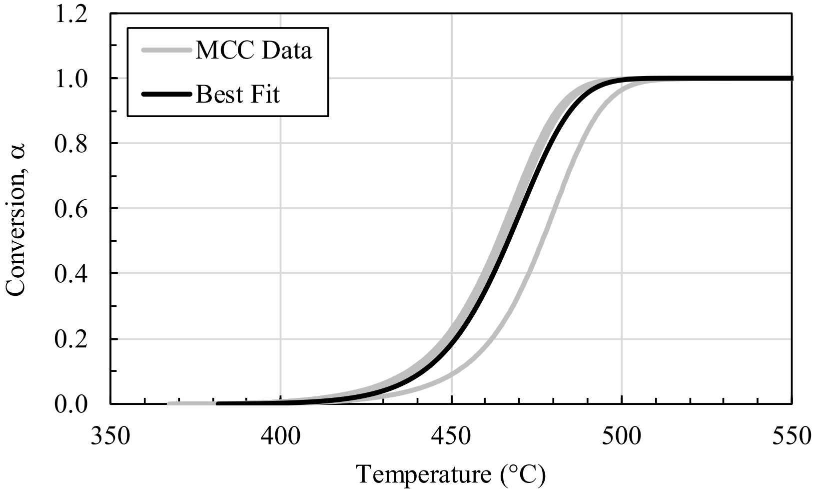
	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4	1.000			
Test 5	1.000			
Test 6	1.000			
Average	1.000			

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	403	428	485	0.992
Test 2	404	428	485	0.992
Test 3	402	427	486	0.991
Test 4	403	427	486	0.989
Test 5	405	429	486	0.993
Test 6	418	441	498	0.995
Average	406	430	488	0.992

	R1	R2	R3	R4
A (1/s)	4.29E+21	0.00E+00		
E (kJ/mol)	324	0		
n	1.16	0.00		

Physical Properties	
ρ (kg/m^3)	881
δ (mm)	1.86



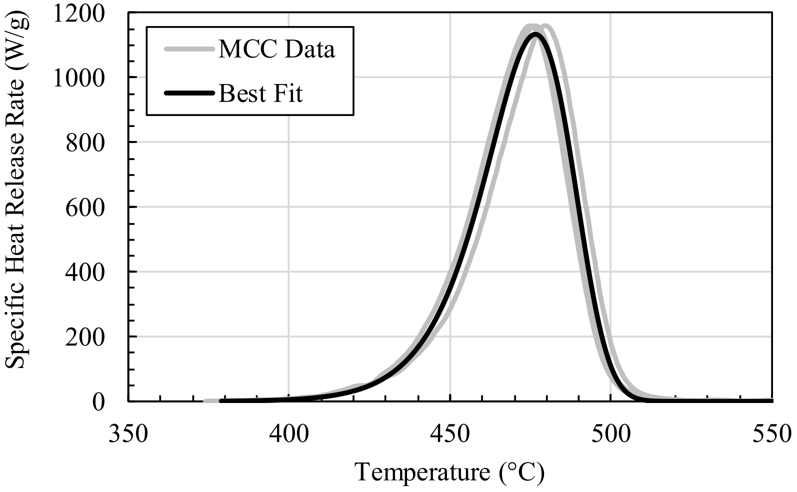


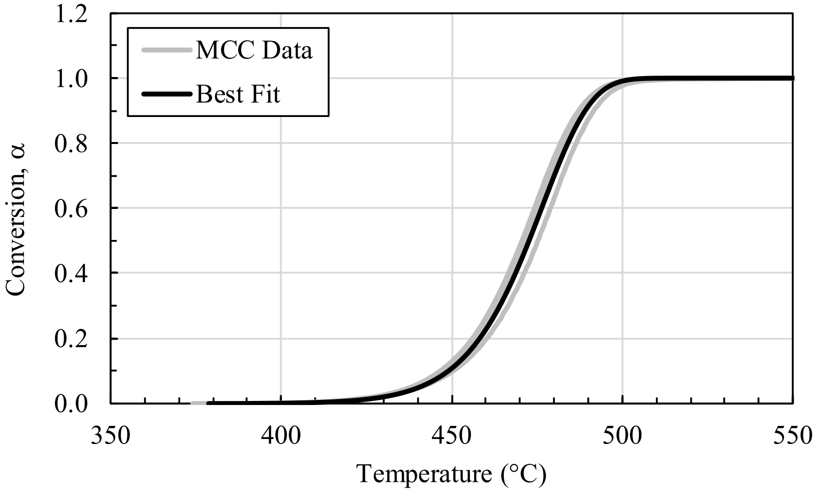
Chevy Mailbu Door Trim MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.09	4.03				4.07	0.032
m_f (mg)	0.54	0.55	0.55				0.55	0.006
η_c (J/g·K)	1012	1012	1013				1012	0.7
Q_{max} (W/g)	1006	1003	1002				1004	1.7
T_{max} (°C)	480	476	475				477	2.3
h_c (kJ/g)	36.3	35.9	36.2				36.1	0.17
Y_p (g/g)	0.132	0.134	0.136				0.13	0.002
$h_{c,gas}$ (kJ/g)	41.8	41.5	41.9				41.7	0.20

	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4				
Test 5				
Test 6				
Average	1.000			
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	417	441	495	0.994
Test 2	416	440	492	0.991
Test 3	415	438	491	0.990
Test 4				
Test 5				
Test 6				
Average	416	439	493	0.992

	R1	R2	R3	R4
A (1/s)	1.32E+23			
E (kJ/mol)	348			
n	1.09			

Physical Properties	
ρ (kg/m^3)	912
δ (mm)	2.40



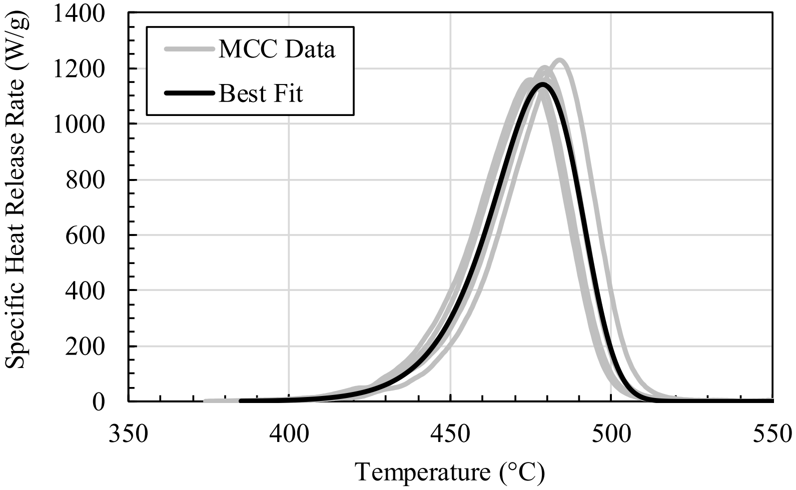


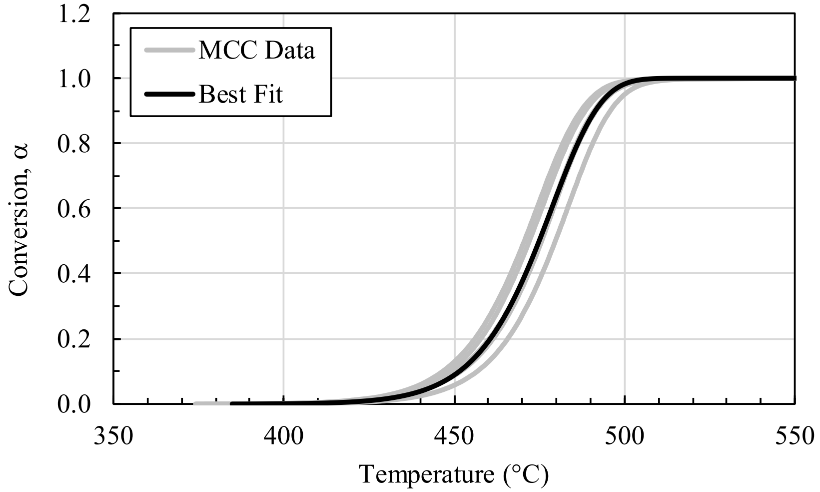
Chevy Mailbu Door Trim MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.09	4.03	4.07	4.02	4.03	4.05	0.030
m_f (mg)	0.54	0.55	0.55	0.56	0.50	0.59	0.55	0.029
η_c (J/g·K)	1012	1012	1013	1048	1046	1055	1031	20.8
Q_{max} (W/g)	1006	1003	1002	1037	1037	1049	1022	21.1
T_{max} (°C)	480	476	475	479	480	484	479	3.1
h_c (kJ/g)	36.3	35.9	36.2	36.2	36.3	36.7	36.3	0.26
Y_p (g/g)	0.132	0.134	0.136	0.138	0.124	0.146	0.14	0.007
$h_{c,gas}$ (kJ/g)	41.8	41.5	41.9	42.0	41.4	43.0	41.9	0.57

	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4	1.000			
Test 5	1.000			
Test 6	1.000			
Average	1.000			
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	417	441	495	0.994
Test 2	416	440	492	0.991
Test 3	415	438	491	0.990
Test 4	420	442	495	0.990
Test 5	420	442	495	0.991
Test 6	424	448	500	0.994
Average	419	442	495	0.992

	R1	R2	R3	R4
A (1/s)	3.26E+23			
E (kJ/mol)	355			
n	1.11			

Physical Properties	
ρ (kg/m^3)	912
δ (mm)	2.40





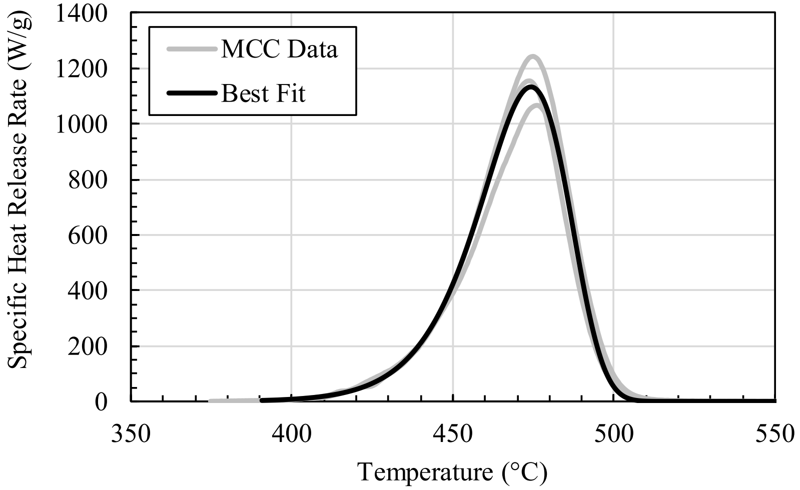
Chevy Mailbu Instrument Panel MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.02	4.00				4.01	0.010
m_f (mg)	0.72	0.77	0.77				0.75	0.029
η_c (J/g·K)	881	943	1013				946	66.1
Q_{max} (W/g)	874	933	1002				936	64.4
T_{max} (°C)	476	474	475				475	1.3
h_c (kJ/g)	33.2	33.2	36.2				34.2	1.72
Y_p (g/g)	0.180	0.192	0.193				0.19	0.007
$h_{c,gas}$ (kJ/g)	40.5	41.0	44.8				42.1	2.34

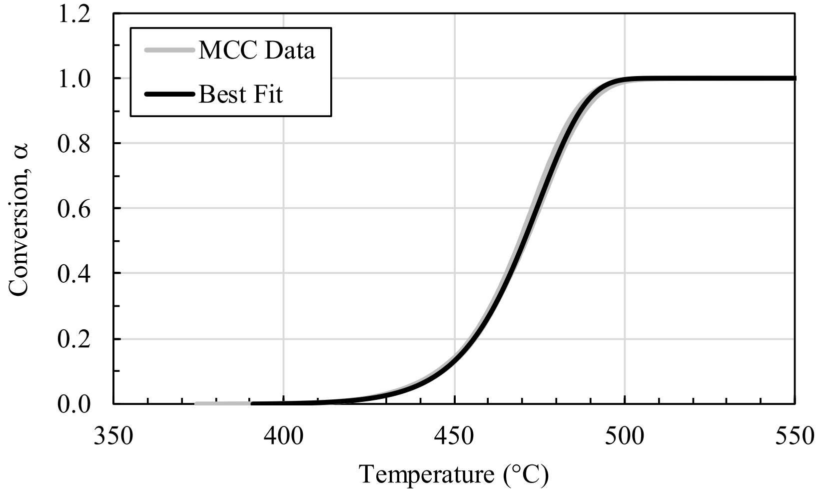
	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4				
Test 5				
Test 6				
Average	1.000			

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	413	435	492	0.992
Test 2	413	437	490	0.989
Test 3	414	438	491	0.990
Test 4				
Test 5				
Test 6				
Average	413	437	491	0.990

	R1	R2	R3	R4
A (1/s)	2.19E+22			
E (kJ/mol)	336			
n	1.05			

Physical Properties	
ρ (kg/m^3)	999
δ (mm)	3.00





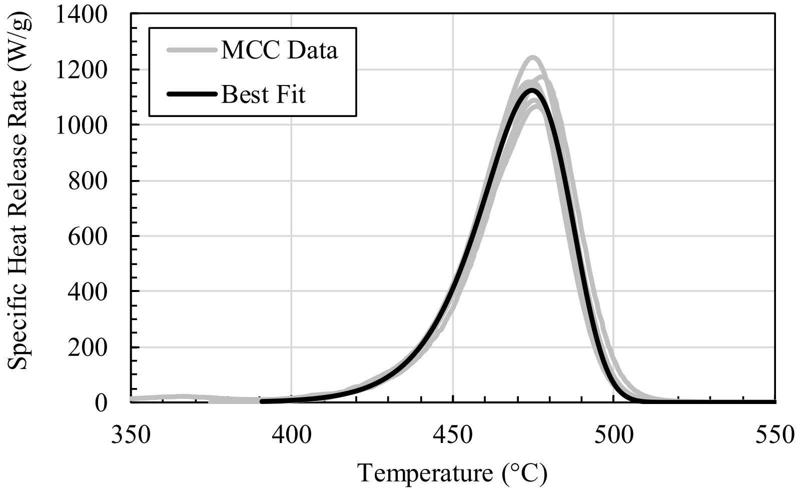
Chevy Mailbu Instrument Panel MCC Data

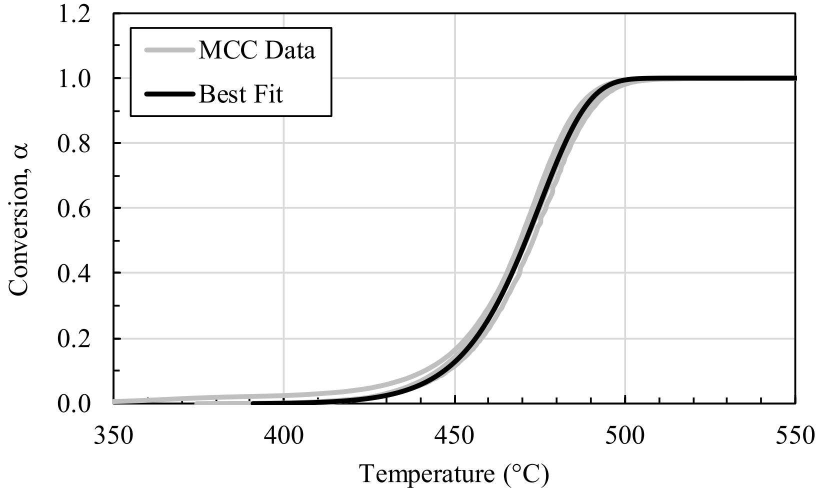
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.02	4.00	4.07	4.04	4.06	4.03	0.028
m_f (mg)	0.72	0.77	0.77	0.74	0.78	0.82	0.77	0.034
η_c (J/g·K)	881	943	1013	901	939	952	938	45.8
Q_{max} (W/g)	874	933	1002	890	931	935	927	44.8
T_{max} (°C)	476	474	475	475	475	478	476	1.3
h_c (kJ/g)	33.2	33.2	36.2	33.8	33.3	34.5	34.0	1.16
Y_p (g/g)	0.180	0.192	0.193	0.182	0.193	0.202	0.19	0.008
$h_{c,gas}$ (kJ/g)	40.5	41.0	44.8	41.4	41.3	43.3	42.0	1.64

	c_1	c_2	c_3	c_4
Test 1	1.000			
Test 2	1.000			
Test 3	1.000			
Test 4	1.000			
Test 5	1.000			
Test 6	1.000			
Average	1.000			
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	413	435	492	0.992
Test 2	413	437	490	0.989
Test 3	414	438	491	0.990
Test 4	412	426	491	0.988
Test 5	414	437	490	0.991
Test 6	417	438	494	0.983
Average	414	435	492	0.989

	R1	R2	R3	R4
A (1/s)	3.29E+22			
E (kJ/mol)	339			
n	1.08			

Physical Properties	
ρ (kg/m^3)	999
δ (mm)	3.00





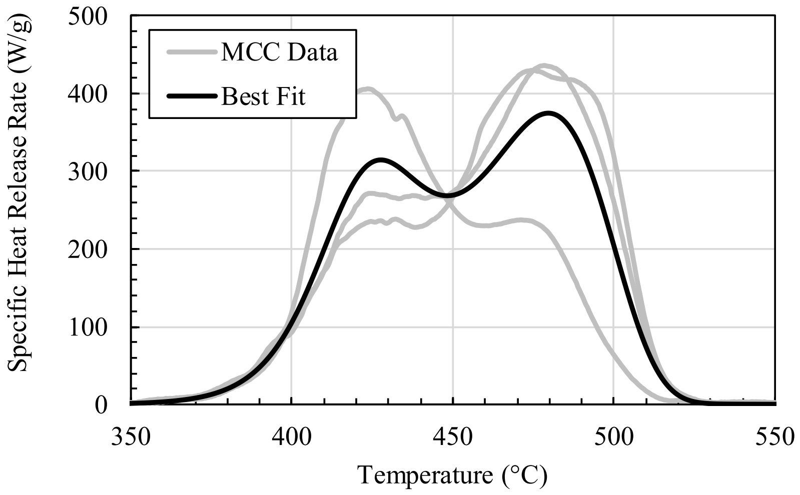
Honda Civic Aftermarket Carpet BTY MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.01	4.07	4.02				4.03	0.032
m_f (mg)	0.02	0.03	0.02				0.02	0.006
η_c (J/g·K)	440	407	433				427	17.2
Q_{max} (W/g)	434	404	428				422	16.0
T_{max} (°C)	479	423	474				459	30.7
h_c (kJ/g)	33.6	28.1	34.2				32.0	3.34
Y_p (g/g)	0.005	0.007	0.005				0.01	0.001
$h_{c,gas}$ (kJ/g)	33.8	28.3	34.4				32.2	3.32

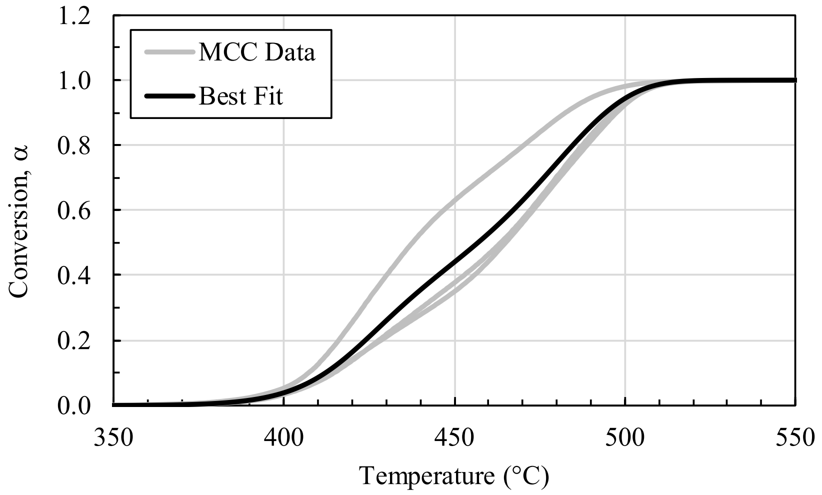
	c_1	c_2	c_3	c_4
Test 1	0.297	0.703		
Test 2	0.630	0.370		
Test 3	0.215	0.785		
Test 4				
Test 5				
Test 6				
Average	0.381	0.619		

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	383	404	502	0.986
Test 2	381	399	491	0.991
Test 3	379	402	503	0.989
Test 4				
Test 5				
Test 6				
Average	381	402	499	0.989

	R1	R2	R3	R4
A (1/s)	1.24E+25	1.22E+14		
E (kJ/mol)	350	223		
n	2.15	1.00		

Physical Properties	
ρ (kg/m^3)	334
δ (mm)	2.90





Honda Civic Aftermarket Carpet BTY MCC Data

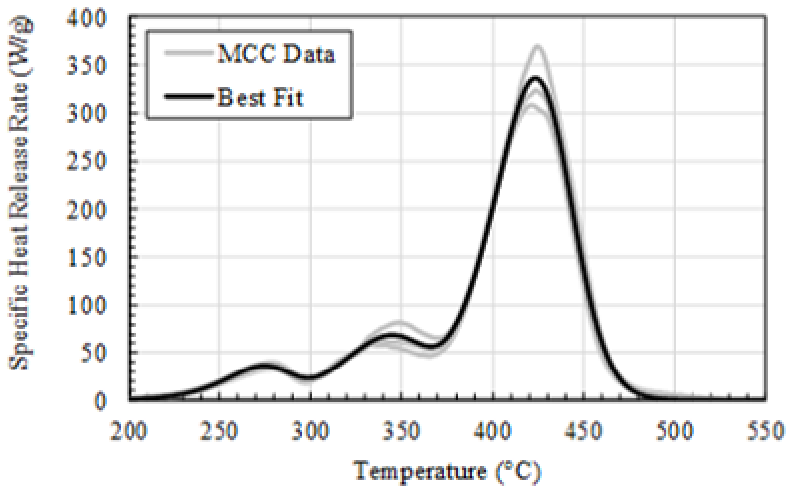
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.06	4.03				4.06	0.025
m_f (mg)	0.12	0.56	0.21				0.30	0.232
η_c (J/g·K)	316	320	295				310	13.4
Q_{max} (W/g)	314	319	292				308	14.1
T_{max} (°C)	424	425	421				423	2.1
h_c (kJ/g)	22.9	22.3	21.8				22.3	0.53
Y_p (g/g)	0.029	0.138	0.052				0.07	0.057
$h_{c,gas}$ (kJ/g)	23.5	25.9	23.0				24.1	1.52

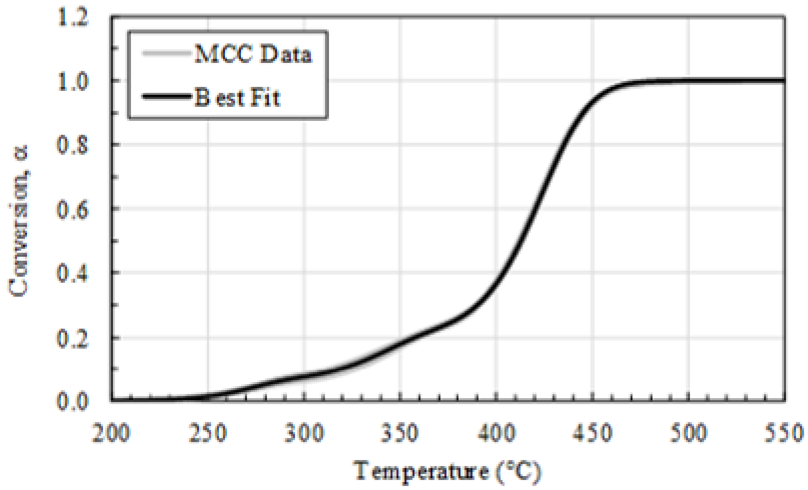
	c_1	c_2	c_3	c_4
Test 1	0.066	0.149	0.785	
Test 2	0.053	0.159	0.788	
Test 3	0.063	0.124	0.813	
Test 4				
Test 5				
Test 6				
Average	0.061	0.144	0.795	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	247	275	452	0.994
Test 2	252	285	454	0.995
Test 3	248	276	454	0.990
Test 4				
Test 5				
Test 6				
Average	249	279	453	0.993

	R1	R2	R3	R4
A (1/s)	3.69E+11	3.89E+10	4.83E+14	
E (kJ/mol)	134	140	213	
n	1.00	1.00	1.34	

Physical Properties	
ρ (kg/m³)	95
δ (mm)	6.00





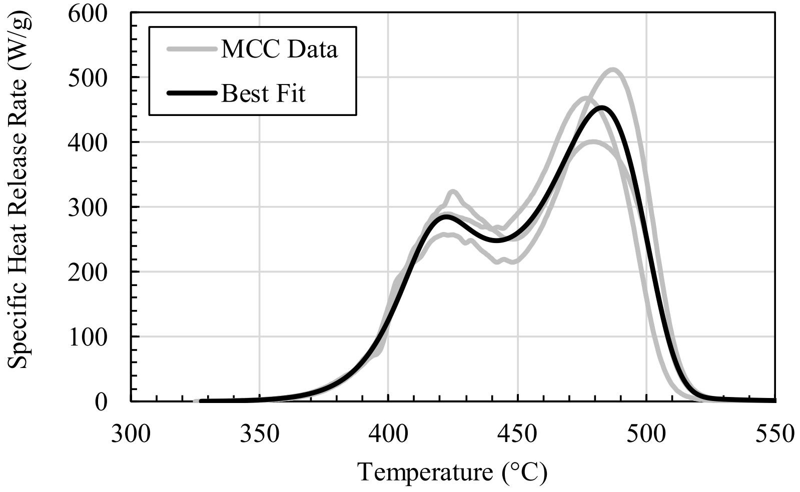
Honda Civic Aftermarket Molded Carpet MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.00	4.08	4.07				4.05	0.044
m_f (mg)	0.00	0.00	0.02				0.01	0.012
η_c (J/g·K)	405	517	472				465	56.4
Q_{max} (W/g)	401	512	466				460	55.9
T_{max} (°C)	479	487	476				481	5.6
h_c (kJ/g)	34.1	35.6	34.2				34.7	0.84
Y_p (g/g)	0.000	0.000	0.005				0.00	0.003
$h_{c,gas}$ (kJ/g)	34.1	35.6	34.4				34.7	0.81

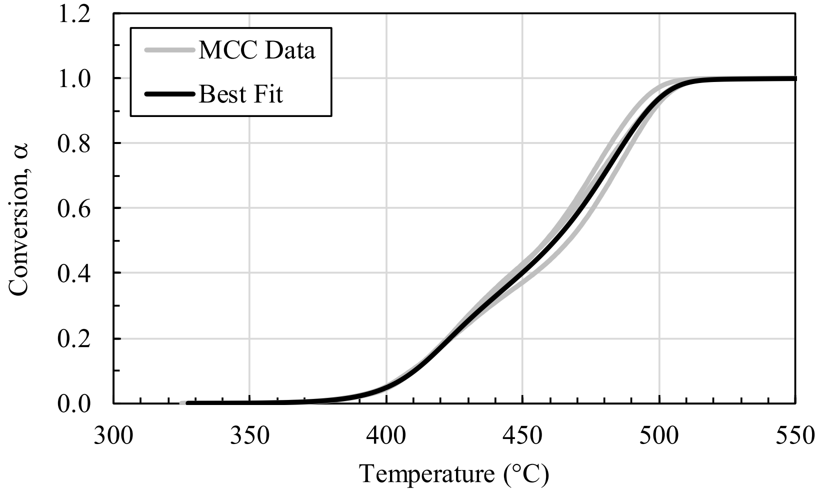
	c_1	c_2	c_3	c_4
Test 1	0.280	0.113	0.607	
Test 2	0.291	0.085	0.624	
Test 3	0.375	0.110	0.515	
Test 4				
Test 5				
Test 6				
Average	0.315	0.103	0.582	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	381	401	501	0.990
Test 2	376	399	503	0.991
Test 3	381	401	496	0.987
Test 4				
Test 5				
Test 6				
Average	379	400	500	0.989

	R1	R2	R3	R4
A (1/s)	2.53E+18	1.22E+29	5.58E+16	
E (kJ/mol)	264	398	261	
n	2.24	1.50	1.00	

Physical Properties	
ρ (kg/m^3)	270
δ (mm)	3.40





Honda Civic Aftermarket Molded Carpet MCC Data

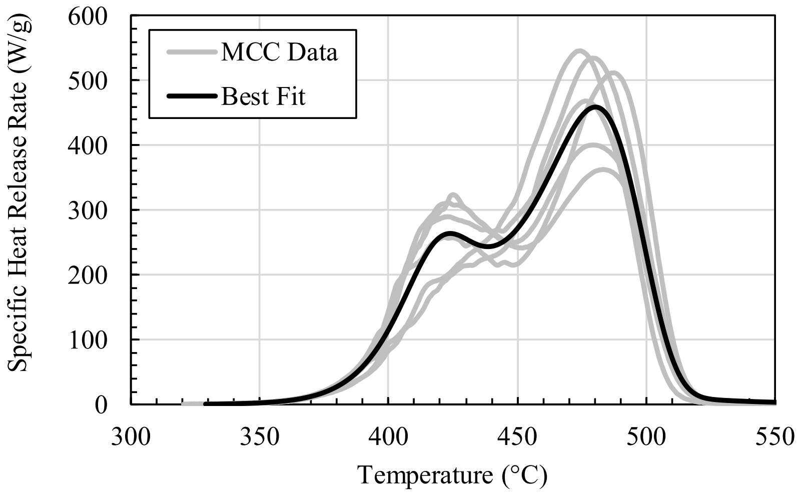
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.00	4.08	4.07	4.04	4.05	4.04	4.05	0.028
m_f (mg)	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.008
η_c (J/g·K)	405	517	472	539	365	550	475	75.6
Q_{max} (W/g)	401	512	466	536	362	546	470	75.2
T_{max} (°C)	479	487	476	479	484	474	480	4.7
h_c (kJ/g)	34.1	35.6	34.2	34.1	32.8	35.1	34.3	0.98
Y_p (g/g)	0.000	0.000	0.005	0.000	0.000	0.000	0.00	0.002
$h_{c,gas}$ (kJ/g)	34.1	35.6	34.4	34.1	32.8	35.1	34.3	0.98

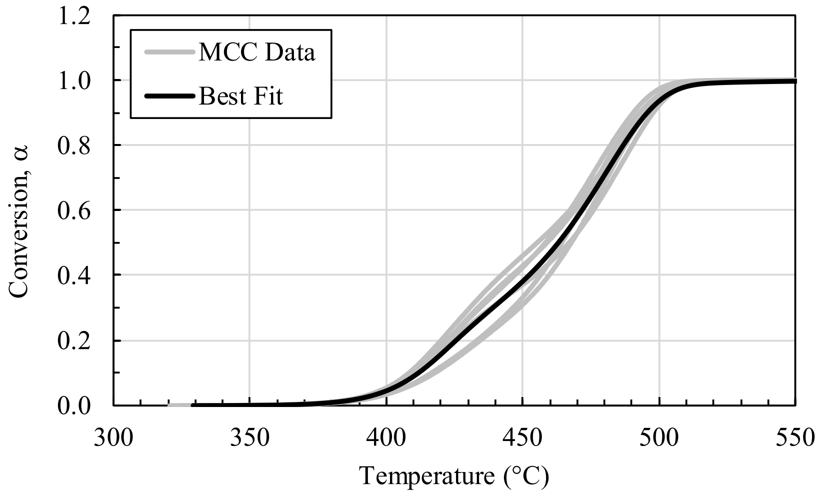
	c_1	c_2	c_3	c_4
Test 1	0.280	0.113	0.607	
Test 2	0.291	0.085	0.624	
Test 3	0.375	0.110	0.515	
Test 4	0.259	0.047	0.694	
Test 5	0.365	0.092	0.543	
Test 6	0.210	0.038	0.752	
Average	0.297	0.081	0.622	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	381	401	501	0.990
Test 2	376	399	503	0.991
Test 3	381	401	496	0.987
Test 4	382	405	501	0.993
Test 5	379	399	502	0.992
Test 6	383	405	499	0.992
Average	380	402	500	0.991

	R1	R2	R3	R4
A (1/s)	3.08E+19	4.11E+28	4.54E+15	
E (kJ/mol)	277	393	245	
n	2.77	1.45	1.00	

Physical Properties	
ρ (kg/m^3)	270
δ (mm)	3.40





Appendix I: Arrhenius Model Parameters for Task 6 Materials

BB Ribbed Flooring MCC Data

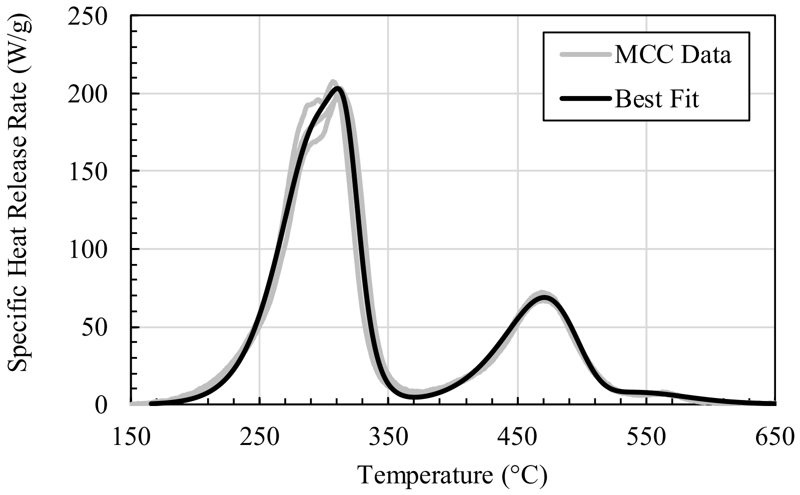
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.00	4.03	4.04				4.02	0.021
m_f (mg)	1.01	1.03	1.01				1.02	0.012
η_c (J/g·K)	149	153	158				153	4.4
Q_{max} (W/g)	147	151	156				151	4.3
T_{max} (°C)	312	313	307				311	3.4
h_c (kJ/g)	15.1	14.6	15.1				14.9	0.27
Y_p (g/g)	0.253	0.256	0.250				0.25	0.003
$h_{c,gas}$ (kJ/g)	20.2	19.7	20.2				20.0	0.29

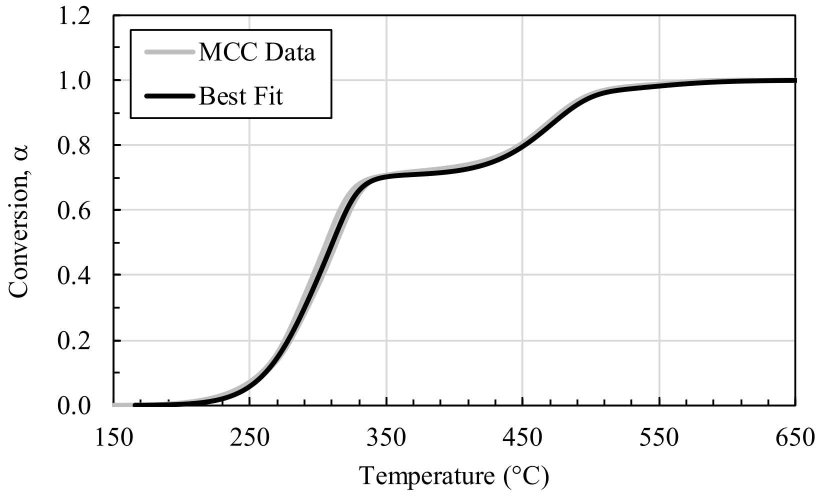
	c_1	c_2	c_3	c_4
Test 1	0.490	0.216	0.239	0.054
Test 2	0.481	0.229	0.254	0.036
Test 3	0.513	0.192	0.251	0.044
Test 4				
Test 5				
Test 6				
Average	0.495	0.213	0.248	0.045

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	232	243	499	0.987
Test 2	234	244	500	0.991
Test 3	231	241	496	0.987
Test 4				
Test 5				
Test 6				
Average	232	243	498	0.988

	R1	R2	R3	R4
A (1/s)	8.96E+08	3.68E+29	3.89E+09	2.99E+08
E (kJ/mol)	111	345	157	156
n	1.00	2.04	1.01	1.56

Physical Properties	
ρ (kg/m^3)	1123
δ (mm)	4.68



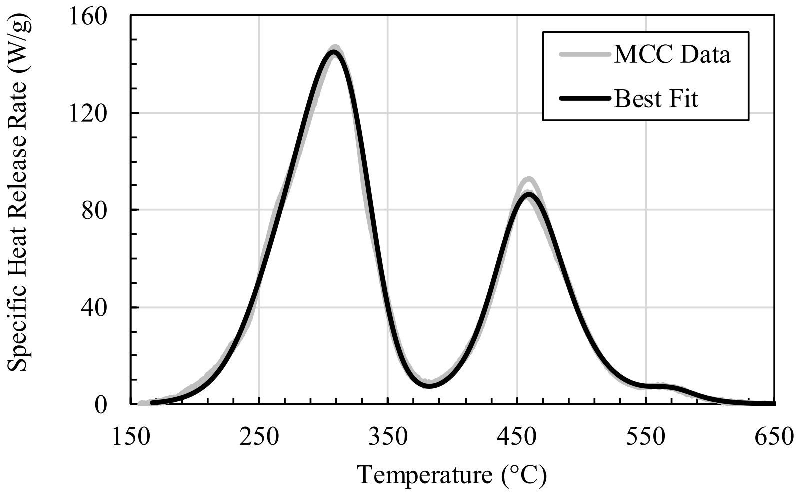


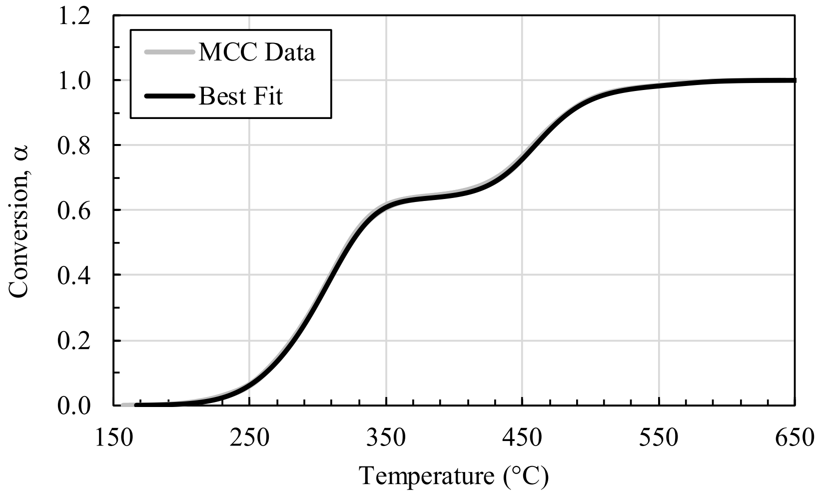
BB Blue Pigskin MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.08	4.03				4.05	0.025
m_f (mg)	0.84	0.82	0.83				0.83	0.010
η_c (J/g·K)	116	119	116				117	1.6
Q_{max} (W/g)	115	118	114				116	1.8
T_{max} (°C)	310	309	308				309	0.6
h_c (kJ/g)	14.9	15.2	15.3				15.1	0.21
Y_p (g/g)	0.207	0.201	0.206				0.20	0.003
$h_{c,gas}$ (kJ/g)	18.8	19.1	19.2				19.0	0.22

	c_1	c_2	c_3	c_4
Test 1	0.125	0.521	0.342	0.012
Test 2	0.140	0.501	0.345	0.014
Test 3	0.174	0.467	0.346	0.012
Test 4				
Test 5				
Test 6				
Average	0.146	0.496	0.344	0.013
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	232	245	504	0.991
Test 2	232	246	504	0.993
Test 3	230	243	505	0.987
Test 4				
Test 5				
Test 6				
Average	231	245	504	0.990

	R1	R2	R3	R4
A (1/s)	9.67E+09	8.13E+07	1.88E+15	3.45E+25
E (kJ/mol)	118	104	233	431
n	2.79	1.15	2.13	1.89

Physical Properties	
ρ (kg/m^3)	1105
δ (mm)	0.79





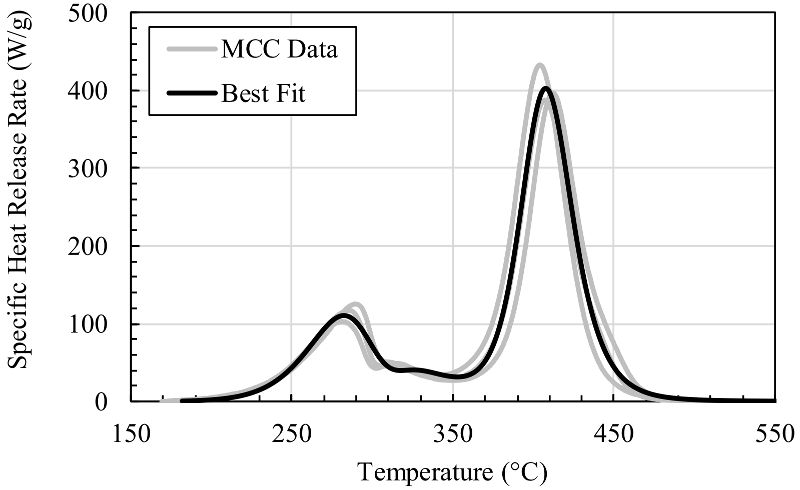
BB High-Back Foam MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.06	4.00	4.02				4.03	0.031
m_f (mg)	0.10	0.03	0.00				0.04	0.051
η_c (J/g·K)	428	388	402				406	20.0
Q_{max} (W/g)	422	385	397				401	19.1
T_{max} (°C)	404	407	412				408	3.9
h_c (kJ/g)	25.5	25.3	25.8				25.5	0.28
Y_p (g/g)	0.025	0.008	0.000				0.01	0.013
$h_{c,gas}$ (kJ/g)	26.2	25.5	25.8				25.8	0.36

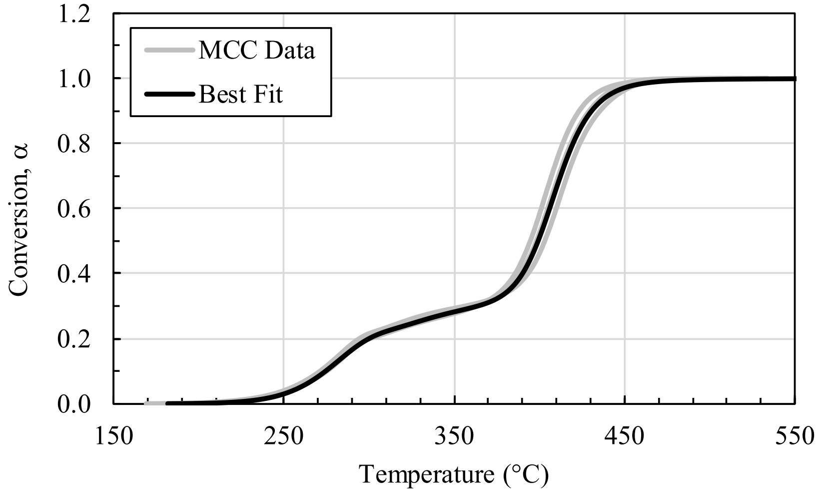
	c_1	c_2	c_3	c_4
Test 1	0.199	0.125	0.675	
Test 2	0.214	0.111	0.675	
Test 3	0.225	0.112	0.663	
Test 4				
Test 5				
Test 6				
Average	0.213	0.116	0.671	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	232	254	432	0.988
Test 2	234	255	438	0.991
Test 3	237	258	446	0.987
Test 4				
Test 5				
Test 6				
Average	234	256	439	0.989

	R1	R2	R3	R4
A (1/s)	7.03E+10	2.19E+24	4.44E+26	
E (kJ/mol)	129	292	361	
n	1.00	5.00	2.17	

Physical Properties	
ρ (kg/m^3)	130
δ (mm)	21.00



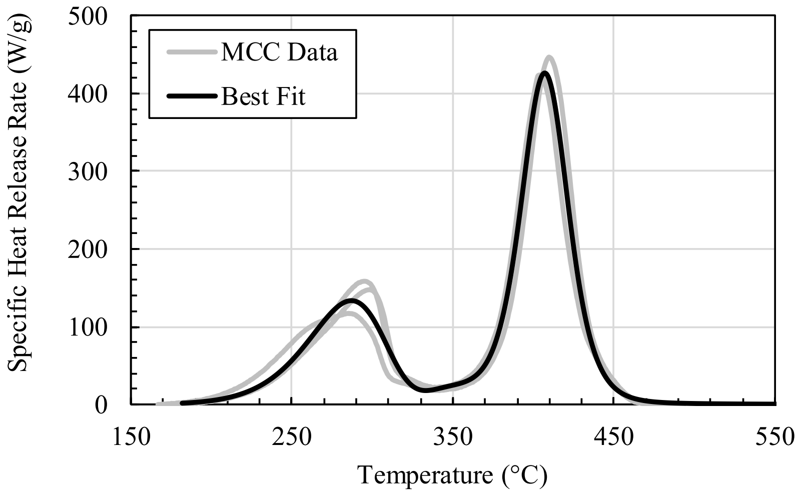


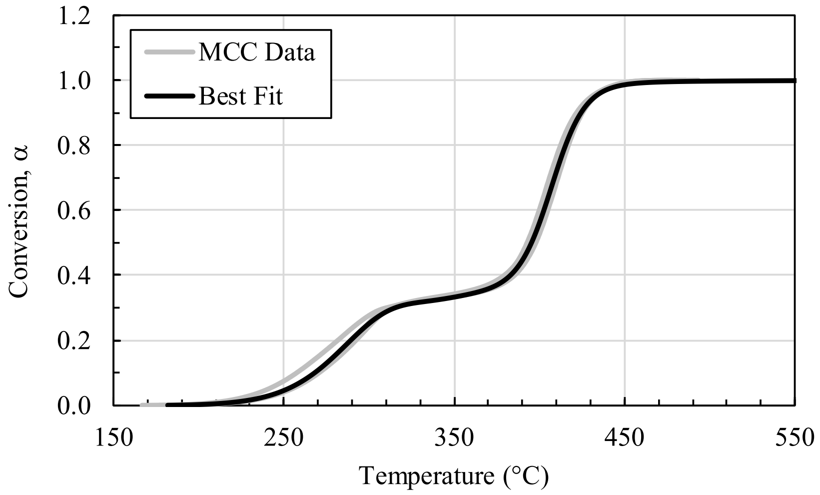
BB Seat Bottom Foam MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.03	4.04	4.02				4.03	0.010
m_f (mg)	0.58	0.57	0.56				0.57	0.010
η_c (J/g·K)	368	388	372				376	10.9
Q_{max} (W/g)	364	384	365				371	11.3
T_{max} (°C)	406	409	404				407	2.7
h_c (kJ/g)	23.0	22.8	22.3				22.7	0.34
Y_p (g/g)	0.144	0.141	0.139				0.14	0.002
$h_{c,gas}$ (kJ/g)	26.8	26.5	25.9				26.4	0.46

	c_1	c_2	c_3	c_4
Test 1	0.310	0.066	0.624	
Test 2	0.312	0.065	0.623	
Test 3	0.316	0.061	0.623	
Test 4				
Test 5				
Test 6				
Average	0.313	0.064	0.623	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	236	254	431	0.989
Test 2	234	253	433	0.989
Test 3	219	240	430	0.981
Test 4				
Test 5				
Test 6				
Average	230	249	431	0.986

	R1	R2	R3	R4
A (1/s)	3.40E+08	2.18E+23	1.04E+27	
E (kJ/mol)	106	292	365	
n	1.00	5.00	1.86	

Physical Properties	
ρ (kg/m^3)	25
δ (mm)	7.50





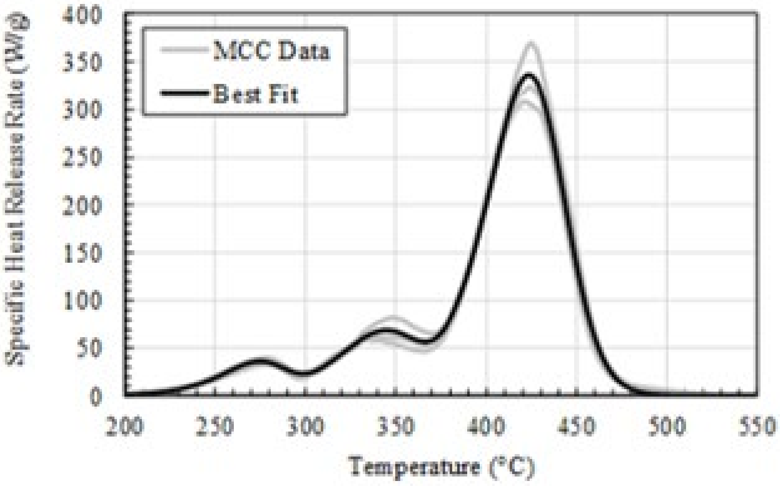
IC Bus Smooth Flooring								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.08	4.06	4.03				4.06	0.025
m_f (mg)	0.12	0.56	0.21				0.30	0.232
η_c (J/g·K)	316	320	295				310	13.4
Q_{max} (W/g)	314	319	292				308	14.1
T_{max} (°C)	424	425	421				423	2.1
h_c (kJ/g)	22.9	22.3	21.8				22.3	0.53
Y_p (g/g)	0.029	0.138	0.052				0.07	0.057
$h_{c,gas}$ (kJ/g)	23.5	25.9	23.0				24.1	1.52

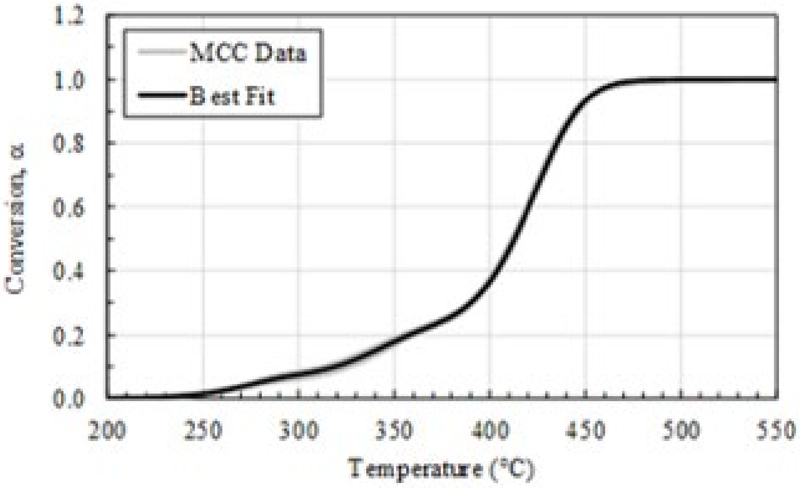
	c_1	c_2	c_3	c_4
Test 1	0.066	0.149	0.785	
Test 2	0.053	0.159	0.788	
Test 3	0.063	0.124	0.813	
Test 4				
Test 5				
Test 6				
Average	0.061	0.144	0.795	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	247	275	452	0.994
Test 2	252	285	454	0.995
Test 3	248	276	454	0.990
Test 4				
Test 5				
Test 6				
Average	249	279	453	0.993

	R1	R2	R3	R4
A (1/s)	3.69E+11	3.89E+10	4.83E+14	
E (kJ/mol)	134	140	213	
n	1.00	1.00	1.34	

Physical Properties	
ρ (kg/m³)	95
δ (mm)	6.00



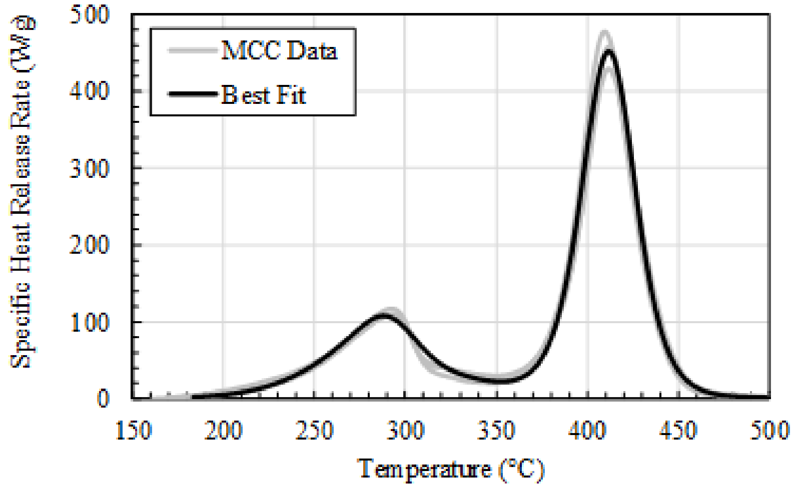


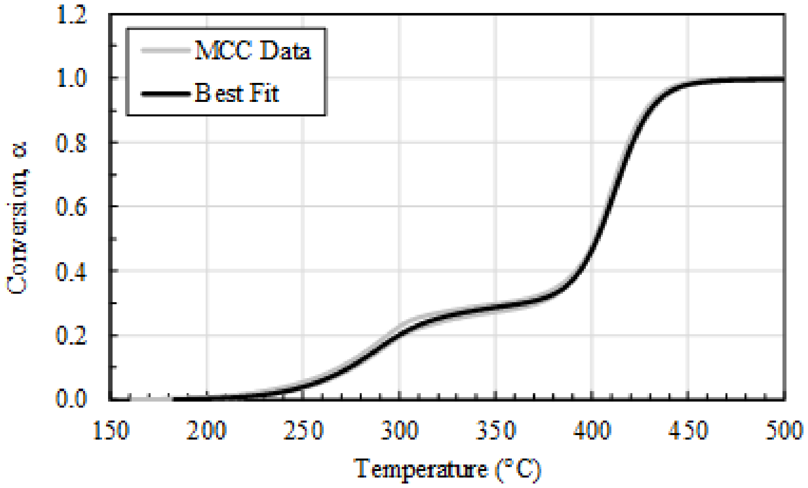
IC Bus High-Back MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.05	4.01	4.06				4.04	0.026
m_f (mg)	0.06	0.05	0.05				0.05	0.006
η_c (J/g·K)	476	428	458				454	24.1
Q_{max} (W/g)	471	424	453				449	23.6
T_{max} (°C)	410	412	412				411	1.3
h_c (kJ/g)	26.0	25.6	26.5				26.0	0.44
Y_p (g/g)	0.015	0.012	0.012				0.01	0.001
$h_{c,gas}$ (kJ/g)	26.4	25.9	26.8				26.4	0.45

	c_1	c_2	c_3	c_4
Test 1	0.166	0.138	0.696	
Test 2	0.175	0.152	0.673	
Test 3	0.141	0.194	0.665	
Test 4				
Test 5				
Test 6				
Average	0.161	0.161	0.678	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	231	257	435	0.989
Test 2	223	247	438	0.990
Test 3	227	253	439	0.990
Test 4				
Test 5				
Test 6				
Average	227	253	437	0.990

	R1	R2	R3	R4
A (1/s)	8.18E+07	7.28E+22	2.33E+26	
E (kJ/mol)	98	262	360	
n	1.00	5.00	1.83	

Physical Properties	
ρ (kg/m^3)	27
δ (mm)	18.00





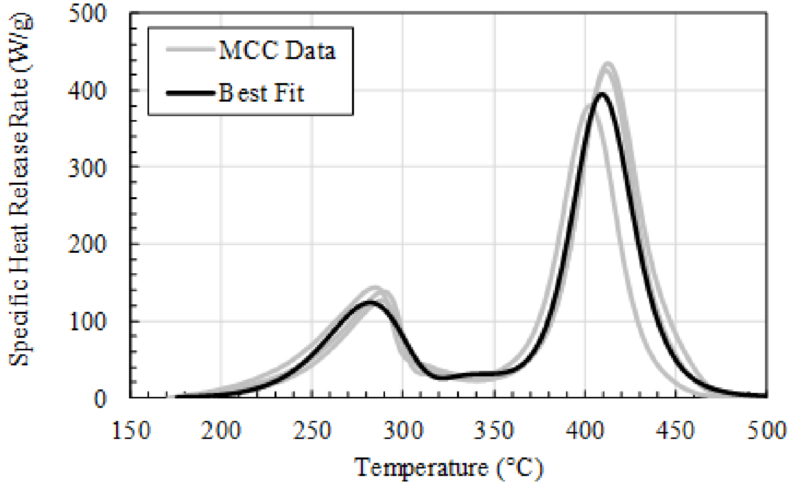
IC Bus Seat Bottom Foam MCC Data

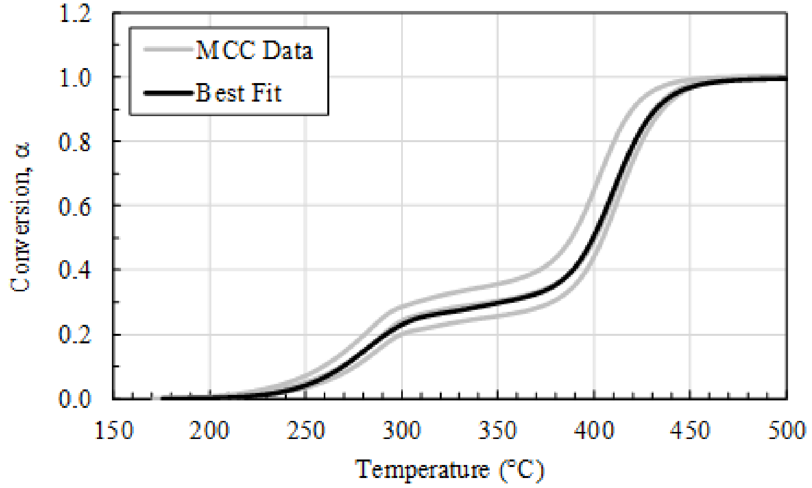
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.07	4.04	4.05				4.05	0.015
m_f (mg)	0.00	0.00	0.00				0.00	0.000
η_c (J/g·K)	383	438	430				417	29.8
Q_{max} (W/g)	380	435	426				414	29.5
T_{max} (°C)	403	413	412				409	5.4
h_c (kJ/g)	25.5	27.9	26.7				26.7	1.22
Y_p (g/g)	0.000	0.000	0.000				0.00	0.000
$h_{c,gas}$ (kJ/g)	25.5	27.9	26.7				26.7	1.22

	c_1	c_2	c_3	c_4
Test 1	0.300	0.097	0.604	
Test 2	0.207	0.085	0.708	
Test 3	0.262	0.087	0.651	
Test 4				
Test 5				
Test 6				
Average	0.256	0.090	0.654	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	221	241	428	0.993
Test 2	237	258	445	0.994
Test 3	230	249	440	0.991
Test 4				
Test 5				
Test 6				
Average	229	250	438	0.992

	R1	R2	R3	R4
A (1/s)	4.70E+09	2.99E+22	4.25E+24	
E (kJ/mol)	117	276	336	
n	1.00	5.00	2.03	

Physical Properties	
ρ (kg/m^3)	108
δ (mm)	13.50



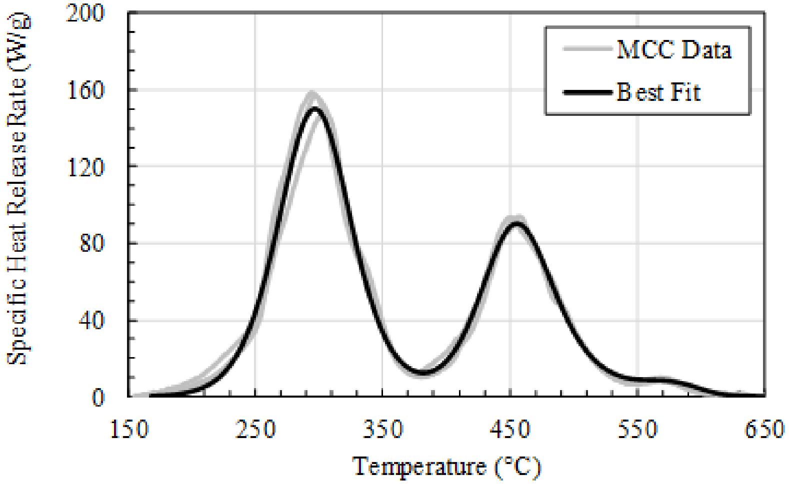


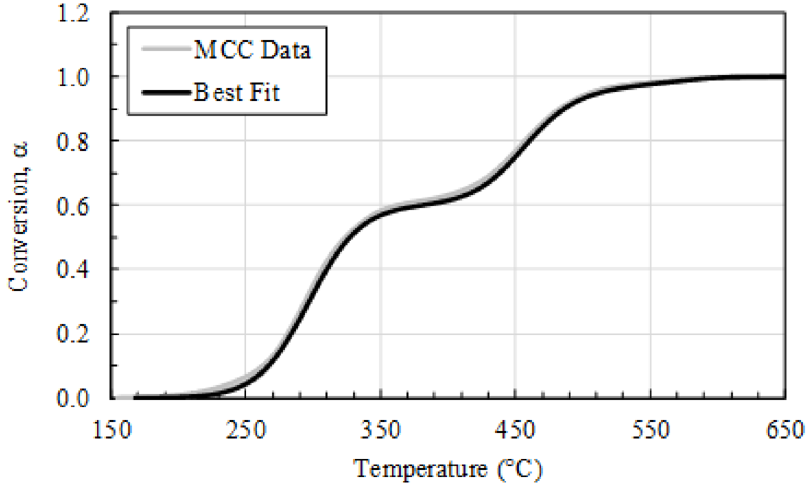
IC Bus Seat Back Closure MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.04	4.03	4.00				4.02	0.021
m_f (mg)	0.82	0.80	0.86				0.83	0.031
η_c (J/g·K)	126	129	117				124	6.3
Q_{max} (W/g)	125	127	115				123	6.4
T_{max} (°C)	296	294	302				297	4.2
h_c (kJ/g)	15.5	15.7	14.7				15.3	0.50
Y_p (g/g)	0.203	0.199	0.215				0.21	0.009
$h_{c,gas}$ (kJ/g)	19.4	19.6	18.8				19.2	0.42

	c_1	c_2	c_3	c_4
Test 1	0.604	0.377	0.019	
Test 2	0.606	0.371	0.023	
Test 3	0.600	0.375	0.025	
Test 4				
Test 5				
Test 6				
Average	0.604	0.374	0.022	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	239	253	509	0.992
Test 2	236	250	505	0.987
Test 3	235	241	506	0.985
Test 4				
Test 5				
Test 6				
Average	237	248	507	0.988

	R1	R2	R3	R4
A (1/s)	3.68E+09	1.55E+14	7.10E+13	
E (kJ/mol)	119	217	248	
n	1.71	2.08	1.14	

Physical Properties	
ρ (kg/m^3)	910
δ (mm)	0.79





Motorcoach Plywood MCC Data

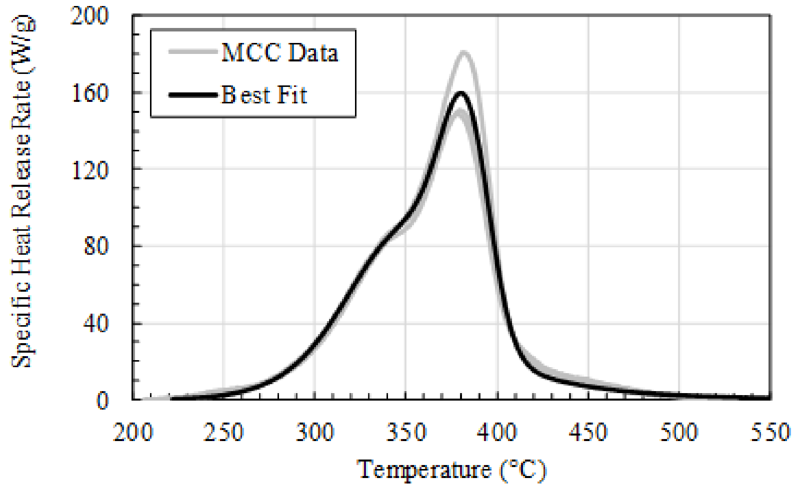
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.09	4.06	4.08				4.08	0.015
m_f (mg)	0.68	0.83	0.86				0.79	0.096
η_c (J/g·K)	153	120	121				131	18.8
Q_{max} (W/g)	151	118	119				129	18.5
T_{max} (°C)	381	379	379				380	1.2
h_c (kJ/g)	10.2	8.9	9.1				9.4	0.68
Y_p (g/g)	0.166	0.204	0.211				0.19	0.024
$h_{c,gas}$ (kJ/g)	12.2	11.2	11.6				11.6	0.52

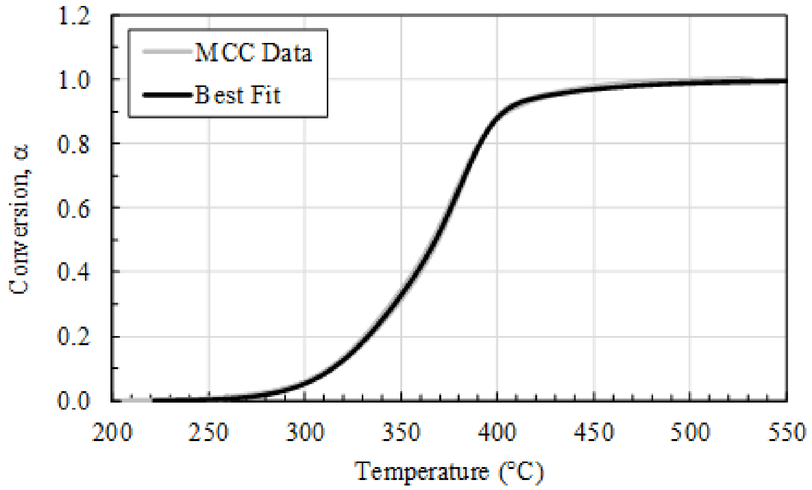
	c_1	c_2	c_3	c_4
Test 1	0.326	0.516	0.158	
Test 2	0.333	0.466	0.201	
Test 3	0.328	0.566	0.106	
Test 4				
Test 5				
Test 6				
Average	0.329	0.516	0.155	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	294	296	422	0.985
Test 2	295	296	427	0.988
Test 3	294	297	428	0.982
Test 4				
Test 5				
Test 6				
Average	294	296	425	0.985

	R1	R2	R3	R4
A (1/s)	4.41E+09	2.06E+18	5.26E+15	
E (kJ/mol)	128	244	216	
n	1.00	1.24	3.56	

Physical Properties	
ρ (kg/m^3)	591
δ (mm)	9.00





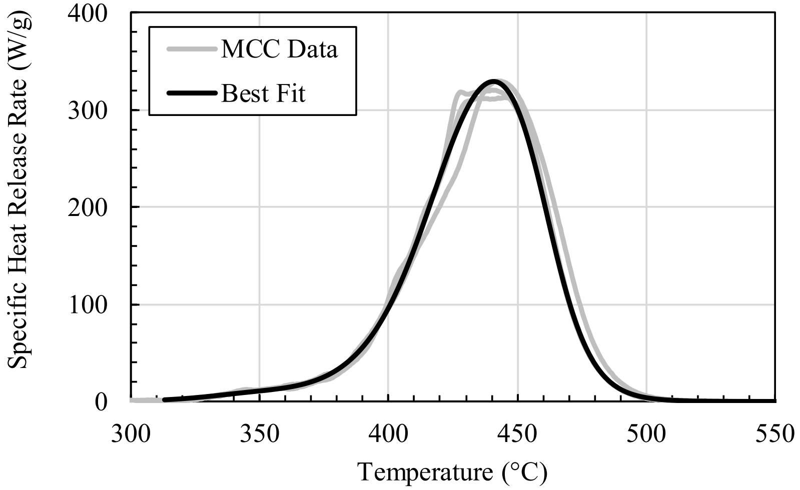
MC Olefin Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.00	4.03	4.03				4.02	0.017
m_f (mg)	0.57	0.56	0.53				0.55	0.021
η_c (J/g·K)	275	278	288				280	6.9
Q_{max} (W/g)	268	276	286				277	9.2
T_{max} (°C)	445	440	443				443	2.4
h_c (kJ/g)	16.7	16.9	17.1				16.9	0.20
Y_p (g/g)	0.143	0.139	0.132				0.14	0.006
$h_{c,gas}$ (kJ/g)	19.5	19.7	19.7				19.6	0.11

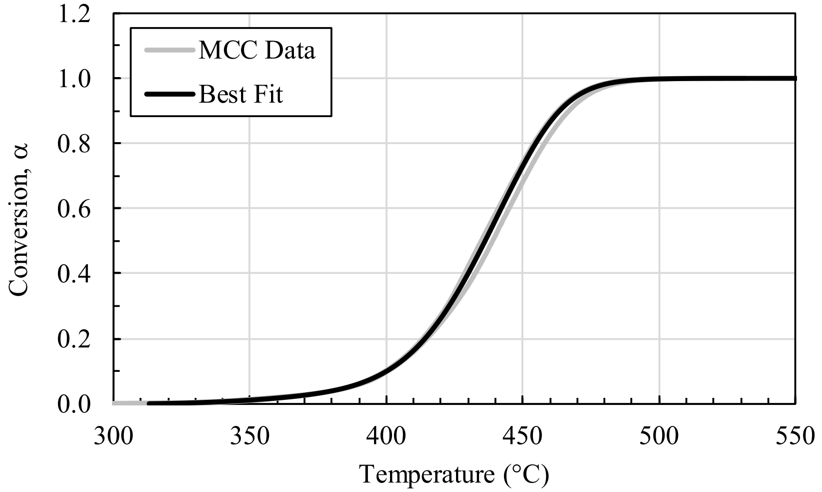
	c_1	c_2	c_3	c_4
Test 1	0.027	0.409	0.564	
Test 2	0.034	0.427	0.539	
Test 3	0.020	0.545	0.435	
Test 4				
Test 5				
Test 6				
Average	0.027	0.460	0.513	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	344	386	470	0.976
Test 2	350	385	470	0.991
Test 3	350	386	474	0.994
Test 4				
Test 5				
Test 6				
Average	348	386	471	0.987

	R1	R2	R3	R4
A (1/s)	3.09E+18	2.75E+16	1.35E+25	
E (kJ/mol)	236	237	363	
n	3.33	1.11	1.61	

Physical Properties	
ρ (kg/m^3)	375
δ (mm)	0.75





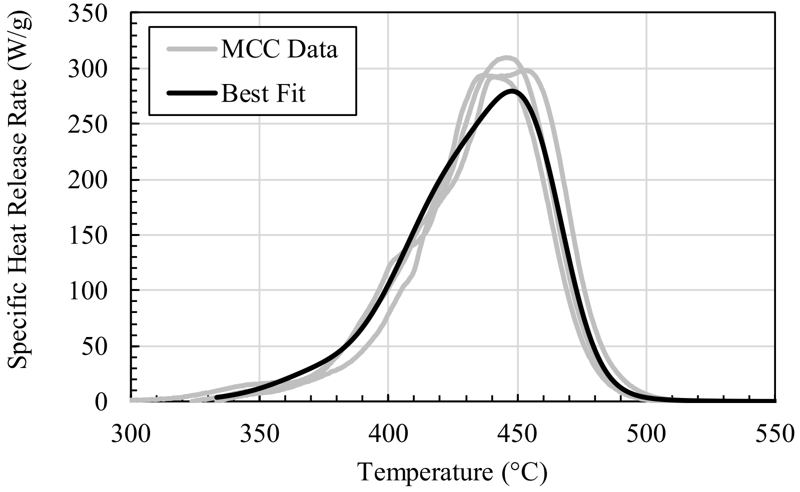
MC Polyester Seat Cover MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.06	4.07	4.08				4.07	0.010
m_f (mg)	0.62	0.55	0.50				0.56	0.060
η_c (J/g·K)	255	257	274				262	10.9
Q_{max} (W/g)	253	254	272				260	10.6
T_{max} (°C)	453	437	445				445	8.1
h_c (kJ/g)	15.9	15.5	16.8				16.1	0.70
Y_p (g/g)	0.153	0.135	0.123				0.14	0.015
$h_{c,gas}$ (kJ/g)	18.8	17.9	19.2				18.6	0.68

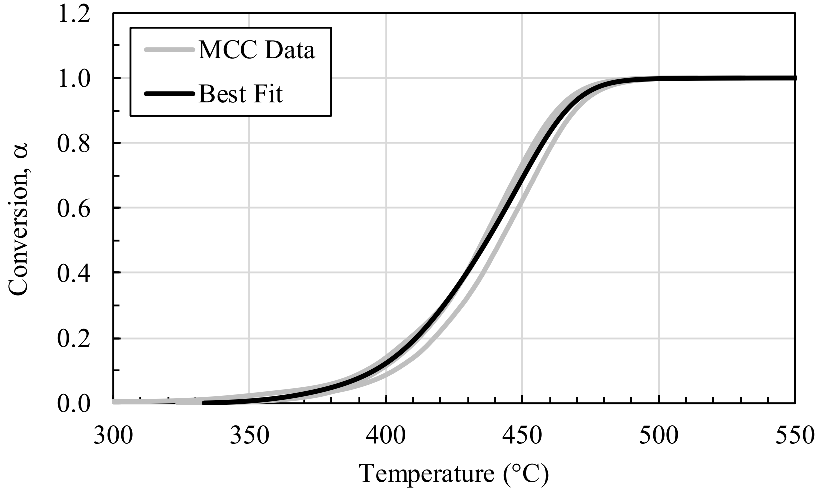
	c_1	c_2	c_3	c_4
Test 1	0.022	0.472	0.507	
Test 2	0.044	0.586	0.370	
Test 3	0.026	0.219	0.755	
Test 4				
Test 5				
Test 6				
Average	0.030	0.426	0.544	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	355	388	476	0.992
Test 2	384	385	469	0.991
Test 3	342	375	471	0.990
Test 4				
Test 5				
Test 6				
Average	360	383	472	0.991

	R1	R2	R3	R4
A (1/s)	2.47E+19	2.67E+17	2.59E+19	
E (kJ/mol)	252	248	286	
n	1.59	1.81	1.25	

Physical Properties	
ρ (kg/m^3)	314
δ (mm)	1.00



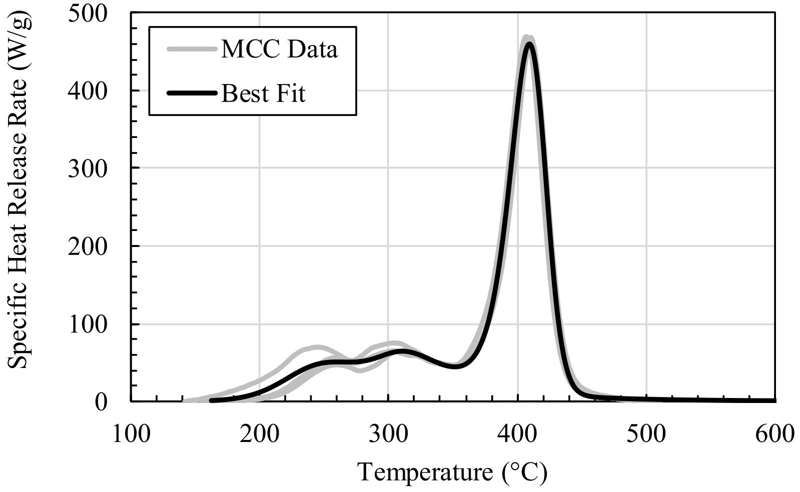


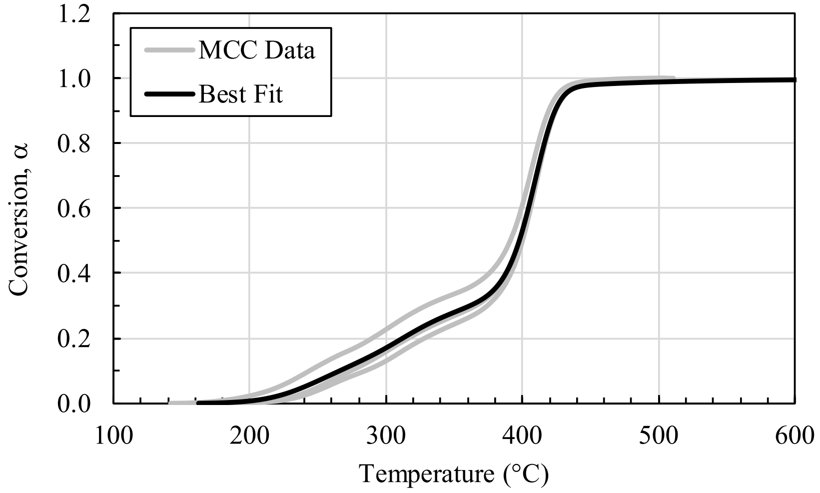
MC FTA Foam MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.02	4.05	4.01				4.03	0.021
m_f (mg)	0.27	0.17	0.14				0.19	0.068
η_c (J/g·K)	444	447	458				450	7.1
Q_{max} (W/g)	438	442	452				444	7.2
T_{max} (°C)	407	411	410				409	1.9
h_c (kJ/g)	26.5	24.4	24.4				25.1	1.17
Y_p (g/g)	0.067	0.042	0.035				0.05	0.017
$h_{c,gas}$ (kJ/g)	28.4	25.5	25.3				26.4	1.71

	c_1	c_2	c_3	c_4
Test 1	0.285	0.110	0.605	
Test 2	0.229	0.121	0.650	
Test 3	0.177	0.163	0.660	
Test 4				
Test 5				
Test 6				
Average	0.230	0.131	0.638	
	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	191	221	426	0.986
Test 2	219	250	431	0.990
Test 3	224	256	432	0.988
Test 4				
Test 5				
Test 6				
Average	211	242	429	0.988

	R1	R2	R3	R4
A (1/s)	3.39E+09	2.05E+16	1.05E+23	
E (kJ/mol)	110	198	315	
n	3.96	3.79	1.33	

Physical Properties	
ρ (kg/m^3)	59
δ (mm)	15.00





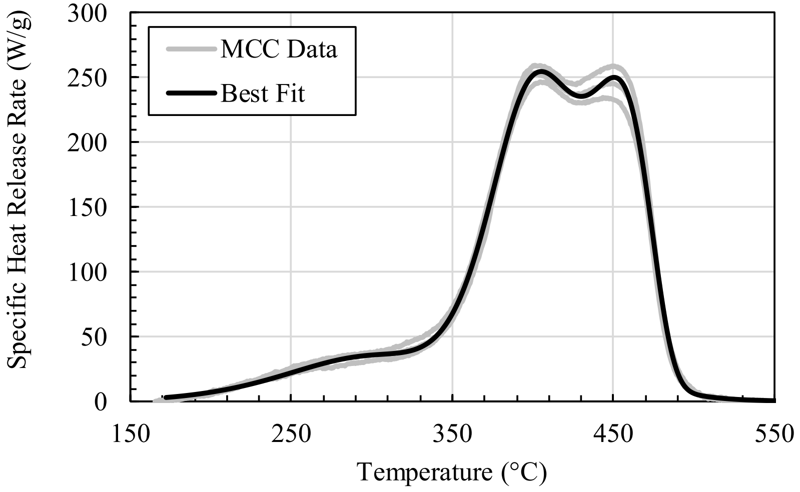
MC Ribbed Flooring MCC Data								
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Mean	St Dev
m_i (mg)	4.02	4.07	4.03				4.04	0.026
m_f (mg)	2.21	2.25	2.23				2.23	0.020
η_c (J/g·K)	112	115	118				115	2.6
Q_{max} (W/g)	111	113	116				113	2.4
T_{max} (°C)	405	401	401				402	2.0
h_c (kJ/g)	13.5	14.5	14.6				14.2	0.60
Y_p (g/g)	0.550	0.553	0.553				0.55	0.002
$h_{c,gas}$ (kJ/g)	30.0	32.4	32.6				31.7	1.48

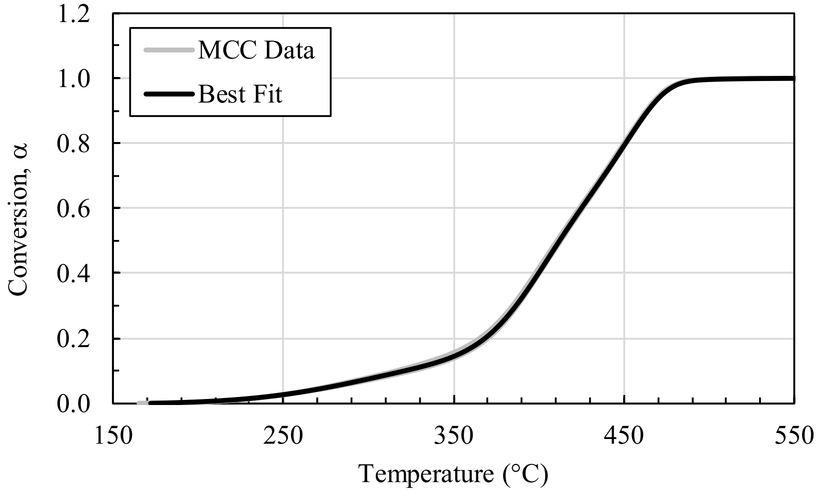
	c_1	c_2	c_3	c_4
Test 1	0.111	0.565	0.324	
Test 2	0.128	0.538	0.334	
Test 3	0.118	0.537	0.345	
Test 4				
Test 5				
Test 6				
Average	0.119	0.547	0.334	

	T_{ig} (°C)	$T_{5\%}$ (°C)	$T_{95\%}$ (°C)	β (K/s)
Test 1	273	279	471	0.988
Test 2	266	274	472	0.989
Test 3	267	276	472	0.986
Test 4				
Test 5				
Test 6				
Average	269	277	472	0.988

	R1	R2	R3	R4
A (1/s)	2.41E+03	3.72E+12	2.24E+14	
E (kJ/mol)	55	179	219	
n	1.00	1.85	1.00	

Physical Properties	
ρ (kg/m^3)	1187
δ (mm)	4.50





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