



**DEVELOPMENT OF A DATABASE OF FULL-SCALE  
CALORIMETER TESTS OF MOTOR VEHICLES**

**DRAFT FINAL REPORT  
Consisting of 99 Pages**

**SwRI® Project No. 01.06939.01.003  
Report Date: February 21, 2008**

**Prepared for:**

**Motor Vehicle Fire Research Institute  
1334 Pendleton Ct.  
Charlottesville, VA 22901**

Prepared by:

Marc L. Janssens, Ph.D.  
Director  
Fire Technology Department

Approved by:

Michael G. MacNaughton, Ph.D.  
Vice President  
Chemistry and Chemical Engineering Division

This report is for the information of the client. This report shall not be reproduced except in full, without the written approval of SwRI.  
Neither this report nor the name of the Institute shall be used in publicity or advertising.

## **ABSTRACT**

This report describes the development of a database of full-scale motor vehicle fire test results. The data were obtained from a careful review of 20 publications<sup>1-20</sup> comprised of: 3 journal articles, 2 conference papers, and 15 reports. To be included in the database, tests had to involve heat release rate measurements. A total of 34 tests in 12 studies were found to meet this requirement. The database consists of four interrelated tables that contain primarily scalar data. The main table includes links to available time-dependent data, i.e., heat release rate, mass loss, interior heat flux, interior temperature and interior CO concentration vs. time. The data may be useful in fire engineering, e.g., fire design of parking garages, fire hazard assessment of automotive materials in post-collision fires, etc. Use of the database is illustrated with two examples.

# TABLE OF CONTENTS

	<i>Page</i>
1.0 INTRODUCTION .....	1
2.0 TEST SERIES.....	1
2.1 SERIES ONE.....	1
2.2 SERIES TWO .....	1
2.3 SERIES THREE .....	2
2.4 SERIES FOUR .....	2
2.5 SERIES FIVE.....	2
2.6 SERIES SIX.....	3
2.7 SERIES SEVEN .....	3
2.8 SERIES EIGHT .....	3
2.9 SERIES NINE.....	4
2.10 SERIES TEN .....	4
2.11 SERIES ELEVEN .....	4
2.12 SERIES TWELVE .....	4
3.0 DATABASE STRUCTURE.....	5
3.1 VEHICLE TABLE .....	5
3.2 LABORATORY TABLE.....	5
3.3 PUBLICATION TABLE .....	5
3.4 TEST TABLE .....	6
3.5 CURVES .....	8
4.0 USING THE DATABASE .....	8
4.1 HEAT OF COMBUSTION .....	8
4.2 DURATION OF BURN PERIOD .....	9
5.0 CONCLUSIONS AND RECOMMENDATIONS .....	12
6.0 REFERENCES .....	13

APPENDIX A – COMPLETE REPORT OF INFORMATION IN THE DATABASE

APPENDIX B – PHOTOGRAPHS FROM TESTS PERFORMED AT BRI

# LIST OF TABLES

	<i>Page</i>
Table 1. Test Table Fields.....	7
Table 2. Results of the Heat of Combustion Query.....	10
Table 3. Results of the Burn Duration Query. ....	11

# LIST OF FIGURES

	<i>Page</i>
Figure 1. Vehicle Table Form with Data from Series 1, Test 1.....	5
Figure 2. Laboratory Table Form with Data from Series 1, Test 1.....	6
Figure 3. Publication Table Form with Data from Series 1, Test 1.....	6
Figure 4. Test Table Form with Data from Series 1, Test 1.....	6
Figure 5. Heat of Combustion Database Query.....	9
Figure 6. Heat of Combustion vs. Publication Year.....	10
Figure 7. Burn Duration Database Query.....	11
Figure 8. Burn Duration Frequency Distribution.....	12

## **1.0 INTRODUCTION**

In 2004 the author of this report presented a survey of full-scale motor vehicle burn tests at the Fifth International Conference on Performance-Based Codes and Fire Safety Design Methods in Luxemburg. The objective of the survey was to collect heat release rate data for motor vehicles and provide recommendations for suitable design fires for performance-based fire design of parking garages and similar structures. The survey covered data obtained in 11 studies spanning a period of 10 years between 1994 and 2004. Subsequently the Motor Vehicle Fire Research Institute (MVFRI) initiated a project to expand the survey with the most recent test results and additional data pertinent to fire hazard assessment of automotive materials. The database that resulted from this effort forms the subject of this report.

## **2.0 TEST SERIES**

A literature search was conducted to find journal articles, conference papers and reports, describing full-scale motor vehicle burn tests with heat release rate measurements. A total of 12 studies were identified. These studies are briefly described below.

### **2.1 Series One**

In 1994 Mangs and Keski-Rahkonen published the results of three tests.<sup>1</sup> The purpose of the tests was to obtain data for fire engineering of parking garages. Each test involved a single, late-1970s model vehicle. The ignition source in the first test consisted of a burning heptane pan fire placed under the left front seat. The ignition source for the remaining two tests consisted of a heptane pan fire placed under the engine. The vehicle was on a load platform under an open oxygen consumption calorimeter. In addition to heat release rate, mass loss, temperature and heat flux at various locations were measured. The tests were terminated at burnout, i.e., when significant flaming ceased and the heat release rate returned to a negligible level.

### **2.2 Series Two**

In October of 1994 the National Testing and Research Institute in Borås, Sweden organized a major conference on fires in tunnels. Eleven papers covered various aspects of the EUREKA fire tests. The remaining 12 presentations dealt with other tunnel fire experiments and fire protection of tunnels in general. The EUREKA EU-499 FIRETUN project consisted of 20 full-scale fire tests of road and rail transportation vehicles, wood cribs, and heptane pools.<sup>21</sup> The tests were conducted between July 1990 and November 1992 in the abandoned Repparfjord tunnel in Norway. Extensive instrumentation was used to measure gas temperature and velocity profiles, tunnel surface temperatures, heat fluxes, smoke obscuration, and gas composition at various distances in both directions from the location of the fire.<sup>22</sup> Temperatures and mass loss of the burning object were also

measured. Several approaches were used to determine the heat release rate of the burning object based on the available temperature, velocity, and gas composition data.<sup>2,23-26</sup> The difficulty was that there was no single extraction point where flow rate and oxygen concentration could be measured as in an oxygen consumption calorimeter, and that the distribution of temperature, velocity, and oxygen concentration across the section of the tunnel had to be accounted for. The project included two tests on automobiles, i.e., one test of a vehicle with a steel body and one test of a vehicle with a plastic body. Heat release rate data are reported for the latter only. All tests were terminated at burnout.

### **2.3 Series Three**

In 1995 Shipp and Spearpoint published the results of two tests on a single motor vehicle to obtain data for fire safety assessment of the Channel tunnel shuttle train.<sup>3</sup> The vehicle was placed under a canopy with insulated side walls simulating a shuttle wagon. Hoods were positioned at both ends of the canopy to capture all products of combustion released in the fire. The first test involved a 1982 model mid-size sedan with a small wood crib ignition source inside the passenger compartment. This test was terminated at 17 minutes when the heat release rate exceeded 8 MW and smoke started overflowing the hoods. The second test involved a 1986 model mid-size sedan with a burning tray of gasoline placed in the engine compartment. The second test was terminated at burnout. Measurements consisted of heat release rate and temperature and heat flux at various locations.

### **2.4 Series Four**

A series of ten tests was conducted at CTICM in France as part of a European research project to develop design rules for steel parking structures subjected to fire.<sup>4</sup> Four of the ten tests generated heat release rate data and mass loss data for a single vehicle. Two of the four tests were conducted under a hood in an open calorimeter. The remaining two tests were conducted in a corner configuration. All tests were terminated at burnout.

### **2.5 Series Five**

TNO in the Netherlands published a report in 1999 describing 18 fire tests in a parking garage in Amsterdam.<sup>5</sup> All tests involved multiple vehicles. The purpose of this study was to evaluate the effectiveness of different types of ventilation systems in a parking garage fire. The heat release rate of the burning vehicle was determined on the basis of mass loss rate measurements and the assumption that the average heat of combustion is 25 MJ/kg. The assumption was based on data from Series Four.<sup>4</sup> The validity of this assumption was confirmed on the basis of 4 of the 18 tests, which included measurements of the enthalpy rise of the gases flowing through the parking garage and an estimate of heat losses to the walls and ceiling of the structure. All tests were terminated at burnout of the vehicle first ignited.

## **2.6 Series Six**

In 1997 and 1998, ten motor vehicle fire tests were conducted at MFPA in Leipzig, Germany.<sup>6</sup> The objectives of the study were to evaluate the burning behavior of motor vehicles parked next to each other and fire propagation from a burning vehicle to adjacent vehicles. Three of the ten experiments involved a single vehicle. Three types of vehicles were tested:

- A vehicle made in the former East Germany (Trabant);
- A vehicle with a steel body; and
- A vehicle with a plastic body.

The tests were performed in a room calorimeter. Heat release rate was measured based on oxygen consumption calorimetry. In addition, vehicle mass loss and temperature and heat flux at various locations were also measured. All tests were terminated at burnout.

## **2.7 Series Seven**

In 1999 two fire tests using a passenger minivan were conducted at the National Institute of Standards and Technology (NIST) as part of an investigation by the Bureau of Alcohol, Tobacco, and Firearms.<sup>7</sup> The tests were conducted under a large open oxygen consumption calorimeter hood. In the first test 0.3 kg of paper was placed inside the passenger compartment with the windows closed. The fire extinguished due to lack of oxygen. The second test was conducted with 2 L of gasoline in the passenger compartment with the driver and passenger windows open. This test was terminated when the passenger compartment was fully involved, approximately 5 minutes after ignition. Measurements included temperature and gas composition (O<sub>2</sub>, CO<sub>2</sub>, and CO) at various locations inside the passenger compartment. Vehicle mass loss was not measured.

## **2.8 Series Eight**

A series of full-scale motor vehicle fire tests were conducted as part of the March 7, 1995 settlement agreement between General Motors Corporation (GM) and the Department of Transportation (DOT). These tests were performed on four different types of motor vehicles representing more than 50% of the sales in the U.S. The vehicles were subjected to a crash test by GM prior to the fire tests in the Combustion Products Collector at Factory Mutual (currently FM Global). A detailed discussion of the objectives and experimental design of these crash and fire tests is provided in the literature<sup>27</sup>. Three types of tests were performed with heat release rate measurements:

- Fires initiated in the engine compartment;<sup>8,11,16</sup>
- Pool fires under the vehicle;<sup>9,10,12,13,15</sup> and
- Comparative tests between a control vehicle and a vehicle with an HVAC system made of FR plastics.<sup>14</sup>

These tests are by far the most extensively instrumented fire experiments on motor vehicles ever conducted. Since the focus was on assessing the fire hazard to occupants, all tests were terminated at or before the time of full involvement of the passenger compartment. Vehicle mass loss was measured in all except the first two tests, but the total mass loss was too low and the data too noisy to be useful.

## **2.9 Series Nine**

CTICM in France, ARBED in Luxemburg, and TNO in the Netherlands performed a research project between July 1998 and June 2001 to demonstrate through fire tests and numerical simulations that exposed steel structures can be designed to withstand motor vehicle fires.<sup>17</sup> The final report of this study includes data for two tests on a single vehicle conducted at CTICM. The tests were performed in the open calorimeter used for some of the Series Four tests.

## **2.10 Series Ten**

Five full-scale tests were conducted at the Building Research Institute in Japan to obtain data for structural fire design of parking garages.<sup>18</sup> Each test involved a single four-door sedan. The first test was performed outdoors. The remaining four tests were performed under an oxygen consumption calorimeter hood. The ignition source was a piece of cloth soaked in alcohol placed on the driver seat. Driver and passenger windows were partially rolled down. Although it is stated that heat release rate was measured based on oxygen consumption calorimetry, the heat release rate data reported are based on mass loss measurements and an assumed heat of combustion of 32 MJ/kg. All tests were terminated at burnout.

## **2.11 Series Eleven**

An additional test was conducted recently in a room calorimeter at CTICM to supplement the data obtained in Series Four and Series Nine. The test involved two vehicles side-by-side. The report<sup>19</sup> includes a heat release rate curve for the first vehicle in an open configuration.

## **2.12 Series Twelve**

Finally, a test was conducted at SP in Sweden to quantify the emissions from a motor vehicle fire.<sup>20</sup> A 1998 model mid-size sedan was placed under SP's industry calorimeter. The ignition source consisted of 0.3 L of mineral spirits poured on the driver and the front passenger seats. The

door on the driver side and one of the doors in the back of the vehicle was partially open to allow sufficient air supply to support combustion. Mass loss was not measured. The test was terminated at burnout.

### 3.0 DATABASE STRUCTURE

A database was developed in MS Access to facilitate the use of results from full-scale motor vehicle tests for fire engineering. A total of 34 tests are included. The database consists of four interrelated tables that are briefly discussed below. A form was developed for each table to facilitate data entry.

#### 3.1 Vehicle Table

The first table includes important information concerning the vehicle that was tested. Figure 1 shows the corresponding form after entering the data from Series 1, Test 1. The ID field contains the primary key automatically assigned by Access. The remaining fields are self-explanatory.

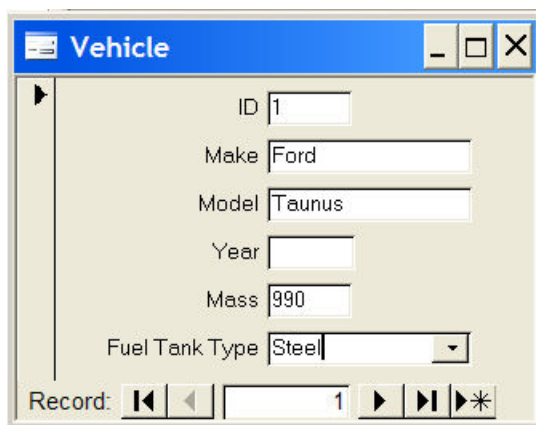
The image shows a screenshot of a Microsoft Access form titled "Vehicle". The form contains several data entry fields: "ID" with the value "1", "Make" with "Ford", "Model" with "Taurus", "Year" (empty), "Mass" with "990", and "Fuel Tank Type" with a dropdown menu set to "Steel". At the bottom of the form, there is a "Record:" label followed by navigation icons and a small box containing the number "1".

Figure 1. Vehicle Table Form with Data from Series 1, Test 1.

#### 3.2 Laboratory Table

The second table includes some important information concerning the laboratory where the test was performed. Figure 2 shows the corresponding form after entering the data from Series 1, Test 1. The ID field contains the primary key automatically assigned by Access. The remaining fields are self-explanatory.

#### 3.3 Publication Table

The third table includes some important information concerning the publication that can be consulted to obtain more information about the test. The ID field contains the primary key automatically assigned by Access. The remaining fields are self-explanatory.

**Figure 2. Laboratory Table Form with Data from Series 1, Test 1.**

**Figure 3. Publication Table Form with Data from Series 1, Test 1.**

### 3.4 Test Table

The fourth table is the main table. It provides information concerning the test setup and conditions and the primary results. There are links to the other three tables and to the vector data (heat release rate vs. time, etc.) in separate MS Excel workbooks. The ID field contains the primary key automatically assigned by Access. The remaining fields are described in Table 1.

**Figure 4. Test Table Form with Data from Series 1, Test 1.**

**Table 1. Test Table Fields.**

<b>Field</b>	<b>Description</b>
Series	Sequential test series number
Test Number	Number of the test within the series
Publication ID	Link to the Publication Table
Laboratory ID	Link to the Laboratory Table
Type of Facility	Type of facility to measure HRR (Corner Calorimeter, Open Calorimeter, Parking Garage, Rail Shuttle Car, Room Calorimeter, Tunnel or Other)
Purpose	Purpose for performing the test (Arson Investigation, Fire Engineering, Fire Hazard Assessment or Other)
Primary Vehicle ID	Link to the Vehicle Table
Fuel Amount	Amount of fuel in the tank in liters
Vehicle Condition	Condition of the vehicle (New, Used or Unknown)
Crashed	Has the vehicle been involved in a crash prior to the test?
Ventilation Conditions	How is air supplied to the passenger compartment?
Number of Target Vehicles	Number of vehicles adjacent to the test vehicle
Ignition Location	Location of ignition source
Ignition Source	Ignition source used to start the fire
Time to Untenable Conditions	Time to untenable conditions in seconds
Type of Conditions	Type of untenability conditions (Flame Penetration, Heat Flux, Temperature, Toxicity or Other)
Start of Burn Period	Defined as the time in min when the HRR first reaches 10% of its peak
End of Burn Period	Defined as the time to decline of the HRR to 10% of its peak
Burnout	Was the vehicle allowed to burn out before the test was terminated?
HRR Curve	Link to Excel workbook that contains HRR data
HRR Measuring Method	Measurement technique used to determine HRR (Mass Loss, Oxygen Consumption, Temperature Rise, Other)
Peak HRR	Maximum HRR measured during the test in kW
Time to Peak HRR	Time to peak HRR in min
Total Heat Released	Total heat released during the test in MJ
Mass Loss Curve	Link to Excel workbook that contains mass loss data
Total Mass Loss	Total mass loss in kg
Interior Heat Flux Curve	Link to Excel workbook that contains interior heat flux data
Interior Temperature Curve	Link to Excel workbook that contains interior temperature data
Interior CO Curve	Link to Excel workbook that contains interior CO concentration data

The start of the burn period is defined as the time when the heat release rate reaches 10% of the peak because there is a large variation between tests of the delay from the start of the test, i.e., application of the ignition source, to the time when the heat release rate starts to rise beyond that from the ignition source. The end of the burn period is defined as the time when the heat release rate drops back to 10% of the peak. This definition eliminates inconsistencies due to the criteria for termination of a test used in different laboratories.

### **3.5 Curves**

The test table has links to Excel workbooks that contain the vector data available. These Excel workbooks were generated by digitizing the relevant graphs in the reference publication. A freeware program called Plot Digitizer (available from SourceForge at <http://plotdigitizer.sourceforge.net/>) was used for this purpose. Five types of data were considered:

- Heat release rate vs. time;
- Mass loss vs. time;
- Gas temperature inside the passenger compartment vs. time;
- Incident heat flux inside the passenger compartment vs. time; and
- CO concentration inside the passenger compartments vs. time.

## **4.0 USING THE DATABASE**

A complete report was generated of the information in the database, including the charts in the linked Excel files. This report can be found in Appendix A. It is obvious from the report that a significant number of fields are blank. The laboratories were contacted to obtain the missing information, without much success. The laboratories were also asked whether they could share any photographic or video documentation of the tests. VTT responded that video tapes could be provided. Unfortunately the funds to cover the costs of the duplication and conversion were not available. BRI supplied a set of photographs without cross-references to the tests in Series Ten. The photographs are duplicated in Appendix B.

Despite the sparse nature of the database, it is still a useful tool for the fire protection engineering community. The two examples in the following sub-sections illustrate the use of the database.

### **4.1 Heat of Combustion**

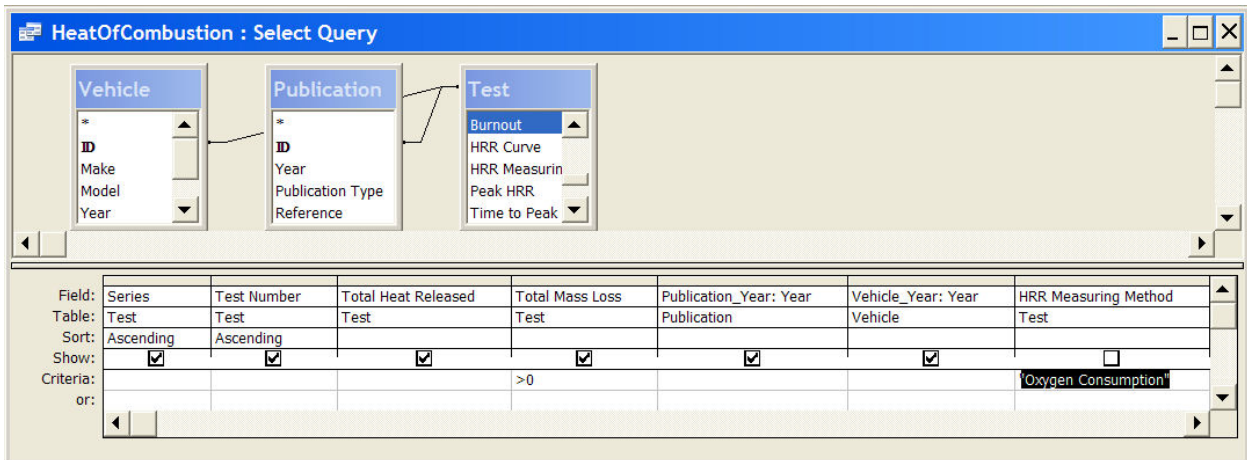
The heat release rates measured in the Series Five and Series Ten tests were obtained by multiplying the measured mass loss rate with an average value of the heat of combustion. TNO and BRI used 25 MJ/kg and 32 MJ/kg respectively. Given the years when these two test series were conducted,

this seems to indicate that the heat of combustion has risen over the years. Perhaps there are more tests with mass loss measurements that could be added to the database if a representative value for the heat of combustion would be known. Figure 5 shows a query of the database to find all tests that meet the following criteria:

1. Heat release rate measurements was based on oxygen consumption calorimetry;
2. Mass loss was measured; and
3. The test was not terminated before burnout.

Table 2 summarizes the results of the query. Figure 6 shows the heat of combustion as a function of the year of publication for the tests that meet the criteria of the query (circles). It would have been better to plot the heat release rate as a function of the year of the vehicle. Unfortunately, the year of the vehicle is not known in most cases as is apparent from Table 2.

The trend line in Figure 6 has a slope of 0.96 and a constant of -1892.6. The line is rather qualitative in nature since, for example, variations in the amount of fuel in the tank between the tests are not accounted for. It seems to indicate that the heat of combustion has indeed increased over time, and the figure could be used to estimate a reasonable value for the heat of combustion based on the year of publication of the mass loss data. Note that the values used by TNO and BRI are reasonably consistent with the trend line (square symbols in Figure 6).



**Figure 5. Heat of Combustion Database Query.**

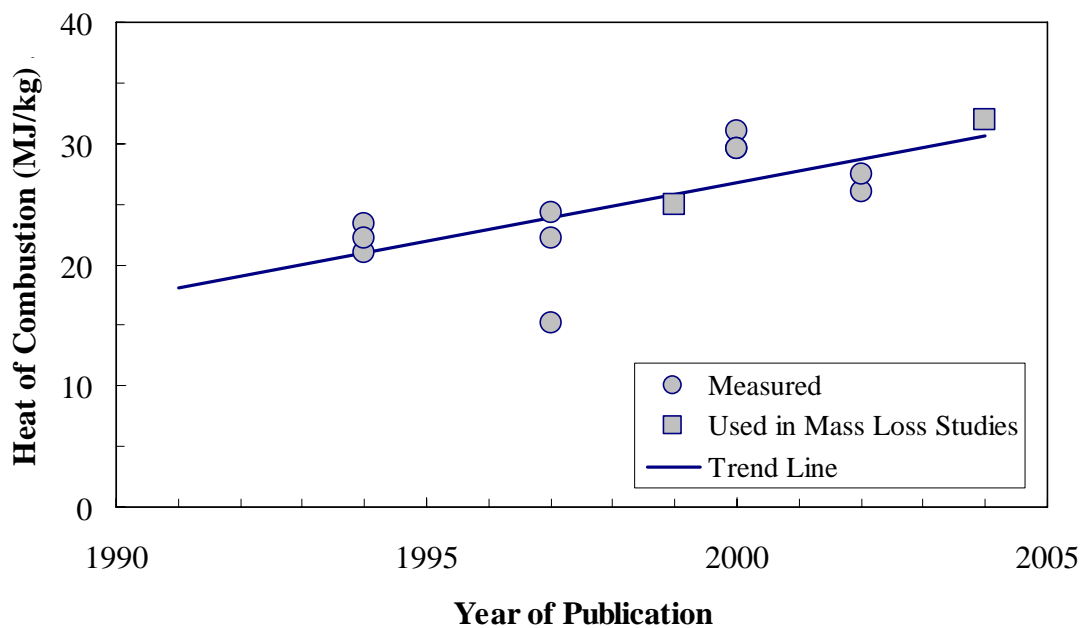
#### 4.2 Duration of Burn Period

In some cases, for example a motor vehicle fire in a congested tunnel pile-up, the fire department might not be able to approach the vehicle and put the fire out. To determine the appropriate level of fire protection for the structure it is of interest to know how long motor vehicle fires last. The Test Table in

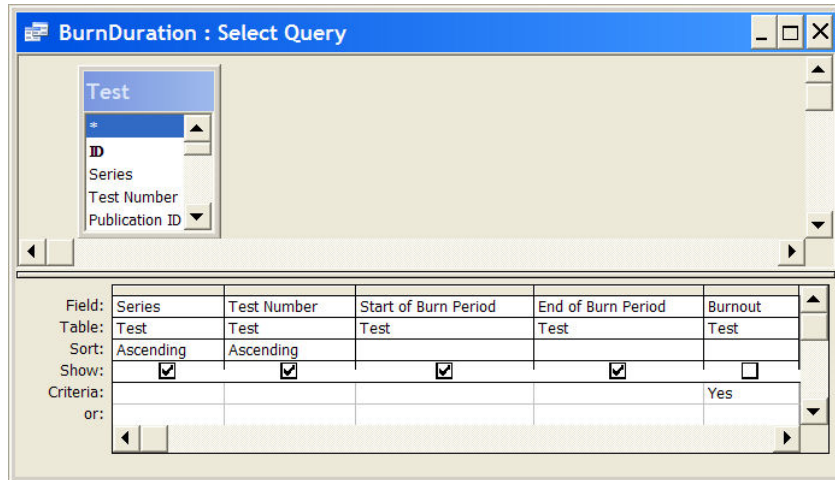
the database does not have a field for the duration of the burning period, but there are fields for the start and the end of the burn period. The duration can be calculated as the difference between the two. Figure 7 shows the query to select all tests that have start and end times. Table 3 gives the results of the query and Figure 8 shows the corresponding frequency distribution. The mean is approximately 48 min with a standard deviation of approximately 23 min.

**Table 2. Results of the Heat of Combustion Query.**

Series	Test Number	Total Heat Released (MJ)	Total Mass Loss (kg)	Heat of Combustion (MJ/kg)	Publication Year	Vehicle Year
1	1	3300	141	23.4	1994	
1	2	3000	143	21.0	1994	
1	3	3900	176	22.2	1994	
4	3	2100	138	15.2	1997	
4	7	6670	275	24.3	1997	
4	8	4090	184	22.2	1997	
6	1	3100	100	31.0	2000	
6	2	3200	108	29.6	2000	
6	3	8000	270	29.6	2000	
9	1	6806	262	26.0	2002	1994
9	2	7000	255	27.5	2002	1994



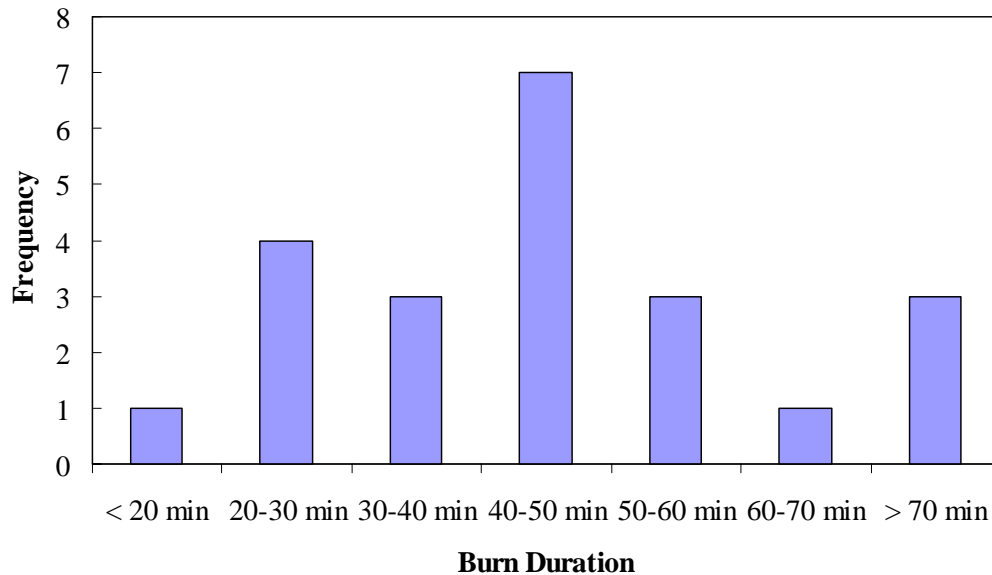
**Figure 6. Heat of Combustion vs. Publication Year.**



**Figure 7. Burn Duration Database Query.**

**Table 3. Results of the Burn Duration Query.**

Series	Test Number	Start (min)	End (min)	Duration (min)
1	1	1.3	71.1	69.8
1	2	3.9	52.5	48.6
1	3	2.9	91.6	88.7
2	1	6.2	56.3	50.1
3	2	5.7	44.3	38.6
4	3	1.7	22.6	20.9
4	7	3.5	54.6	51.1
4	8	12.3	55.1	42.8
5	1	8.6	26.2	17.6
5	11	10.5	43.3	32.8
5	12	4.5	32.2	27.7
6	1	4.3	28.9	24.6
6	2	10.3	67.2	56.9
6	3	3.9	51.3	47.4
9	1	6.3	45.1	38.8
9	2	4.9	49.6	44.7
10	2	3.4	51.8	48.4
10	3	8.8	89.4	80.6
10	4	8.1	55.0	46.9
10	5	12.2	59.7	47.5
11	1	17.7	131.6	113.9
12	1	10.6	35.8	25.2
			N	22
			Mean	48.3
			SD	23.1



**Figure 8. Burn Duration Frequency Distribution.**

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

This report describes the development of a database of full-scale motor vehicle fire test results. The data were obtained from a careful review of 20 publications. The data may be useful in fire engineering, e.g., fire design of parking garages and similar structures, fire hazard assessment of automotive materials in post-collision fires, etc. Unfortunately many of the fields in the database are blank. This is because the data reported in the publications describing the tests are incomplete. It is recommended to make the database accessible for free over the Internet and to have the laboratories that conducted the tests fill in the blanks. In addition, this will encourage laboratories to expand the database with recent test results. Finally, fire engineers using the data will be able to submit comments and suggestions for improvement of the database.

## 6.0 REFERENCES

1. Mangs, J. and Keski-Rahkonen, O. (1994). "Characterization of the Fire Behavior of a Burning Passenger Car. Part I: Car Fire Experiments," *Fire Safety Journal*, Vol. 23, 1994, pp. 17-35.
2. Steinert, C. (1994). "Smoke and Heat Production in Tunnel Fires," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp.123-137.
3. Shipp, M. and Spearpoint, M. (1995). "Measurements of the Severity of Fires Involving Private Motor Vehicles." *Fire and Materials*, Vol. 19, pp. 143-151.
4. Joyeux, D. (1997). "Natural Fires in Closed Car Parks – Car Fire Tests." CTICM Report No. INC 96/294d DJ/NB, CTICM, Metz, France.
5. Van Oerle, N., Lemaire, A. and van de Leur, P. (1999). "Effectiveness of Forced Ventilation in Closed Car Parks (in Dutch)." TNO Report No. 1999-CVB-RR1442, TNO, Delft, the Netherlands.
6. Steinert, C. (2000). "Experimental Investigation of Burning and Fire Jumping Behavior of Automobiles (in German)." VFDB, Vol. 49, pp. 163-172.
7. Stroup, D., DeLauter, L., Lee, L. and Roadermel, G. (2001). "Passenger Minivan Fire Tests," FR 4011, National Institute of Standards and Technology, Gaithersburg, MD.
8. Santrock, J. (2001). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 3: Propagation in an Engine Compartment Fire in a 1996 Passenger Van," NHTSA 1998 3588-119, General Motors Corporation, Warren, MI.
9. Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 4: Propagation of an Underbody Gasoline Pool Fire in a 1996 Passenger Van," NHTSA 1998 3588-143, General Motors Corporation, Warren, MI.
10. Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 6: Propagation of an Underbody Gasoline Pool Fire in a 1997 Rear Wheel Drive Passenger Car," NHTSA 1998-3588-158, General Motors Corporation, Warren, MI.
11. Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 7: Propagation of an Engine Compartment Fire in a 1997 Rear Wheel Drive Passenger Car," NHTSA 1998-3588-178, General Motors Corporation, Warren, MI.
12. Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 9: Propagation of a Rear-Underbody Gasoline Pool Fire in a 1998 Sport Utility Vehicle," NHTSA 1998-3588-188, General Motors Corporation, Warren, MI.

13. Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 10: Propagation of a Mid-Underbody Gasoline Pool Fire in a 1998 Sport Utility Vehicle," NHTSA 1998-3588-189, General Motors Corporation, Warren, MI.
14. Santrock, J. (2002). "Demonstration of Enhanced Fire Safety Technology-Fire Retardant Materials-Part 1: Full Scale Vehicle Fire Tests of a Control Vehicle and a Test Vehicle Containing an HVAC Module Made from Polymers Containing Flame Retardant Chemicals," NHTSA 1998-3588-190, General Motors Corporation, Warren, MI.
15. Santrock, J. (2003). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 12: Propagation of an Underbody Gasoline Pool Fire in a 1998 Front-Wheel Drive Passenger Vehicle," NHTSA 1998-3588-201, General Motors Corporation, Warren, MI.
16. Santrock, J. (2003). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 13: Propagation of an Engine Compartment Fire in a 1998 Front-Wheel Drive Passenger Vehicle," NHTSA 1998-3588-203, General Motors Corporation, Warren, MI.
17. Joyeux, D., Kruppa, J., Cajot, L., Schleich, J., Van de Leur, P., and Twilt, L. (2002). "Demonstration of Real Fire Tests in Car Parks and High Buildings," Final Report, Contract No. 7215 PP 025, CTICM, Metz, France.
18. Shintani, Y., Kakae, N., Harada, K., Masuda, H., Takahashi, W. (2004). "Experimental Investigation of Burning Behavior of Automobiles," 6<sup>th</sup> Asia-Oceania Symposium on Fire Science and Technology, pp. 618-629.
19. Anonymous (2004). "CTICM Fire Tests on Cars," CITCM, Metz, France.
20. Lönnermark, A. and Blomqvist, P. (2006). "Emissions from an Automobile Fire," Chemosphere, Vol. 62, pp. 1043-1056.
21. Haack, A. (1994). "Introduction to the Eureka-EU 499 Firetun Project," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp. 3-19.
22. Richter, E., and Vauquelin, O. (1994). "Description of Measuring Techniques Used in the EUREKA Project," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp. 20-35.
23. French, S. (1994). "EUREKA 499 HGV Fire Test (November 1992)," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp. 63-85.

24. Grant, G., and Drysdale, D. (1997). "Estimating Heat Release Rates from Large-Scale Tunnel Fires," in Fifth International Symposium on Fire Safety Science, Melbourne, Australia, pp. 1213-1224.
25. Ingason, H. (1994). "Heat Release Rate Measurements in Tunnel Fires," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp. 86-103.
26. Sørli, R., and Mathisen, H. (1994). "Measurements and Calculations of the Heat Release Rate in Tunnel Fires: Fire Test 'Heavy Goods Vehicle'," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp. 104-122.
27. Jensen, J., and Santrock, J. (1998). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Vehicle Crash and Fire Propagation Test Program," in 16<sup>th</sup> International Technical Conference on the Enhanced Safety of Vehicles, Windsor, ON, pp. 813-827.

**APPENDIX A**  
**COMPLETE REPORT OF INFORMATION IN THE DATABASE**  
**(Consisting of 68 Pages)**

**Test Series** 1 **Test Number** 1

**Lab Name** VTT

**City** Espoo **Country** Finland

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Ford

**Vehicle Model** Taunus

**Vehicle Year**

**Vehicle Mass (kg)** 990

**Fuel Tank Type** Steel

**Fuel Amount (L)** 30

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Left door 10 cm ajar with the window completely open, right door closed with window rolled down 5 cm

**Number of Target Vehicles** 0

**Ignition Location** Under left front seat

**Ignition Source** 1.5 L of heptane in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 1.3

**End of Burn Period (min)** 71.1

**Burnout** ✓

**HRR Curve** [01-01-01-HRR.XLS](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1521

**Time to Peak HRR (min)** 33.4

**Total Heat Released (MJ)** 3300

**Mass Loss Curve** [01-01-01-ML.XLS](#)

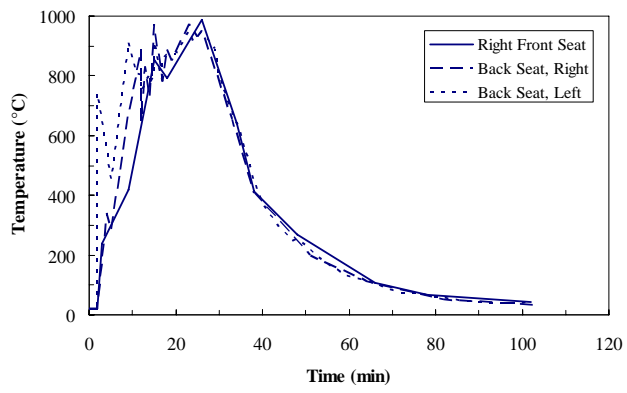
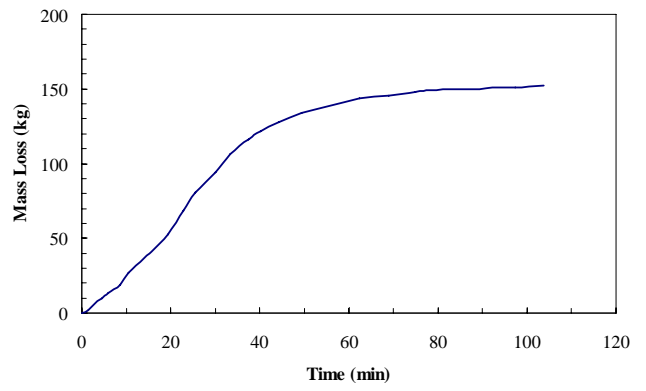
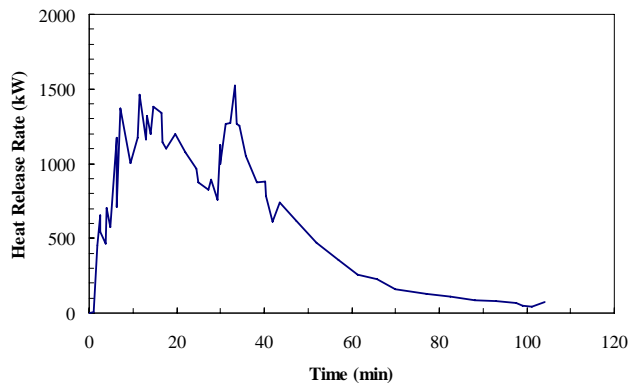
**Total Mass Loss (kg)** 141

**Interior Heat Flux Curve**

**Interior Temperature Curve** [01-01-01-TEMP.XLS](#)

**Interior CO Curve**

**Reference** Mangs, J. and Keski-Rahkonen, O. (1994 ). "Characterization of the Fire Behavior of a Burning Passenger Car. Part I: Car Fire Experiments," Fire Safety Journal, Vol. 23, 1994, pp. 17-35.



**Test Series** 1 **Test Number** 2

**Lab Name** VTT

**City** Espoo

**Country** Finland

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Datsun

**Vehicle Model** 160J Sedan

**Vehicle Year**

**Vehicle Mass (kg)** 918

**Fuel Tank Type** Steel

**Fuel Amount (L)** 30

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** All doors closed, left front window completely open, other windows rolled down 5 cm

**Number of Target Vehicles** 0

**Ignition Location** Under the engine

**Ignition Source** 3 L of heptane in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 3.9

**End of Burn Period (min)** 52.5

**Burnout** ✓

**HRR Curve** [01-02-01-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1859

**Time to Peak HRR (min)** 24.3

**Total Heat Released (MJ)** 3000

**Mass Loss Curve** [01-02-01-ML.xls](#)

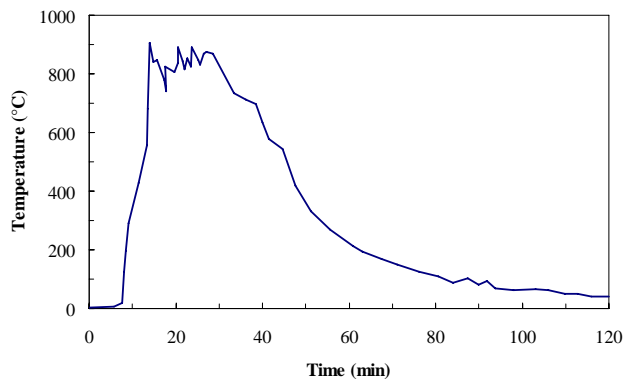
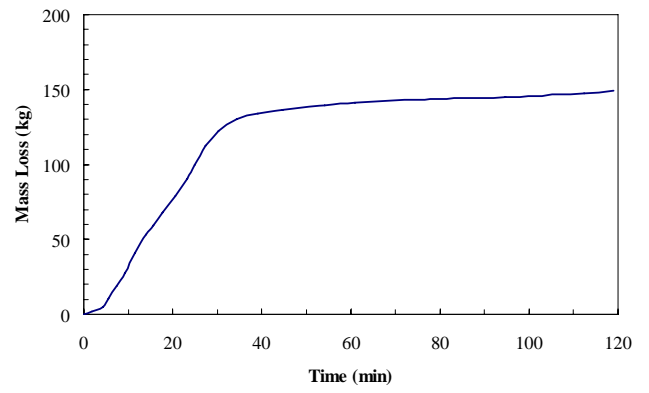
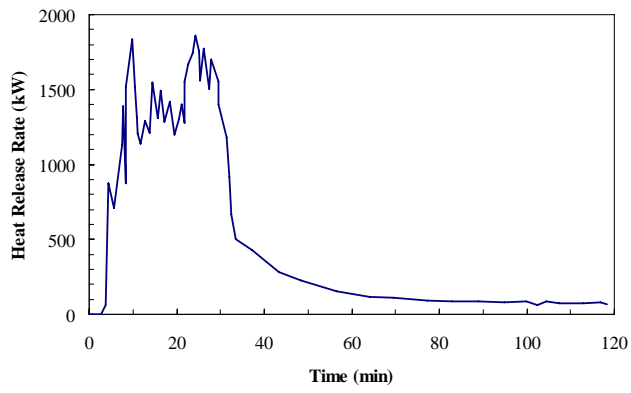
**Total Mass Loss (kg)** 143

**Interior Heat Flux Curve**

**Interior Temperature Curve** [01-02-01-TEMP.xls](#)

**Interior CO Curve**

**Reference** Mangs, J. and Keski-Rahkonen, O. (1994 ). "Characterization of the Fire Behavior of a Burning Passenger Car. Part I: Car Fire Experiments," Fire Safety Journal, Vol. 23, 1994, pp. 17-35.



**Test Series** 1 **Test Number** 3

**Lab Name** VTT

**City** Espoo

**Country** Finland

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Datsun

**Vehicle Model** 180B Sedan

**Vehicle Year**

**Vehicle Mass (kg)** 1102

**Fuel Tank Type** Steel

**Fuel Amount (L)** 30

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** All doors closed, left front window completely open, other windows rolled down 5 cm

**Number of Target Vehicles** 0

**Ignition Location** Under the engine

**Ignition Source** 3 L of heptane in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 2.9

**End of Burn Period (min)** 91.6

**Burnout** ✓

**HRR Curve** [01-03-01-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1972

**Time to Peak HRR (min)** 12

**Total Heat Released (MJ)** 3900

**Mass Loss Curve** [01-03-01-ML.xls](#)

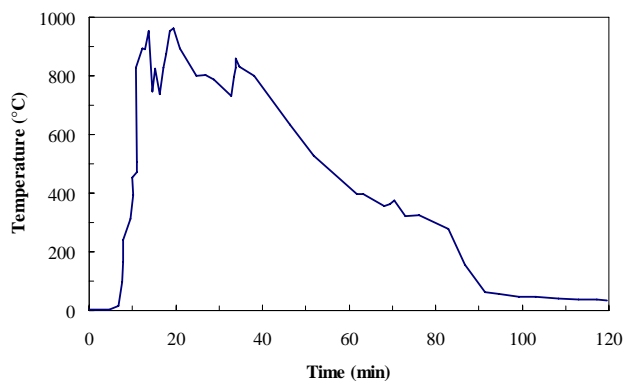
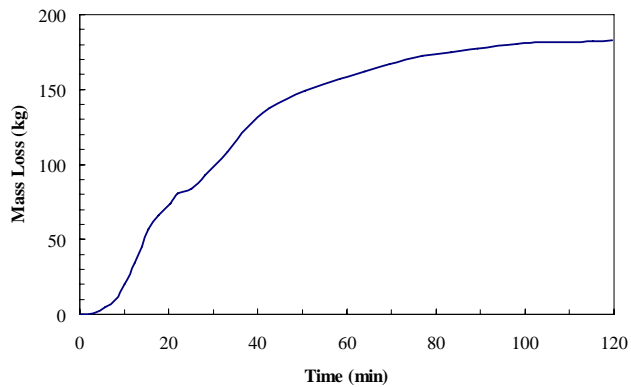
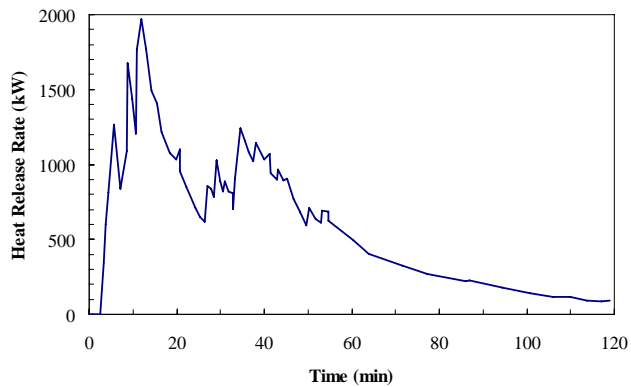
**Total Mass Loss (kg)** 176

**Interior Heat Flux Curve**

**Interior Temperature Curve** [01-03-01-TEMP.xls](#)

**Interior CO Curve**

**Reference** Mangs, J. and Keski-Rahkonen, O. (1994 ). "Characterization of the Fire Behavior of a Burning Passenger Car. Part I: Car Fire Experiments," Fire Safety Journal, Vol. 23, 1994, pp. 17-35.



**Test Series** 2 **Test Number** 1

**Lab Name** TU Braunschweig

**City** Braunschweig

**Country** Germany

**Type of Facility** Tunnel

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Unknown

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location**

**Ignition Source**

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 6.2

**End of Burn Period (min)** 56.3

**Burnout** ✓

**HRR Curve** [02-01-02-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 6206

**Time to Peak HRR (min)** 9.2

**Total Heat Released (MJ)** 7000

**Mass Loss Curve**

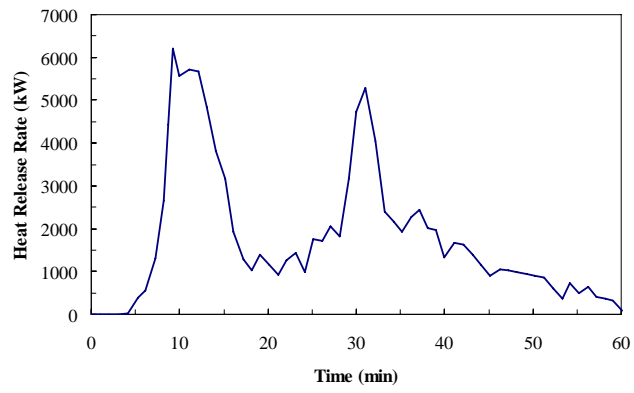
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Steinert, C. (1994). "Smoke and Heat Production in Tunnel Fires," in International Conference on Fires in Tunnels, Swedish National Testing and Research Institute, Borås, Sweden, pp.123-137.



**Test Series** 3 **Test Number** 1

**Lab Name** FRS BRE

**City** Watford

**Country** UK

**Type of Facility** Rail Shuttle Car

**Purpose of Test** Fire Engineering

**Vehicle Make** Austin

**Vehicle Model** Meastro

**Vehicle Year** 1982

**Vehicle Mass (kg)**

**Fuel Tank Type** Steel

**Fuel Amount (L)** 40

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and front passenger side windows completely open

**Number of Target Vehicles** 0

**Ignition Location** On front seat

**Ignition Source** No. 7 wood crib (peak HRR of about 10 kW)

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 3.9

**End of Burn Period (min)** 19.2

**Burnout**

**HRR Curve** [03-01-03-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 8482

**Time to Peak HRR (min)** 15.2

**Total Heat Released (MJ)** 4008

**Mass Loss Curve**

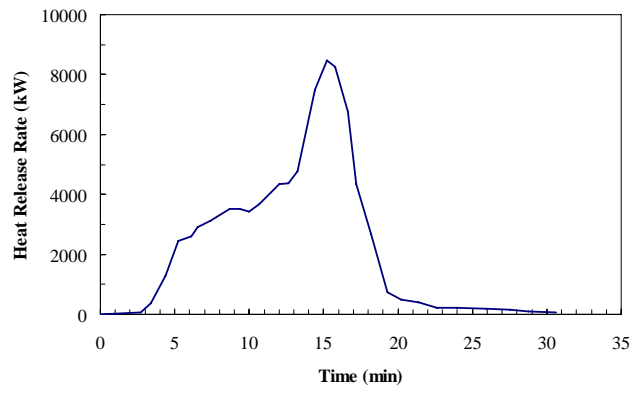
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shipp, M. and Spearpoint, M. (1995). "Measurements of the Severity of Fires Involving Private Motor Vehicles," Fire and Materials, Vol. 19, pp. 143-151.



**Test Series** 3 **Test Number** 2

**Lab Name** FRS BRE

**City** Watford

**Country** UK

**Type of Facility** Rail Shuttle Car

**Purpose of Test** Fire Engineering

**Vehicle Make** Citroen

**Vehicle Model** BX 14 RE

**Vehicle Year** 1986

**Vehicle Mass (kg)**

**Fuel Tank Type** Plastic

**Fuel Amount (L)** 44

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and front passenger side windows completely open

**Number of Target Vehicles** 0

**Ignition Location** Engine compartment under hood

**Ignition Source** 400 mL gasoline in foil tray (100 mL spilled)

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 5.7

**End of Burn Period (min)** 44.3

**Burnout** ✓

**HRR Curve** [03-02-03-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 4390

**Time to Peak HRR (min)** 14.4

**Total Heat Released (MJ)** 4957

**Mass Loss Curve**

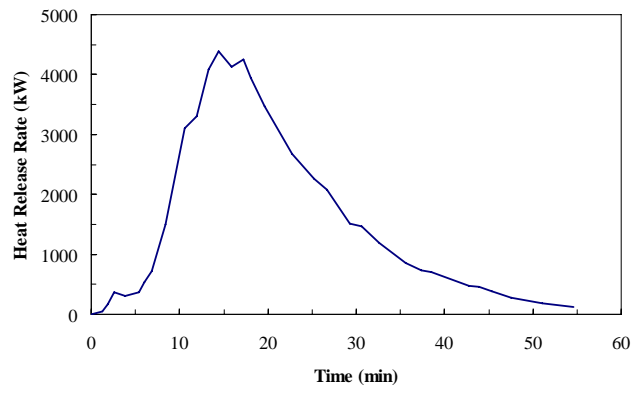
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shipp, M. and Spearpoint, M. (1995). "Measurements of the Severity of Fires Involving Private Motor Vehicles," Fire and Materials, Vol. 19, pp. 143-151.



**Test Series** 4 **Test Number** 3

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Corner Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Renault

**Vehicle Model** 5

**Vehicle Year**

**Vehicle Mass (kg)** 757

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** Under left front seat

**Ignition Source** 1.5 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 1.7

**End of Burn Period (min)** 22.6

**Burnout** ✓

**HRR Curve** [04-03-04-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 3439

**Time to Peak HRR (min)** 10

**Total Heat Released (MJ)** 2100

**Mass Loss Curve** [04-03-04-ML.XLS](#)

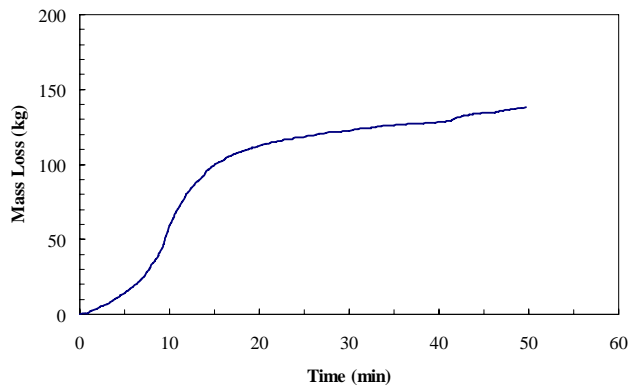
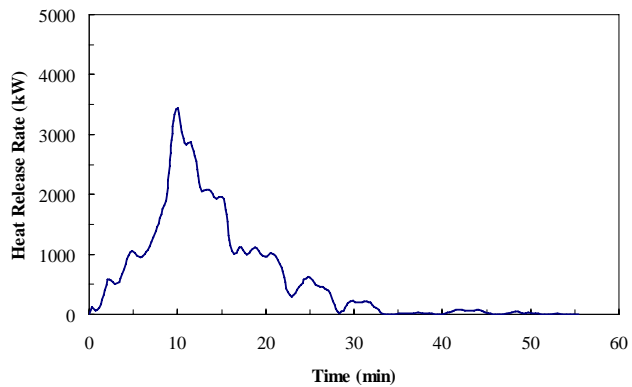
**Total Mass Loss (kg)** 138

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Joyeux, D. (1997). "Natural Fires in Closed Car Parks: Car Fire Tests," CTICM Report No. INC 96/294d DJ/NB, CTICM, Metz, France.



**Test Series** 4 **Test Number** 7

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 1303

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** Under left front seat

**Ignition Source** 1.5 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 3.5

**End of Burn Period (min)** 54.6

**Burnout** ✓

**HRR Curve** [04-07-04-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 8188

**Time to Peak HRR (min)** 25.2

**Total Heat Released (MJ)** 6670

**Mass Loss Curve** [04-07-04-ML.xls](#)

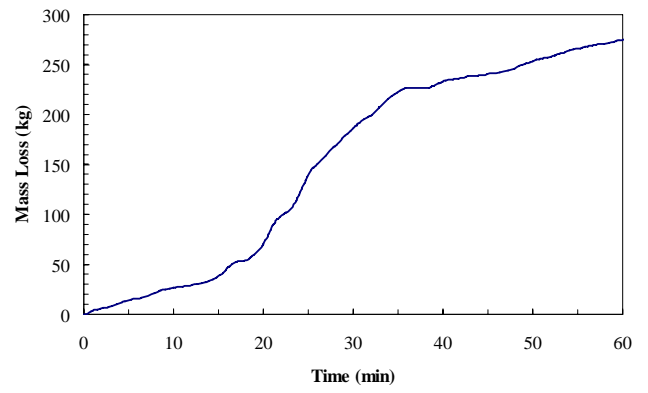
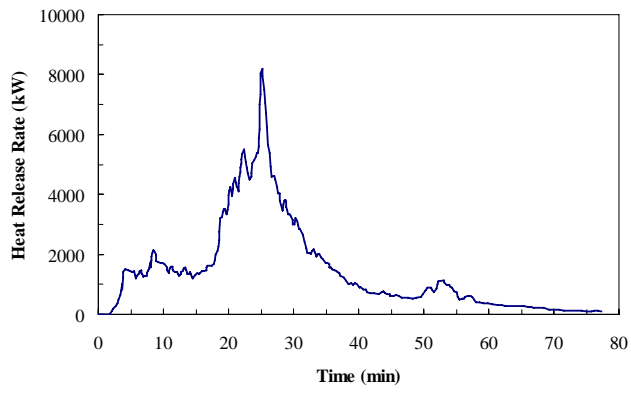
**Total Mass Loss (kg)** 275

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Joyeux, D. (1997). "Natural Fires in Closed Car Parks: Car Fire Tests," CTICM Report No. INC 96/294d DJ/NB, CTICM, Metz, France.



**Test Series** 4 **Test Number** 8

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 830

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** Under gear box

**Ignition Source** 1 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 12.3

**End of Burn Period (min)** 55.1

**Burnout** ✓

**HRR Curve** [04-08-04-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 4063

**Time to Peak HRR (min)** 24.1

**Total Heat Released (MJ)** 4090

**Mass Loss Curve** [04-08-04-ML.xls](#)

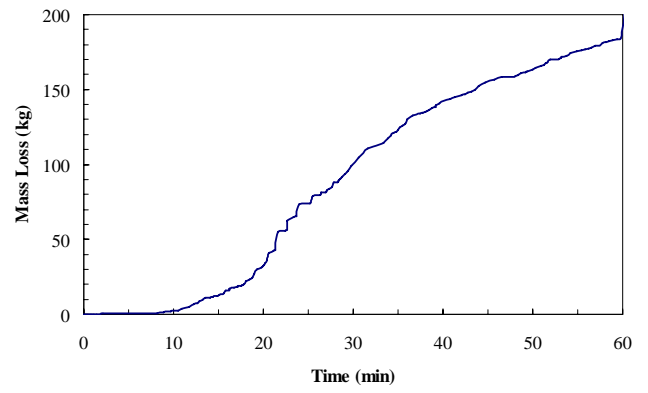
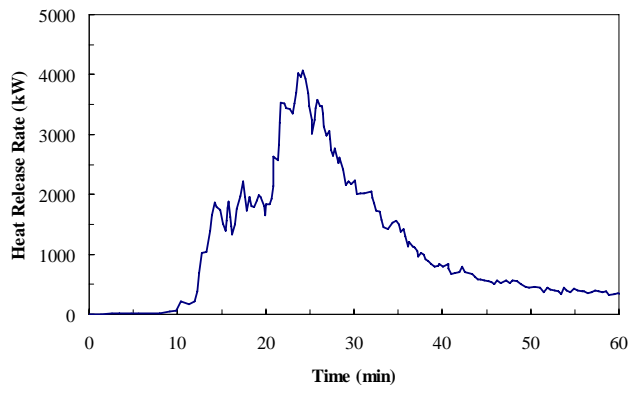
**Total Mass Loss (kg)** 184

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Joyeux, D. (1997). "Natural Fires in Closed Car Parks: Car Fire Tests," CTICM Report No. INC 96/294d DJ/NB, CTICM, Metz, France.



**Test Series** 5 **Test Number** 1

**Lab Name** TNO

**City** Delft

**Country** Netherlands

**Type of Facility** Parking Garage

**Purpose of Test** Fire Engineering

**Vehicle Make** Peugeot

**Vehicle Model** 309

**Vehicle Year**

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles**

**Ignition Location**

**Ignition Source**

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 8.6

**End of Burn Period (min)** 26.2

**Burnout** ✓

**HRR Curve** [05-01-05-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 8872

**Time to Peak HRR (min)** 20.8

**Total Heat Released (MJ)** 4134

**Mass Loss Curve** [05-01-05-ML.xls](#)

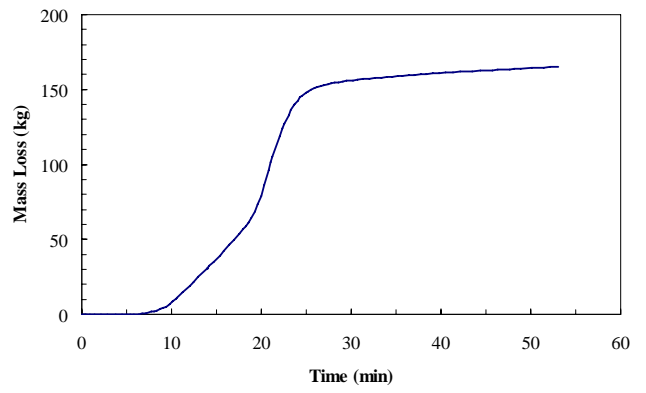
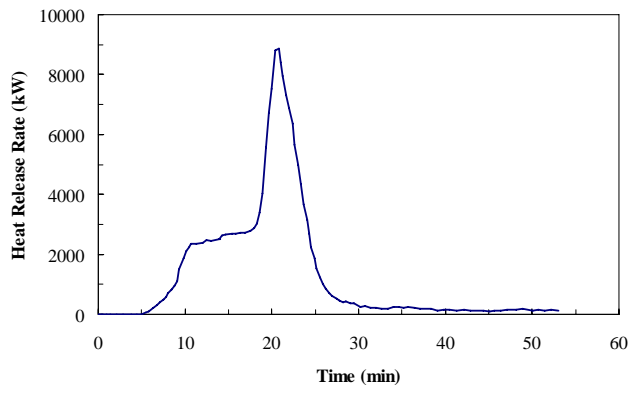
**Total Mass Loss (kg)** 165

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Van Oerle, N., Lemaire, A. and van de Leur, P. (1999). "Effectiveness of Forced Ventilation in Closed Car Parks (in Dutch)," TNO Report No. 1999-CVB-RR1442, TNO, Delft, the Netherlands.



**Test Series** 5 **Test Number** 11

**Lab Name** TNO

**City** Delft

**Country** Netherlands

**Type of Facility** Parking Garage

**Purpose of Test** Fire Engineering

**Vehicle Make** Renault

**Vehicle Model** Espace

**Vehicle Year**

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles**

**Ignition Location**

**Ignition Source**

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 10.5

**End of Burn Period (min)** 43.3

**Burnout** ✓

**HRR Curve** [05-11-05-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 4270

**Time to Peak HRR (min)** 15.8

**Total Heat Released (MJ)** 5028

**Mass Loss Curve** [05-11-05-ML.xls](#)

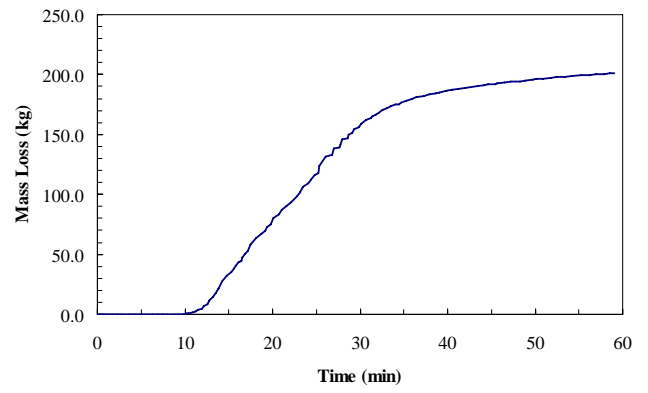
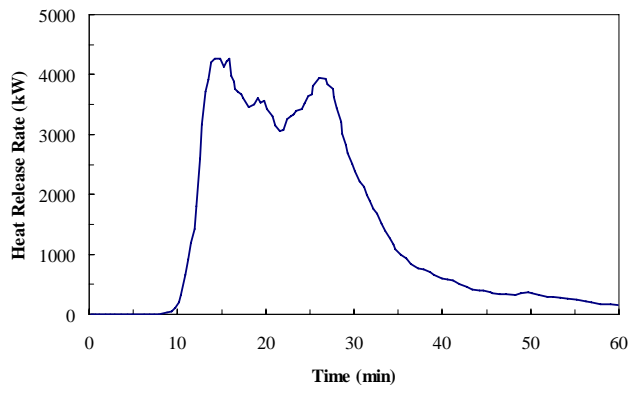
**Total Mass Loss (kg)** 201

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Van Oerle, N., Lemaire, A. and van de Leur, P. (1999). "Effectiveness of Forced Ventilation in Closed Car Parks (in Dutch)," TNO Report No. 1999-CVB-RR1442, TNO, Delft, the Netherlands.



**Test Series** 5 **Test Number** 12

**Lab Name** TNO

**City** Delft

**Country** Netherlands

**Type of Facility** Parking Garage

**Purpose of Test** Fire Engineering

**Vehicle Make** Opel

**Vehicle Model** Kadett

**Vehicle Year**

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles**

**Ignition Location**

**Ignition Source**

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 4.5

**End of Burn Period (min)** 32.2

**Burnout** ✓

**HRR Curve** [05-12-05-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 4549

**Time to Peak HRR (min)** 15.4

**Total Heat Released (MJ)** 3466

**Mass Loss Curve** [05-12-05-ML.xls](#)

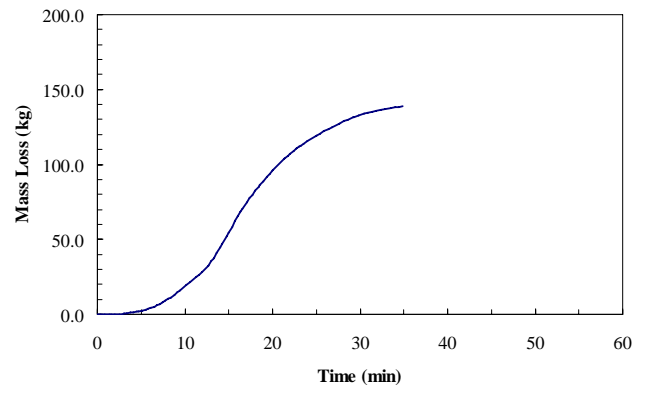
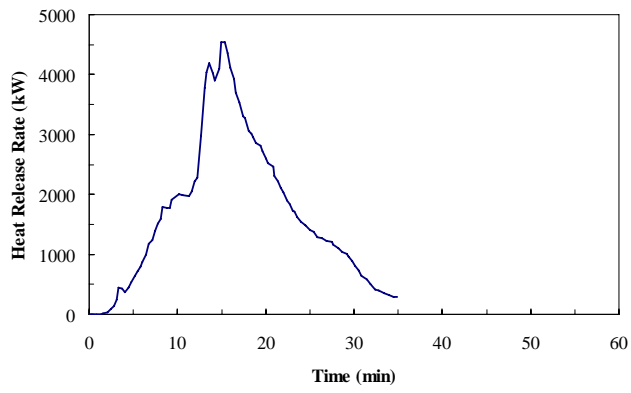
**Total Mass Loss (kg)** 139

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Van Oerle, N., Lemaire, A. and van de Leur, P. (1999). "Effectiveness of Forced Ventilation in Closed Car Parks (in Dutch)," TNO Report No. 1999-CVB-RR1442, TNO, Delft, the Netherlands.



**Test Series** 6 **Test Number** 1

**Lab Name** MPA

**City** Leipzig

**Country** Germany

**Type of Facility** Room Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Trabant

**Vehicle Model** Limousine

**Vehicle Year**

**Vehicle Mass (kg)** 695

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 15

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Slight gap at top of windows

**Number of Target Vehicles** 0

**Ignition Location** Front seat

**Ignition Source** 250 mL isopropanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 4.3

**End of Burn Period (min)** 28.9

**Burnout** ✓

**HRR Curve** [06-01-06-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 3630

**Time to Peak HRR (min)** 12.4

**Total Heat Released (MJ)** 3100

**Mass Loss Curve**

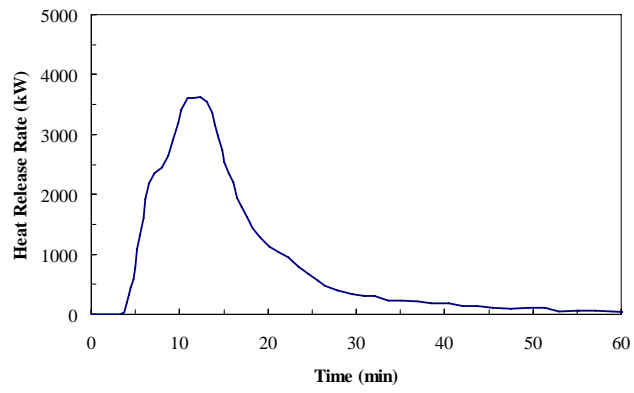
**Total Mass Loss (kg)** 100

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Steinert, C. (2000). "Experimental Investigation of Burning and Fire Jumping Behavior of Automobiles (in German)," VFDB, Vol. 49, pp. 163-172.



**Test Series** 6 **Test Number** 2

**Lab Name** MPA

**City** Leipzig

**Country** Germany

**Type of Facility** Room Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Rover-Austin

**Vehicle Model** Metro LS

**Vehicle Year**

**Vehicle Mass (kg)** 893

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 15

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Slight gap at top of windows

**Number of Target Vehicles** 0

**Ignition Location** Front seat

**Ignition Source** 250 mL isopropanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 10.3

**End of Burn Period (min)** 67.2

**Burnout** ✓

**HRR Curve** [06-02-06-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1710

**Time to Peak HRR (min)** 27.6

**Total Heat Released (MJ)** 3200

**Mass Loss Curve**

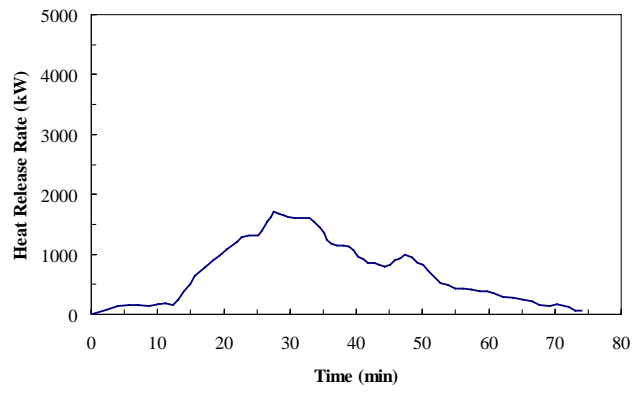
**Total Mass Loss (kg)** 108

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Steinert, C. (2000). "Experimental Investigation of Burning and Fire Jumping Behavior of Automobiles (in German)," VFDB, Vol. 49, pp. 163-172.



**Test Series** 6 **Test Number** 3

**Lab Name** MPA

**City** Leipzig

**Country** Germany

**Type of Facility** Room Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Citroen

**Vehicle Model** BX 16 RE

**Vehicle Year**

**Vehicle Mass (kg)** 1067

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 15

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Slight gap at top of windows

**Number of Target Vehicles** 0

**Ignition Location** Front seat

**Ignition Source** 250 mL isopropanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 3.9

**End of Burn Period (min)** 51.3

**Burnout** ✓

**HRR Curve** [06-03-06-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 4470

**Time to Peak HRR (min)** 17

**Total Heat Released (MJ)** 8000

**Mass Loss Curve**

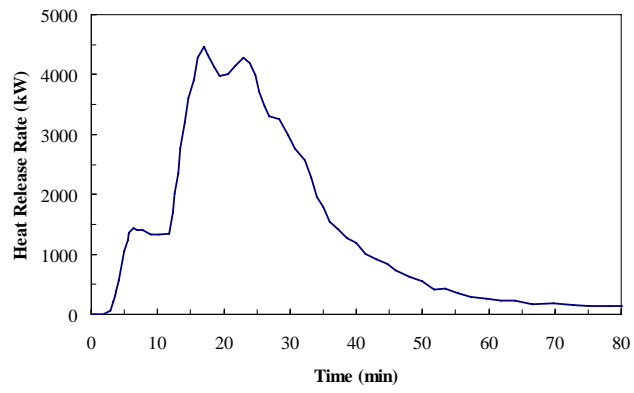
**Total Mass Loss (kg)** 270

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Steinert, C. (2000). "Experimental Investigation of Burning and Fire Jumping Behavior of Automobiles (in German)," VFDB, Vol. 49, pp. 163-172.



**Test Series** 7 **Test Number** 2

**Lab Name** NIST BFRL

**City** Gaithersburg, MD **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Arson Investigation

**Vehicle Make** Unknown

**Vehicle Model** Unknown (Minivan)

**Vehicle Year** 1995

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger window open

**Number of Target Vehicles** 0

**Ignition Location** Poured on driver's seat

**Ignition Source** 2 L of gasoline

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 0.2

**End of Burn Period (min)** 4.8

**Burnout**

**HRR Curve** [07-02-07-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 2405

**Time to Peak HRR (min)** 2.3

**Total Heat Released (MJ)** 459

**Mass Loss Curve**

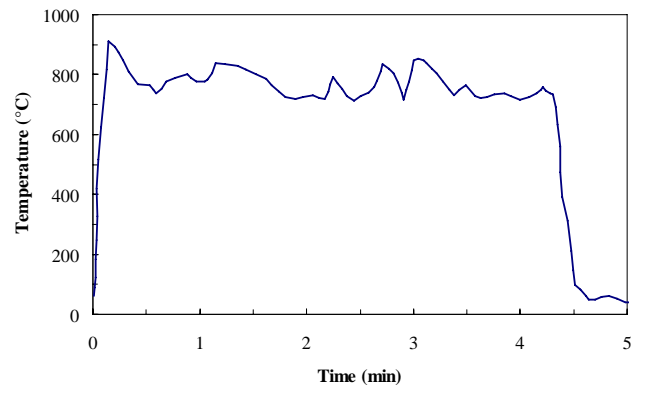
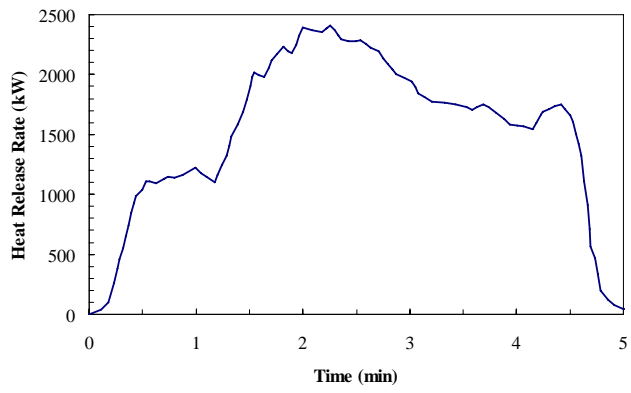
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve** [07-02-07-TEMP.XLS](#)

**Interior CO Curve**

**Reference** Stroup, D., DeLauter, L., Lee, L. and Roadermel, G. (2001). "Passenger Minivan Fire Tests," FR 4011, National Institute of Standards and Technology, Gaithersburg, MD.



**Test Series** 8 **Test Number** 1

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Dodge

**Vehicle Model** Caravan Sport

**Vehicle Year** 1996

**Vehicle Mass (kg)** 1981

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger window slightly open

**Number of Target Vehicles** 0

**Ignition Location** Around battery and power distributor housing

**Ignition Source** Electrical wire igniter

**Untenable Conditions (s)** 160

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-01-08-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1545

**Time to Peak HRR (min)** 10.7

**Total Heat Released (MJ)** 254

**Mass Loss Curve**

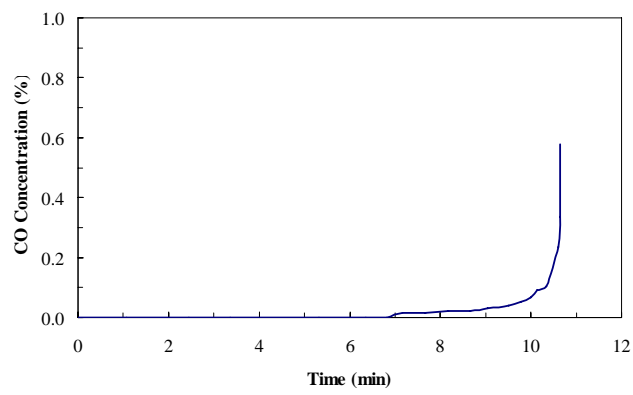
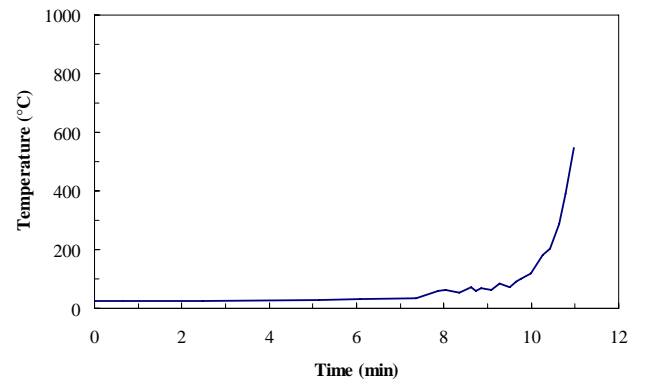
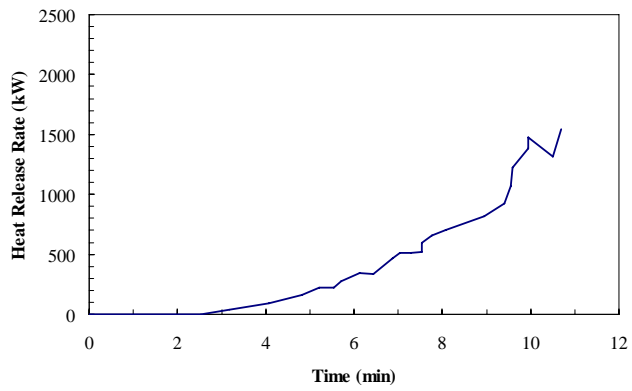
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve** [08-01-08-TEMP.xls](#)

**Interior CO Curve** [08-01-08-XCO.xls](#)

**Reference** Santrock, J. (2001). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 3: Propagation in an Engine Compartment Fire in a 1996 Passenger Van," NHTSA 1998 3588-119, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 2

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Plymouth

**Vehicle Model** Voyager

**Vehicle Year** 1996

**Vehicle Mass (kg)** 1946

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 38

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Rear hatch window broken, left rear vent window open, left rear quarter panel cracked from crash

**Number of Target Vehicles** 0

**Ignition Location** Under vehicle

**Ignition Source** Pool from 243 ML/min fuel tank leak ignited at 30s

**Untenable Conditions (s)** 165

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-02-09-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 4797

**Time to Peak HRR (min)** 4.6

**Total Heat Released (MJ)** 421

**Mass Loss Curve**

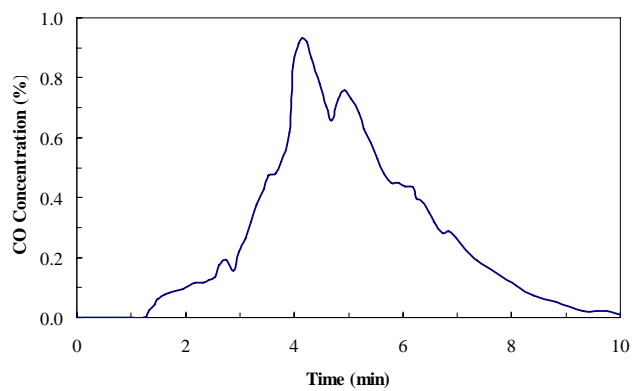
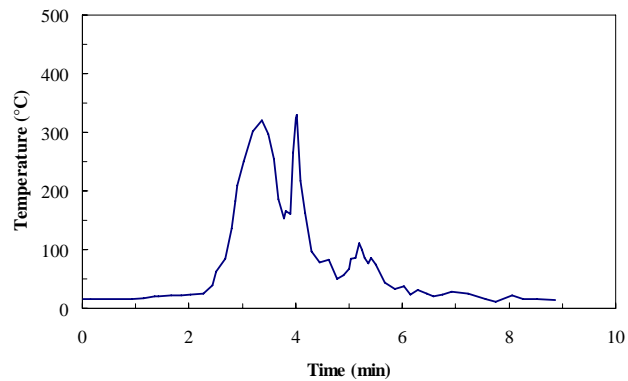
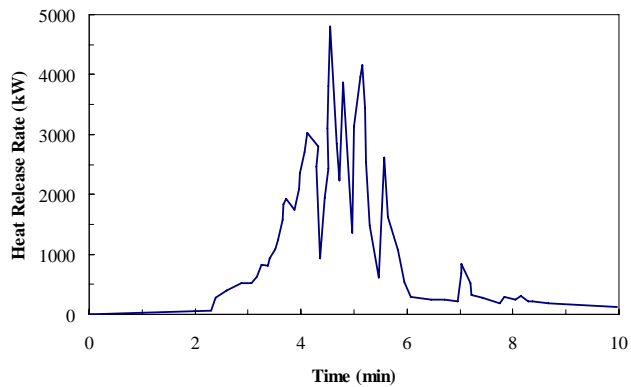
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve** [08-02-09-TEMP.xls](#)

**Interior CO Curve** [08-02-09-XCO.xls](#)

**Reference** Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 4: Propagation of an Underbody Gasoline Pool Fire in a 1996 Passenger Van," NHTSA 1998 3588-143, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 3

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Chevrolet

**Vehicle Model** Camaro

**Vehicle Year** 1997

**Vehicle Mass (kg)** 1811

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Left side door window and rear compartment lift window were shattered, gap between the bottom of the left door and frame

**Number of Target Vehicles** 0

**Ignition Location** Under vehicle

**Ignition Source** Pool from 515 ML/min fuel tank leak ignited at 30s

**Untenable Conditions (s)** 165

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-03-10-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1181

**Time to Peak HRR (min)** 3.8

**Total Heat Released (MJ)** 130

**Mass Loss Curve**

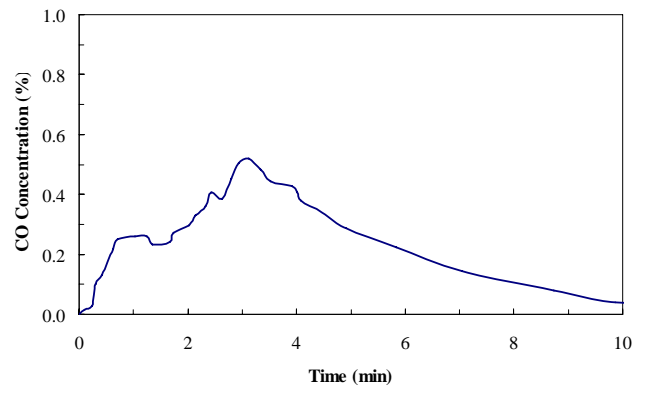
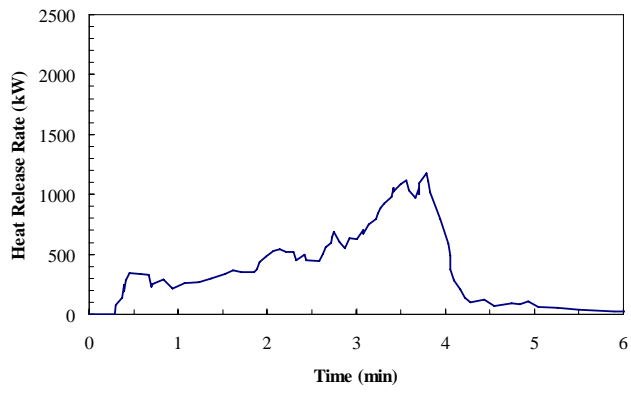
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve** [08-03-10-XCO.xls](#)

**Reference** Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 6: Propagation of an Underbody Gasoline Pool Fire in a 1997 Rear Wheel Drive Passenger Car," NHTSA 1998-3588-158, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 4

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Chevrolet

**Vehicle Model** Camaro

**Vehicle Year** 1997

**Vehicle Mass (kg)** 1849

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Windshield and right door window were broken and a section of the weld seam between the floor pan and inner rocker panel was separated

**Number of Target Vehicles** 0

**Ignition Location** Engine compartment

**Ignition Source** Propane torch flame impinging on HVAC module

**Untenable Conditions (s)** 630

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-04-11-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1161

**Time to Peak HRR (min)** 16

**Total Heat Released (MJ)** 233

**Mass Loss Curve**

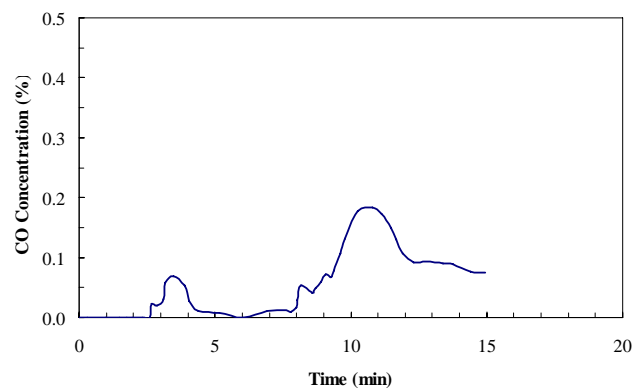
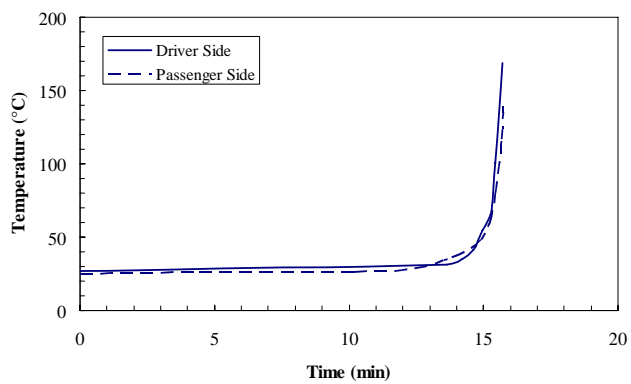
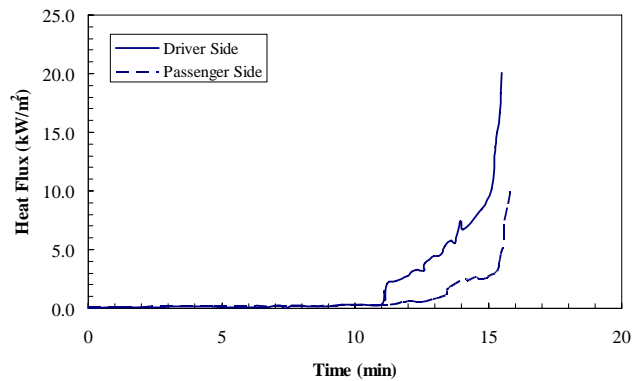
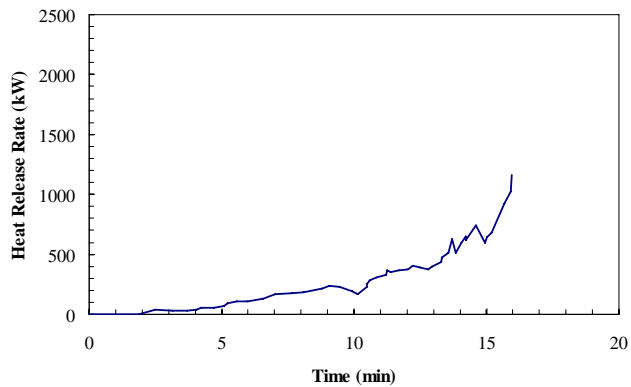
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-04-11-FLUX.xls](#)

**Interior Temperature Curve** [08-04-11-TEMP.xls](#)

**Interior CO Curve** [08-04-11-XCO.xls](#)

**Reference** Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 7: Propagation of an Engine Compartment Fire in a 1997 Rear Wheel Drive Passenger Car," NHTSA 1998-3588-178, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 5

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Ford

**Vehicle Model** Explorer

**Vehicle Year** 1998

**Vehicle Mass (kg)** 2249

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Window openings on the left and right quarter panels; additional opening on the rear lift gate, left rear door, door frames and seams along the rear compartment floor panels

**Number of Target Vehicles** 0

**Ignition Location** Under vehicle

**Ignition Source** Pool from 750 ML/min fuel tank leak ignited at 30s

**Untenable Conditions (s)** 125

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-05-12-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1337

**Time to Peak HRR (min)** 2.5

**Total Heat Released (MJ)** 131

**Mass Loss Curve**

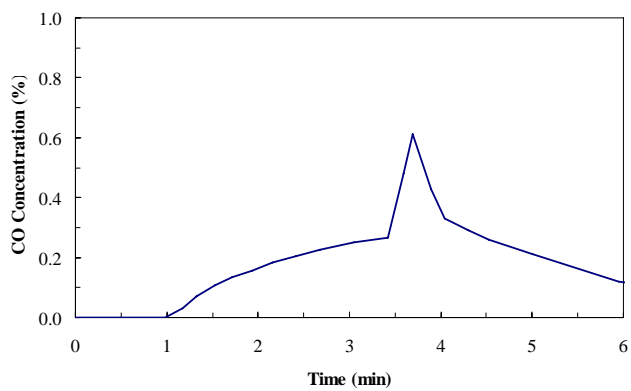
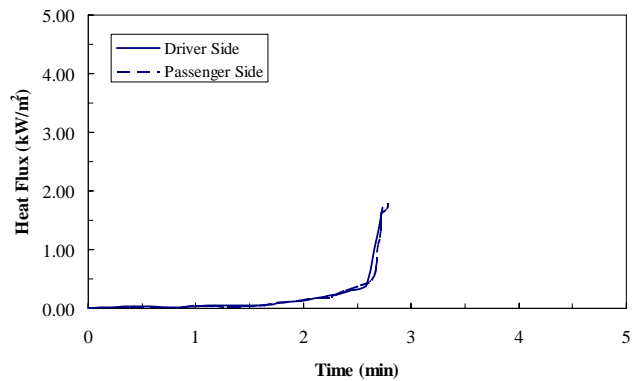
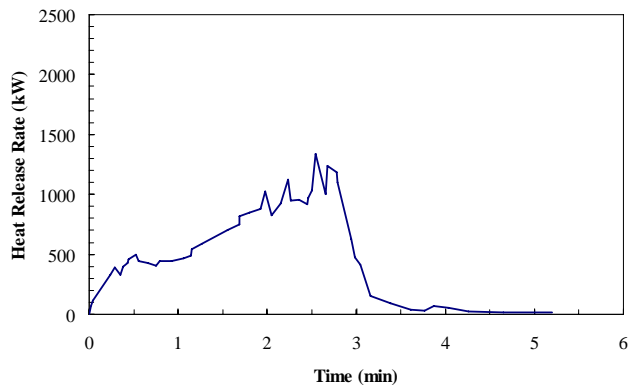
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-05-12-FLUX.xls](#)

**Interior Temperature Curve**

**Interior CO Curve** [08-05-12-XCO.xls](#)

**Reference** Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 9: Propagation of a Rear-Underbody Gasoline Pool Fire in a 1998 Sport Utility Vehicle," NHTSA 1998-3588-188, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 6

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Ford

**Vehicle Model** Explorer

**Vehicle Year** 1998

**Vehicle Mass (kg)** 2232

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Pass through openings under left front seat; shift lever; drain holes, left door and door sills

**Number of Target Vehicles** 0

**Ignition Location** Under vehicle (mid-body)

**Ignition Source** Pool from 350 ML/min fuel tank leak ignited at 30s

**Untenable Conditions (s)** 10

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-06-13-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 484

**Time to Peak HRR (min)** 4.3

**Total Heat Released (MJ)** 90

**Mass Loss Curve**

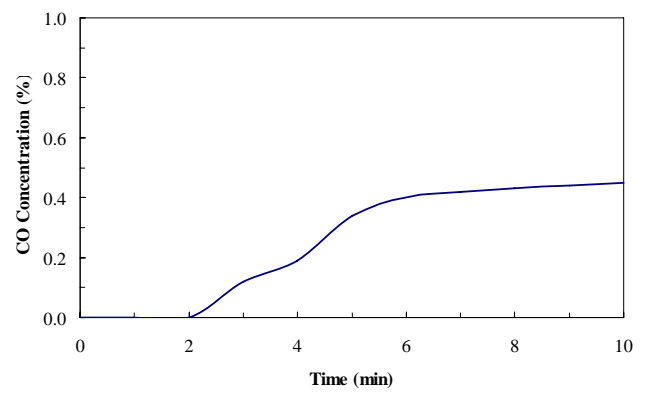
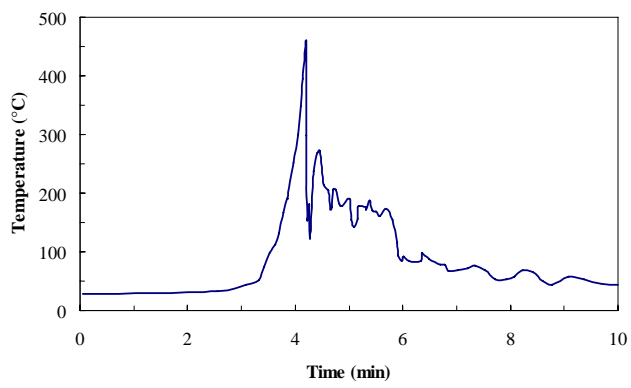
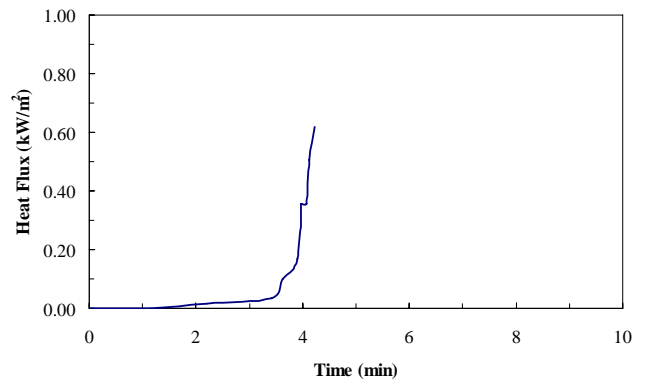
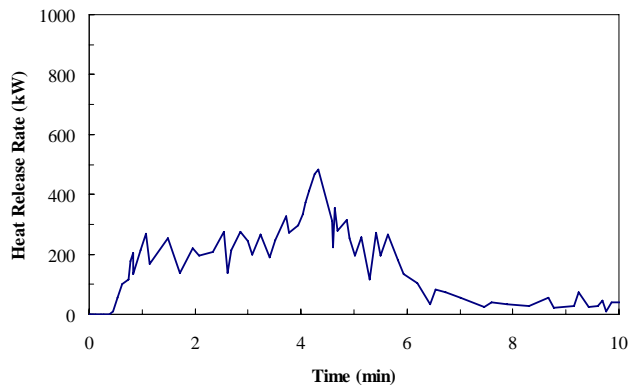
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-06-13-FLUX.xls](#)

**Interior Temperature Curve** [08-06-13-TEMP.xls](#)

**Interior CO Curve** [08-06-13-XCO.xls](#)

**Reference** Santrock, J. (2002). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 10: Propagation of a Mid-Underbody Gasoline Pool Fire in a 1998 Sport Utility Vehicle," NHTSA 1998-3588-189, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 7

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Chevrolet

**Vehicle Model** Camaro (Modified - FR HVAC)

**Vehicle Year** 1999

**Vehicle Mass (kg)** 1848

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Doors closed with windows raised to full closed position, right window glass (passenger door) of the vehicle broken

**Number of Target Vehicles** 0

**Ignition Location** In air cleaner housing in engine compartment

**Ignition Source** Nichrome wires wrapped around PP sheet (1.2 kW)

**Untenable Conditions (s)** 767

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-07-14-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 2973

**Time to Peak HRR (min)** 12.7

**Total Heat Released (MJ)** 445

**Mass Loss Curve**

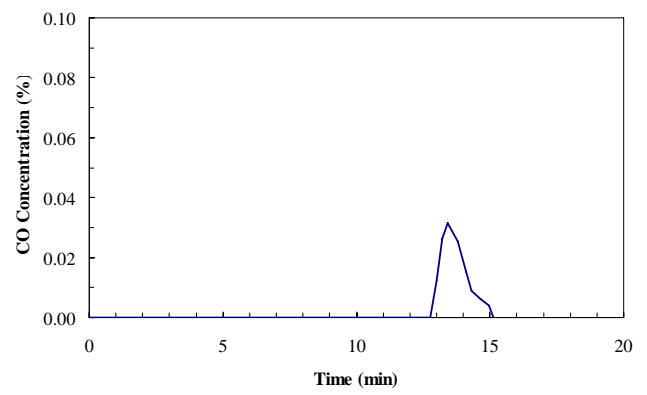
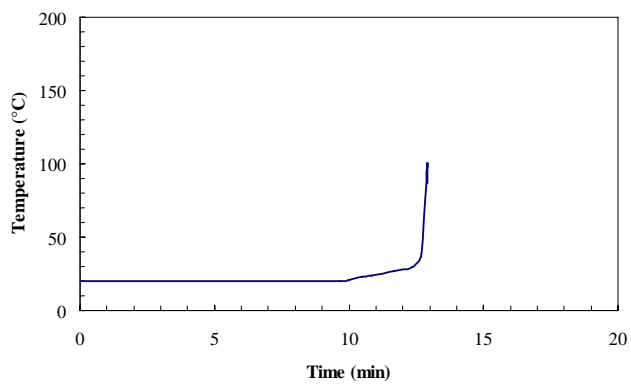
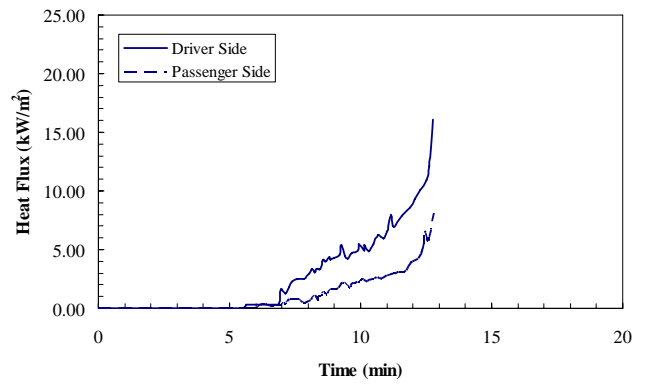
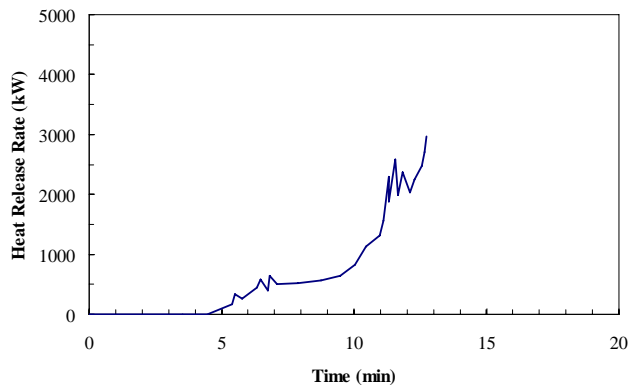
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-07-14-FLUX.xls](#)

**Interior Temperature Curve** [08-07-14-TEMP.xls](#)

**Interior CO Curve** [08-07-14-XCO.xls](#)

**Reference** Santrock, J. (2002). "Demonstration of Enhanced Fire Safety Technology-Fire Retardant Materials-Part 1: Full Scale Vehicle Fire Tests of a Control Vehicle and a Test Vehicle Containing FR Chemicals," NHTSA 1998-3588-190, GM Corporation, Warren,



**Test Series** 8 **Test Number** 8

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Chevrolet

**Vehicle Model** Camaro

**Vehicle Year** 1999

**Vehicle Mass (kg)** 1848

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Doors closed with windows raised to full closed position, right window glass (passenger door) of the vehicle broken

**Number of Target Vehicles** 0

**Ignition Location** In air cleaner housing in engine compartment

**Ignition Source** Nichrome wires wrapped around PP sheet (1.2 kW)

**Untenable Conditions (s)** 770

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-08-14-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 3173

**Time to Peak HRR (min)** 12.9

**Total Heat Released (MJ)** 540

**Mass Loss Curve**

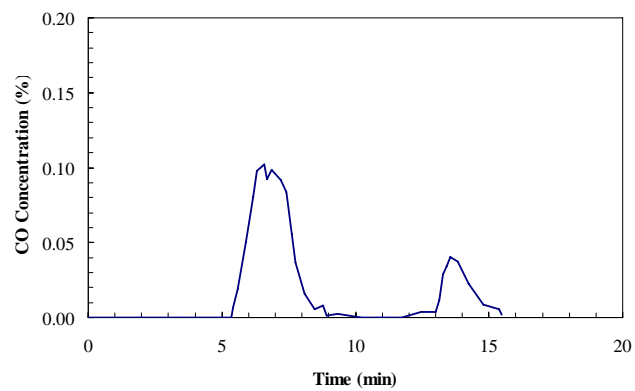
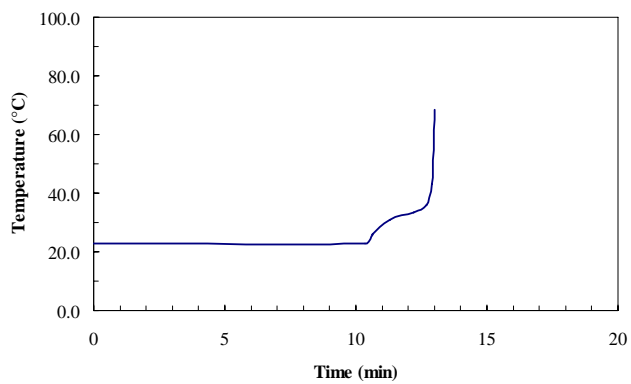
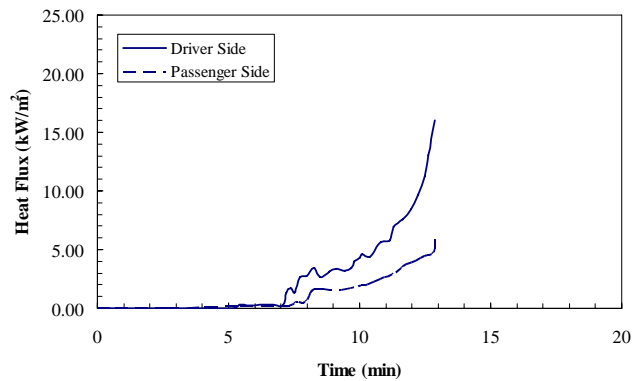
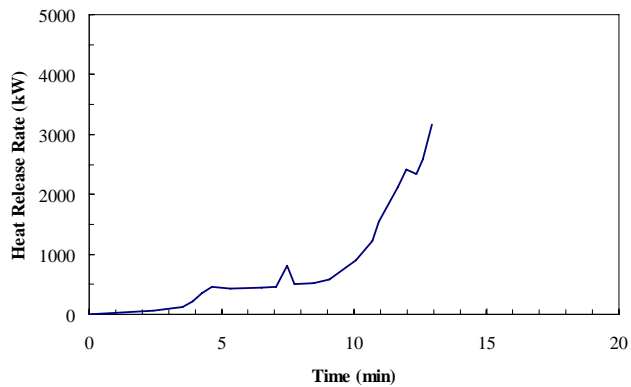
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-08-14-FLUX.xls](#)

**Interior Temperature Curve** [08-08-14-TEMP.xls](#)

**Interior CO Curve** [08-08-14-XCO.xls](#)

**Reference** Santrock, J. (2002). "Demonstration of Enhanced Fire Safety Technology-Fire Retardant Materials-Part 1: Full Scale Vehicle Fire Tests of a Control Vehicle and a Test Vehicle Containing FR Chemicals," NHTSA 1998-3588-190, GM Corporation, Warren,



**Test Series** 8 **Test Number** 9

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Honda

**Vehicle Model** Accord

**Vehicle Year** 1998

**Vehicle Mass (kg)** 1649

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** All doors closed and front door windows raised, left and right rear door glass broken

**Number of Target Vehicles** 0

**Ignition Location** Under vehicle

**Ignition Source** Pool from 400 ML/min fuel tank leak ignited at 35s

**Untenable Conditions (s)** 83

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-09-15-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 780

**Time to Peak HRR (min)** 2.6

**Total Heat Released (MJ)** 1816

**Mass Loss Curve**

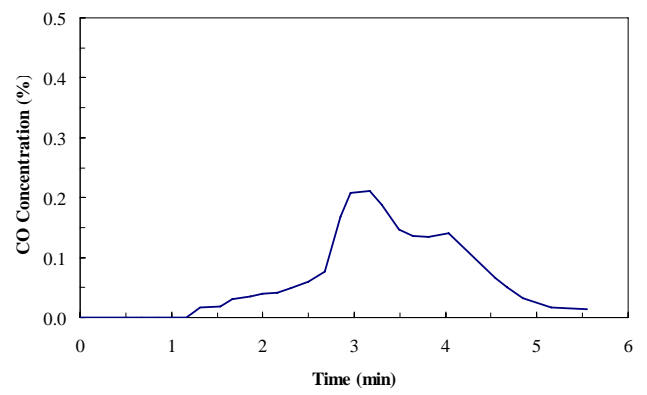
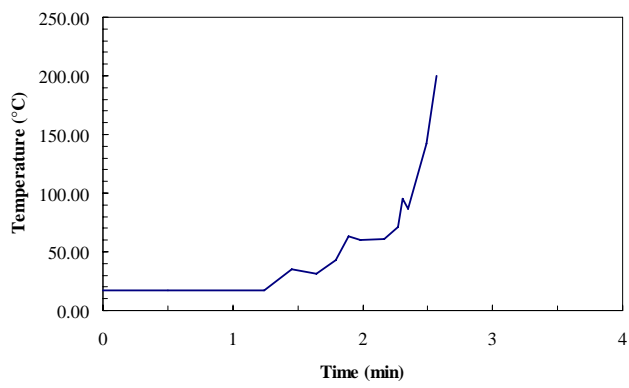
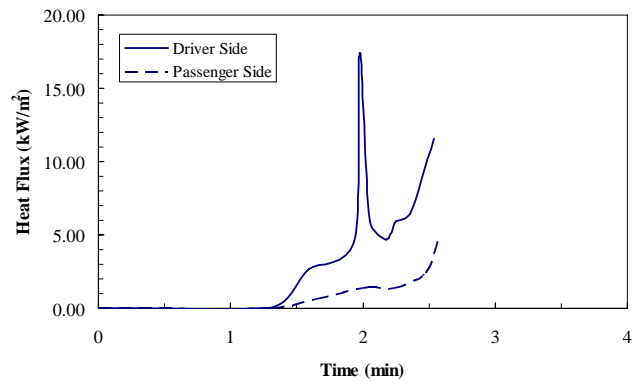
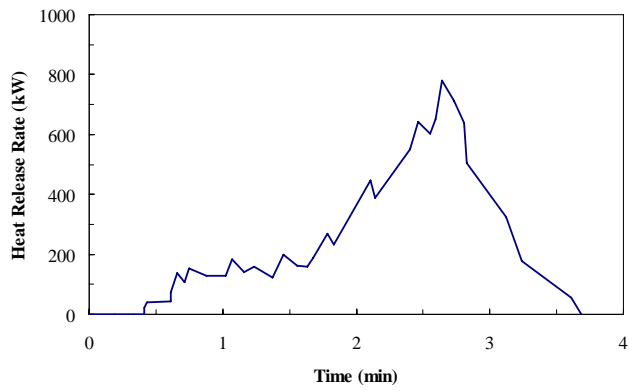
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-09-15-FLUX.xls](#)

**Interior Temperature Curve** [08-09-15-TEMP.xls](#)

**Interior CO Curve** [08-09-15-XCO.xls](#)

**Reference** Santrock, J. (2003). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 12: Propagation of an Underbody Gasoline Pool Fire in a 1998 Front-Wheel Drive Passenger Vehicle," NHTSA 1998-3588-201, General Motors Corporation, Warren, MI.



**Test Series** 8 **Test Number** 10

**Lab Name** FM Research Center

**City** West Gloucester, RI **Country** USA

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Hazard Assessment

**Vehicle Make** Honda

**Vehicle Model** Accord

**Vehicle Year** 1998

**Vehicle Mass (kg)** 1738

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Windshield and right front door glass broken

**Number of Target Vehicles** 0

**Ignition Location** Windshield washer fluid reservoir

**Ignition Source** Methanol vapor

**Untenable Conditions (s)** 1560

**Type of Conditions** Flame Penetration

**Start of Burn Period (min)**

**End of Burn Period (min)**

**Burnout**

**HRR Curve** [08-10-16-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1189

**Time to Peak HRR (min)** 27.1

**Total Heat Released (MJ)** 199

**Mass Loss Curve**

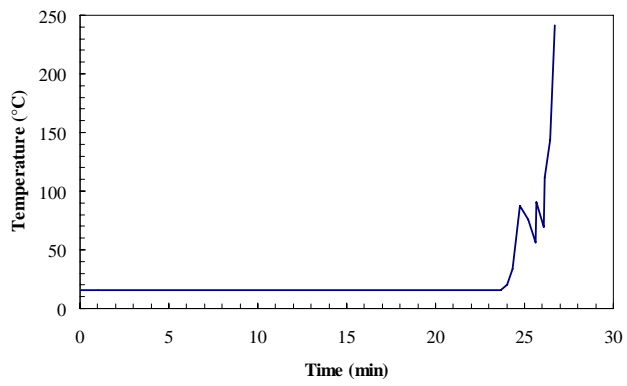
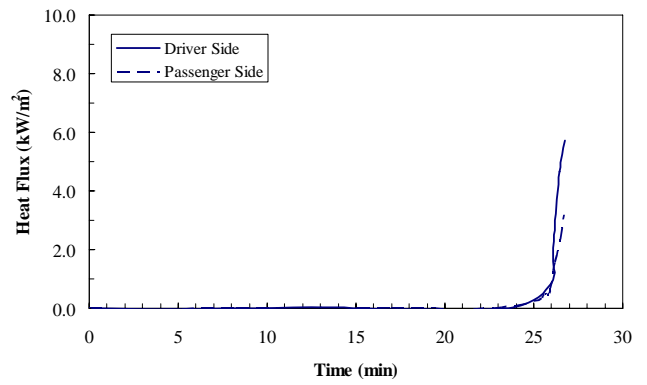
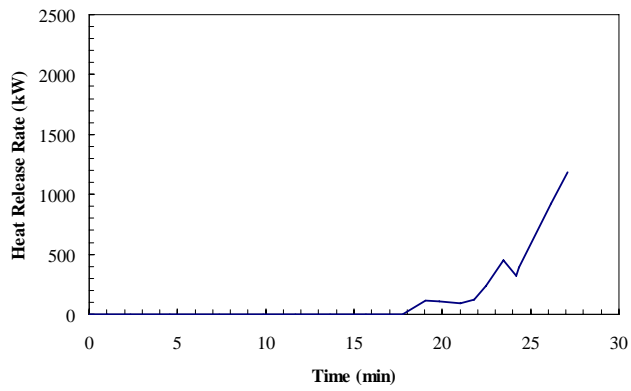
**Total Mass Loss (kg)**

**Interior Heat Flux Curve** [08-10-16-FLUX.xls](#)

**Interior Temperature Curve** [08-10-16-TEMP.xls](#)

**Interior CO Curve**

**Reference** Santrock, J. (2003). "Evaluation of Motor Vehicle Fire Initiation and Propagation, Part 13: Propagation of an Engine Compartment Fire in a 1998 Front-Wheel Drive Passenger Vehicle," NHTSA 1998-3588-203, General Motors Corporation, Warren, MI.



**Test Series** 9 **Test Number** 1

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Corner Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Peugeot

**Vehicle Model** 406 Break

**Vehicle Year** 1994

**Vehicle Mass (kg)** 1454

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 40

**Vehicle Condition** New

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** Under gear box

**Ignition Source** 1.5 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 6.3

**End of Burn Period (min)** 45.1

**Burnout** ✓

**HRR Curve** [09-01-17-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 9854

**Time to Peak HRR (min)** 37.8

**Total Heat Released (MJ)** 6806

**Mass Loss Curve** [09-01-17-ML.xls](#)

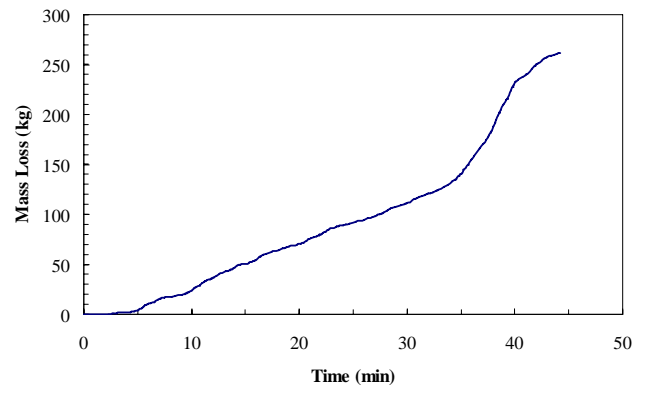
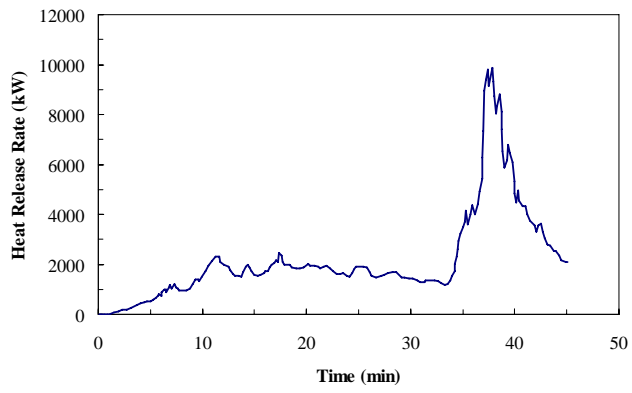
**Total Mass Loss (kg)** 262

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Joyeux, D., Kruppa, J., Cajot, L., Schleich, J., Van de Leur, P., and Twilt, L. (2002). "Demonstration of Real Fire Tests in Car Parks and High Buildings," Final Report, Contract No. 7215 PP 025, CTICM, Metz, France.



**Test Series** 9 **Test Number** 2

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Corner Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Peugeot

**Vehicle Model** 406 Berline

**Vehicle Year** 1994

**Vehicle Mass (kg)** 1382

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 41

**Vehicle Condition** New

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** Under gear box

**Ignition Source** 1.5 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 4.9

**End of Burn Period (min)** 49.6

**Burnout** ✓

**HRR Curve** [09-02-17-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 8283

**Time to Peak HRR (min)** 36.9

**Total Heat Released (MJ)** 7000

**Mass Loss Curve** [09-02-17-ML.xls](#)

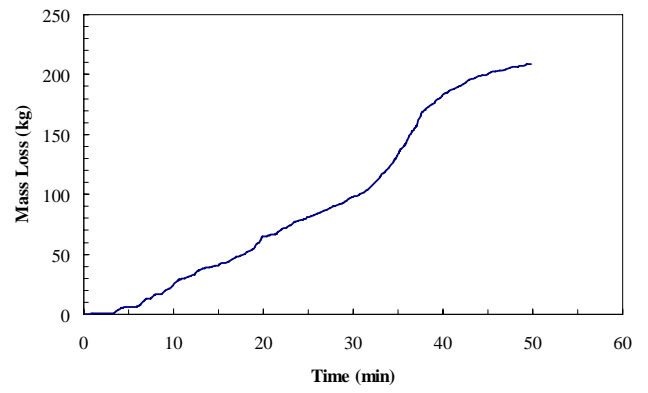
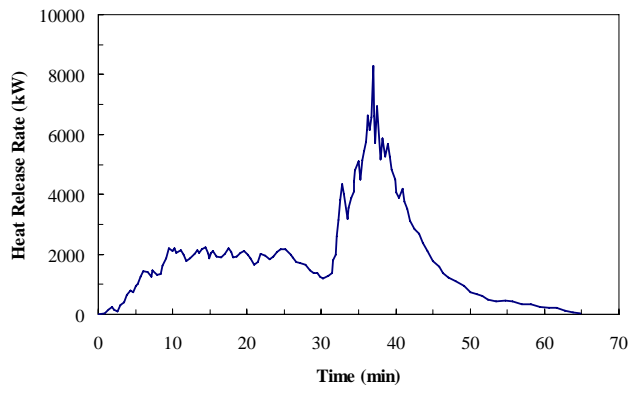
**Total Mass Loss (kg)** 255

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Joyeux, D., Kruppa, J., Cajot, L., Schleich, J., Van de Leur, P., and Twilt, L. (2002). "Demonstration of Real Fire Tests in Car Parks and High Buildings," Final Report, Contract No. 7215 PP 025, CTICM, Metz, France.



**Test Series** 10 **Test Number** 2

**Lab Name** BRI

**City** Tsukuba

**Country** Japan

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 1182

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger windows rolled down 10 cm

**Number of Target Vehicles** 0

**Ignition Location** Driver's seat

**Ignition Source** Cloth soaked with methanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 3.4

**End of Burn Period (min)** 51.8

**Burnout** ✓

**HRR Curve** [10-02-18-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 3801

**Time to Peak HRR (min)** 24.1

**Total Heat Released (MJ)** 5280

**Mass Loss Curve**

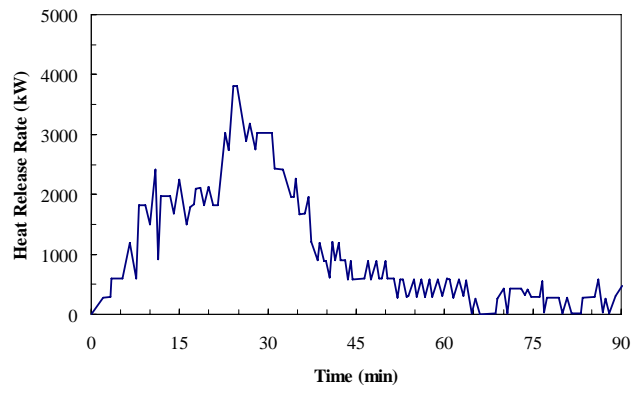
**Total Mass Loss (kg)** 165

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shintani, Y., Kakae, N., Harada, K., Masuda, H., Takahashi, W. (2004). "Experimental Investigation of Burning Behavior of Automobiles," 6th Asia-Oceania Symposium on Fire Science and Technology, pp. 618-629.



**Test Series** 10 **Test Number** 3

**Lab Name** BRI

**City** Tsukuba

**Country** Japan

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 1470

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger windows rolled down 10 cm

**Number of Target Vehicles** 0

**Ignition Location** Driver's seat

**Ignition Source** Cloth soaked with methanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 8.8

**End of Burn Period (min)** 89.4

**Burnout** ✓

**HRR Curve** [10-03-18-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 3650

**Time to Peak HRR (min)** 46.9

**Total Heat Released (MJ)** 5280

**Mass Loss Curve**

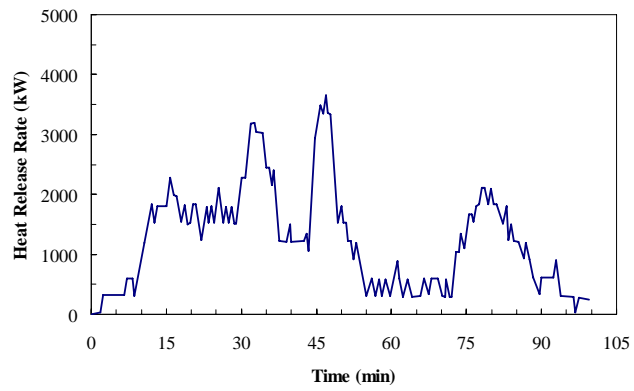
**Total Mass Loss (kg)** 186

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shintani, Y., Kakae, N., Harada, K., Masuda, H., Takahashi, W. (2004). "Experimental Investigation of Burning Behavior of Automobiles," 6th Asia-Oceania Symposium on Fire Science and Technology, pp. 618-629.



**Test Series** 10 **Test Number** 4

**Lab Name** BRI

**City** Tsukuba

**Country** Japan

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 1920

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger windows rolled down 10 cm

**Number of Target Vehicles** 0

**Ignition Location** Driver's seat

**Ignition Source** Cloth soaked with methanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 8.1

**End of Burn Period (min)** 55

**Burnout** ✓

**HRR Curve** [10-04-18-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 3332

**Time to Peak HRR (min)** 34.4

**Total Heat Released (MJ)** 7648

**Mass Loss Curve**

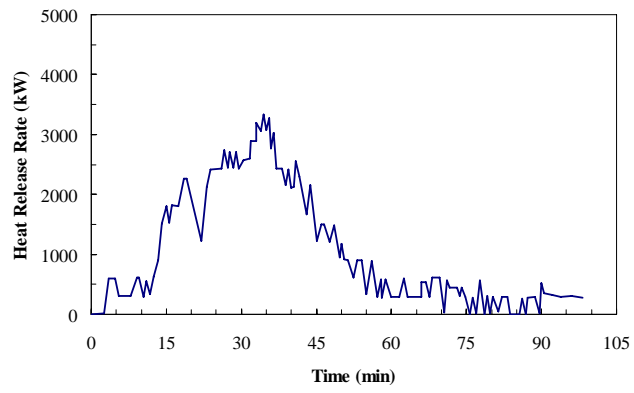
**Total Mass Loss (kg)** 239

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shintani, Y., Kakae, N., Harada, K., Masuda, H., Takahashi, W. (2004). "Experimental Investigation of Burning Behavior of Automobiles," 6th Asia-Oceania Symposium on Fire Science and Technology, pp. 618-629.



**Test Series** 10 **Test Number** 5

**Lab Name** BRI

**City** Tsukuba

**Country** Japan

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year**

**Vehicle Mass (kg)** 1380

**Fuel Tank Type** Unknown

**Fuel Amount (L)**

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Driver and passenger windows rolled down 10 cm

**Number of Target Vehicles** 0

**Ignition Location** Driver's seat

**Ignition Source** Cloth soaked with methanol

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 12.2

**End of Burn Period (min)** 59.7

**Burnout** ✓

**HRR Curve** [10-05-18-HRR.xls](#)

**HRR Measuring Method** Mass Loss

**Peak HRR (kW)** 4073

**Time to Peak HRR (min)** 38.3

**Total Heat Released (MJ)** 6144

**Mass Loss Curve**

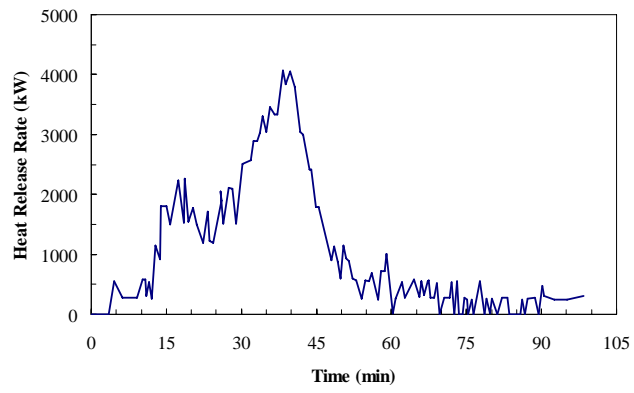
**Total Mass Loss (kg)** 192

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Shintani, Y., Kakae, N., Harada, K., Masuda, H., Takahashi, W. (2004). "Experimental Investigation of Burning Behavior of Automobiles," 6th Asia-Oceania Symposium on Fire Science and Technology, pp. 618-629.



**Test Series** 11 **Test Number** 1

**Lab Name** CTICM

**City** Metz

**Country** France

**Type of Facility** Room Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Citroen

**Vehicle Model** BX

**Vehicle Year** 1989

**Vehicle Mass (kg)** 874

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 40

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions** Passenger front window open, all other windows closed

**Number of Target Vehicles** 1

**Ignition Location** Under driver's seat

**Ignition Source** 1.5 L gasoline in open tray

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 17.7

**End of Burn Period (min)** 131.6

**Burnout** ✓

**HRR Curve** [11-01-19-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 1780

**Time to Peak HRR (min)** 24

**Total Heat Released (MJ)** 8500

**Mass Loss Curve**

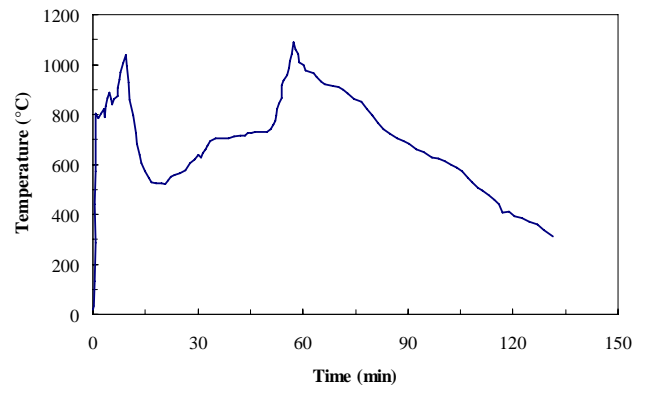
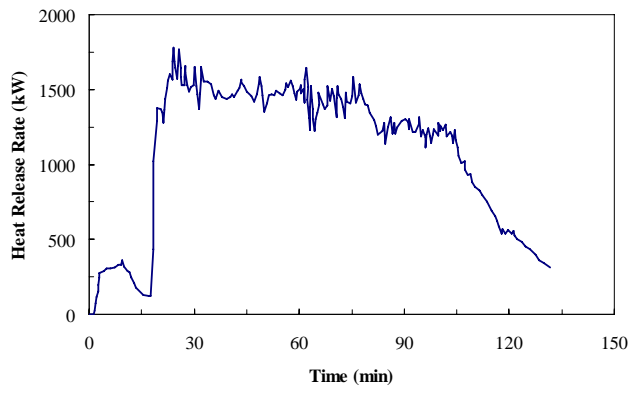
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve** [11-01-19-TEMP.xls](#)

**Interior CO Curve**

**Reference** Anonymous (2004). "CTICM Fire Tests on Cars," CITCM, Metz, France.



**Test Series** 12 **Test Number** 1

**Lab Name** SP

**City** Borås

**Country** Sweden

**Type of Facility** Open Calorimeter

**Purpose of Test** Fire Engineering

**Vehicle Make** Unknown

**Vehicle Model** Unknown

**Vehicle Year** 1998

**Vehicle Mass (kg)**

**Fuel Tank Type** Unknown

**Fuel Amount (L)** 0

**Vehicle Condition** Used

**Post-Collision**

**Ventilation Conditions**

**Number of Target Vehicles** 0

**Ignition Location** On driver's seat and right rear passenger seat

**Ignition Source** 0.21 L of mineral spirits

**Untenable Conditions (s)**

**Type of Conditions**

**Start of Burn Period (min)** 10.6

**End of Burn Period (min)** 35.8

**Burnout** ✓

**HRR Curve** [12-01-20-HRR.xls](#)

**HRR Measuring Method** Oxygen Consumption

**Peak HRR (kW)** 3618

**Time to Peak HRR (min)** 28.4

**Total Heat Released (MJ)** 3800

**Mass Loss Curve**

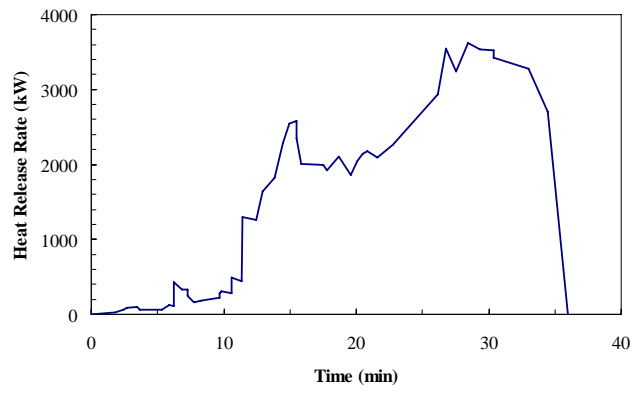
**Total Mass Loss (kg)**

**Interior Heat Flux Curve**

**Interior Temperature Curve**

**Interior CO Curve**

**Reference** Lönnermark, A. and Blomqvist, P. (2006). "Emissions from an Automobile Fire,"  
Chemosphere, Vol. 62, pp. 1043-1056.



**APPENDIX B**  
**PHOTOGRAPHS FROM TESTS PERFORMED AT BRI**  
**(Consisting of 9 Pages)**

# Compact Sedan

550 cc



Ignition



5 min



5 min



10 min



10 min



50 min



End

# Mid-Size Sedan

2000 cc



Ignition



20 min



20 min



30 min



30 min



80 min



End

# Mid-Size Sedan

2000 cc



Ignition



20 min



20 min



30 min



30 min



80 min



End

# Large Sedan

3000 cc



Ignition



30 min



30 min



40 min



40 min



80 min



End

# Large Sedan

3000 cc



Ignition



20 min



20 min



40 min



40 min



60 min



End

# Luxury Sedan

5800 cc



Ignition



70 min



70 min



90 min



90 min



140 min



End

# Sports Utility Vehicle

3000 cc



Ignition



20 min



20 min



40 min



40 min



70 min



End

# Sports Utility Vehicle

3000 cc



Ignition



20 min



20 min



50 min



50 min



80 min



End

# Minivan

3000 cc



Ignition



10 min



10 min



20 min



20 min



50 min



End