

Full-Scale Burn Test of a 2001 Full-Size Pickup Truck

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ABSTRACT

Temperature measurements during a full-scale burn test of a 2001 full-size pickup truck showed that the fire progressed in distinct stages in both the engine and passenger compartments. Although the fire started in the engine compartment and had a relatively long growth period, when a localized area reached about 700°C, a distinct transition occurred where the rate of fire spread increased, leading to full involvement of all engine compartment combustibles. As the engine compartment became fully involved, a hot gas layer then accumulated at the ceiling of the passenger compartment, producing a strong vertical temperature gradient. When the temperature at the ceiling reached about 600°C, another distinct transition occurred where the rate of fire spread increased, leading to full involvement of the passenger compartment. The highest temperature during the test occurred within the engine compartment in an area that had the greatest fuel load, and not the area of origin. Although oxidation and melted aluminum patterns were created during the fire, neither was useful in identifying the area of origin of the fire.

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INTRODUCTION

During the course of vehicle fire investigations, physical evidence is typically examined in an effort to determine important characteristics of the fire such as the cause and origin. However, there are currently no studies in the literature involving full-scale vehicle burn tests which correlate the features of a fire, such as area of origin, to the resulting physical evidence. In this study, the results of a full-scale burn test of a full-size 2001 pickup truck are presented. First, the experimental set-up and procedure are described, including the location and type of thermocouples used and the manner and location in which the fire was initiated. The results of the burn test are then presented, including contour plots of the horizontal temperature variation within the engine compartment and vertical temperature profiles within the passenger compartment at key points in time during the test. The manner in which oxidation patterns originally present on steel surfaces immediately after the fire evolved and changed over the course of several years is then illustrated and discussed. Variations in the melt damage to aluminum components are then presented. Using the measured temperature versus time data at each measurement location within the engine compartment, the estimated energy flux available to melt aluminum components was calculated. These results were compared to the observed areas of aluminum melt damage within the engine compartment and

to variations in the available fuel load. A summary of the key results from the test are then presented.

EXPERIMENTAL SET-UP

The test vehicle for this study was a 2001 Ford F-150 with a crew cab. It was fully functioning, with all fluids at their normal operating levels prior to the test with the exception of gasoline, which had been removed from the tank. The positive battery cable was removed from the battery terminal prior to the test, ensuring that any melted copper wiring observed after the test was due to the heat of the fire and not to electrical activity.

The vehicle was instrumented with 40 24-gauge, K-type thermocouples with fiberglass insulation. The measurement junction of each thermocouple was created with a thermocouple welder that produced a nominal bead diameter of 1 mm. As shown in [Figure 1](#), 22 of these thermocouples were located in the engine compartment, 16 were in the passenger compartment and 2 were located on exterior body panels. [Table 1](#) describes each thermocouple location. The engine and passenger compartment thermocouples were held in place with steel wires in a grid-like manner, with the bead not in contact with any objects. Some thermocouples were located along the perimeter of the engine compartment to facilitate temperature contour plots at selected times. With the exception of channel 15, which failed at the onset of the test, all the engine compartment thermocouples were within 4

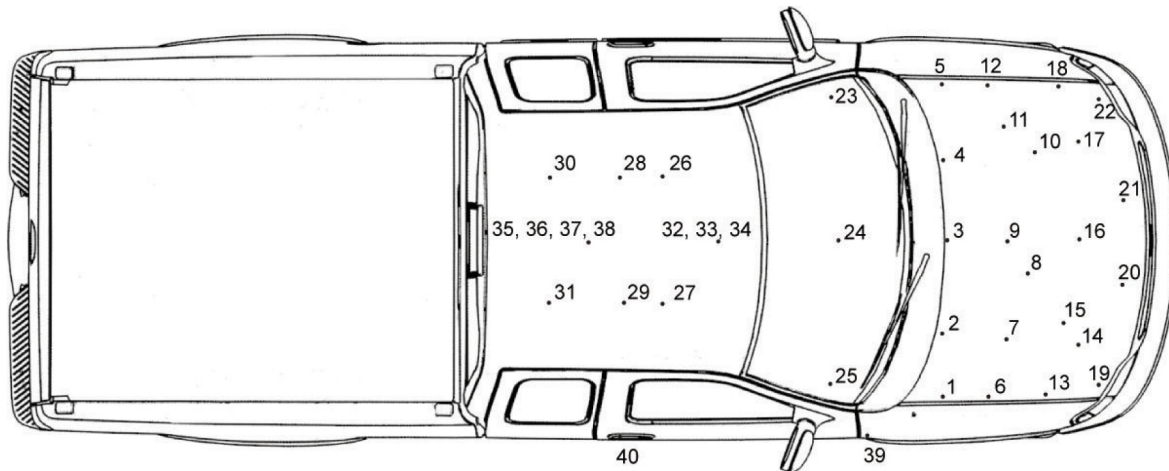


Figure 1. Top view of instrumentation locations.



Figure 3. Overview of the engine compartment components, fuel load and the point of origin of the fire.

inches of the hood surface. The passenger compartment thermocouples were located on the dashboard, seats, and headrests and positioned vertically on thermocouple trees located between the front seats and in the back seat. The temperature data were collected with two calibrated, Fluke Hydra II data acquisition systems, each sampling at 1 Hz. The test was documented with five real-time video cameras located around the vehicle and by a digital SLR camera.

The wind speed and wind direction during the test were monitored with a weather station that was located approximately 100 meters from the test vehicle. As shown in in [Figure 2](#), the wind speed was generally less than 4 mph (6.4 kph) over the duration of the test. The vehicle was facing

120 degrees (southeast) during the test, with the wind direction generally coming from between 270 degrees (west) and 360 degrees (north).

The fire was initiated using a small butane torch near the upper portion of the passenger side of the cooling fan shroud, as shown in [Figure 3](#). All data acquisition and video were synchronized to start at the time the torch was applied to this material. The torch was continuously applied to this location for 5 minutes and 7 seconds, and then the hood was closed.

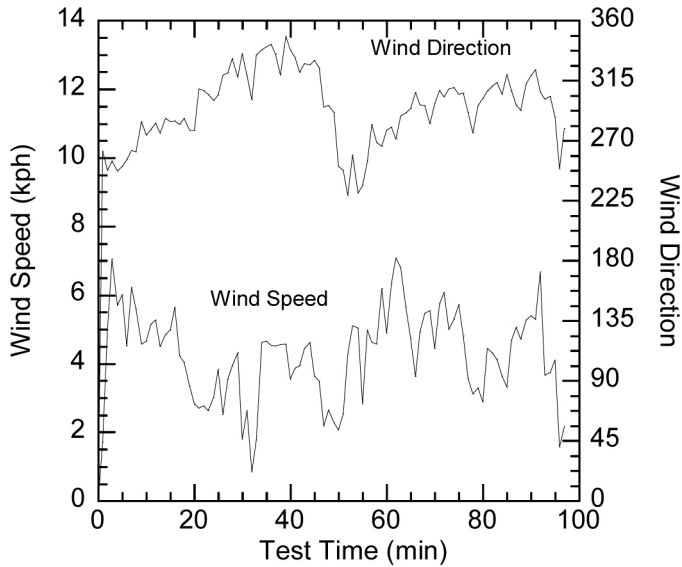


Figure 2. Wind speed and direction during the test.

During the course of the burn test, several of the engine compartment thermocouples and one of the body panel thermocouple channels failed, as shown in [Table 2](#). As described in the next section, these engine compartment thermocouple failures occurred well after the peak burning period and during the cool-down phase of the fire, except for Channel 15, which failed at the onset of the test.

Because the thermocouple beads used in this study were exposed to radiation from the high-temperature combustion products, surfaces, and surrounding gases, the measured temperature may deviate from the true gas temperature near the thermocouple. The extent of this temperature difference is largely dependent on the temperature difference between the radiating sources and the local gas temperature surrounding the thermocouple. By comparing the results from an aspirated thermocouple to a bare thermocouple during a full-scale building fire experiment, Luo [1] found that the measured temperature from bare thermocouples could be 100°C higher than the aspirated thermocouples during the fire growth stage and 200°C higher at flashover. However, during a steady-state fire environment, the temperature difference between bare thermocouples and aspirated thermocouples was negligible in the upper, hot gas level and about 80°C higher for the bare thermocouples at the floor level.

Table 1. Thermocouple locations.

Thermocouple	Description
1	Bulkhead passenger side
2	Bulkhead connector block
3	Throttle body
4	Bulkhead vacuum booster
5	Bulkhead driver side
6	Battery
7	Engine oil fill cap
8	Alternator
9	Air intake tube
10	Air filter
11	Master cylinder
12	Fuse panel
13	Windshield cleaner reservoir
14	Radiator passenger side
15	Engine block passenger side
16	Radiator center
17	Radiator driver side
18	Coolant reservoir
19	Headlight passenger side
20	Radiator cover passenger
21	Radiator cover driver side
22	Headlight driver side
23	Dashboard driver side
24	Dashboard center
25	Dashboard passenger side
26	Front seat driver side
27	Front seat passenger side
28	Headrest driver side
29	Headrest passenger side
30	Rear seat driver side
31	Rear seat passenger side
32	Between front seats console
33	Between front seats
34	Between front seats ceiling
35	Backseat floor
36	Backseat dashboard
37	Backseat mid-level
38	Backseat ceiling
39	Quarter panel passenger side
40	Door panel passenger side

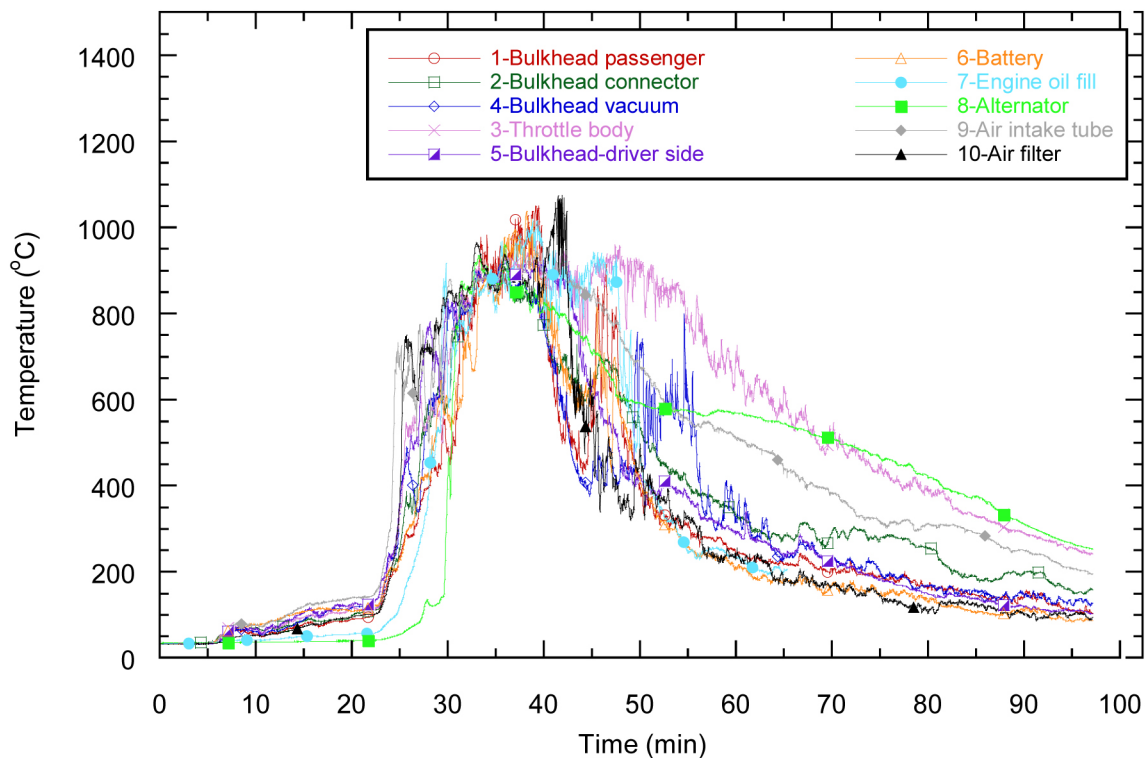


Figure 4. Temperature at measurement locations 1-10.

Table 2. Summary of thermocouple failures.

Thermocouple	Time of failure (min)
7	65.3
14	50.0
15	0.00
16	53.4
17	54.8
19	59.2
20	56.4
22	53.7
40	51.0

RESULTS

The temperature data collected during the test are shown in Figure 4, Figure 5, Figure 6, Figure 7. To better illustrate the various stages of the fire and how it propagated from the engine compartment into the passenger compartment, the maximum and minimum temperature at any location in the engine and passenger compartments at each point in time is shown in Figure 8. This figure also provides reference points for subsequent horizontal temperature profiles in the engine compartment and vertical temperature gradient plots in the passenger compartment which will be described in more detail below.

As illustrated in Figure 9, the fire initially spread from the area of origin towards the center of the radiator and then to the air intake tube and air filter. At about 21 minutes, damage to the paint on the hood was observed, as shown in Figure 10. However, this damage was not above the area of origin, but was instead over the air intake tube. At 25 minutes, more smoke was visible, as shown in Figure 11. At this test time, the temperature at the air intake tube was about 700°C and was the highest temperature location within the engine compartment, as shown in Figure 12. In this figure and all subsequent temperature contour plots, the major engine compartment components from Figure 3 were outlined and then superimposed over the contour plot to provide reference points.

From a test time of about 25-30 minutes, a distinct transition occurred as the rate of fire spread and the temperature at all the engine compartment measuring locations increased. A photograph of the vehicle at a time of 28 minutes in Figure 13 illustrates a larger area of paint damage to the hood as more fuel within the engine compartment became involved. At this point in time, burning material dropped down and was burning on the ground. At a test time of 30 minutes, the fire spread to a large portion of the engine compartment and penetrated the aluminum hood, as shown in Figure 14. The associated temperature distribution within the engine compartment at that time is shown in Figure 15. However, the temperature of the interior had not increased substantially above ambient temperature, as shown in Figure 16. In this figure, positive Z is down,

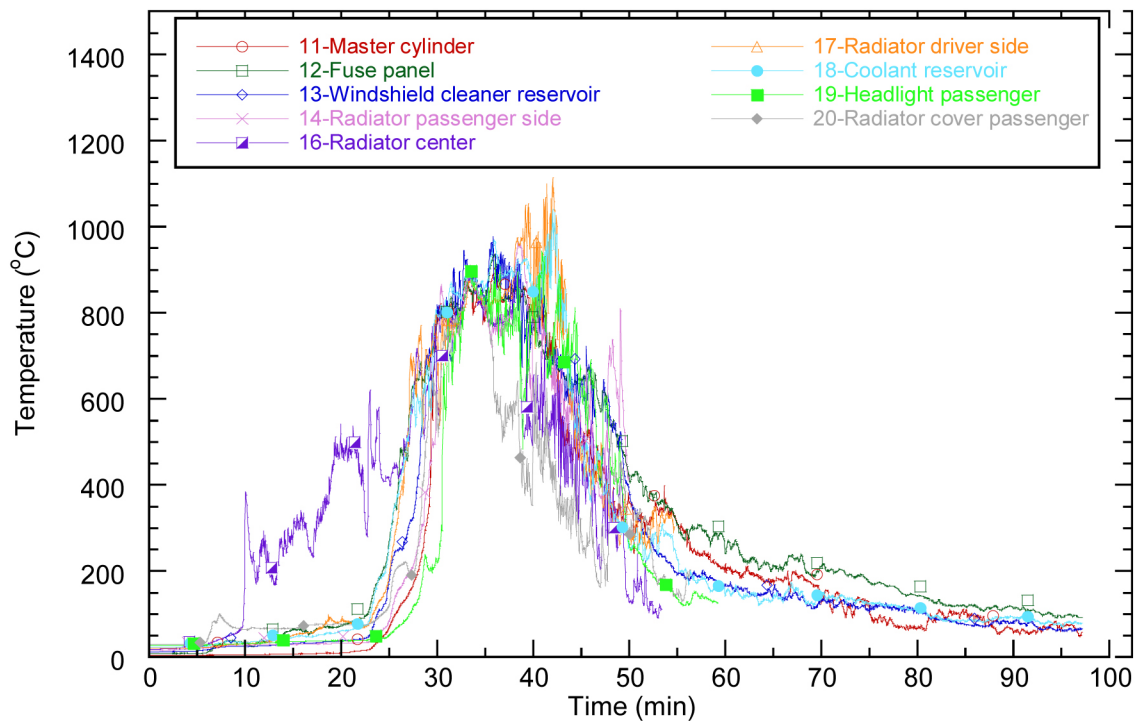


Figure 5. Temperature at measurement locations 11-20.

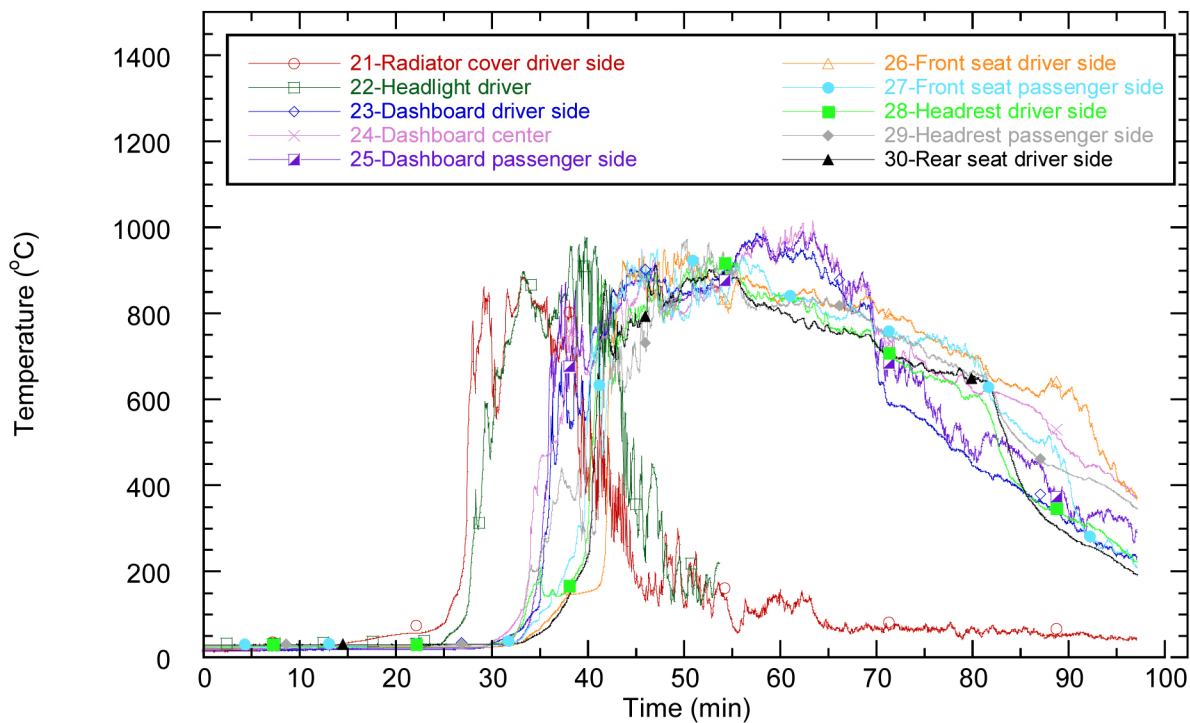


Figure 6. Temperature at measurement locations 21-30.

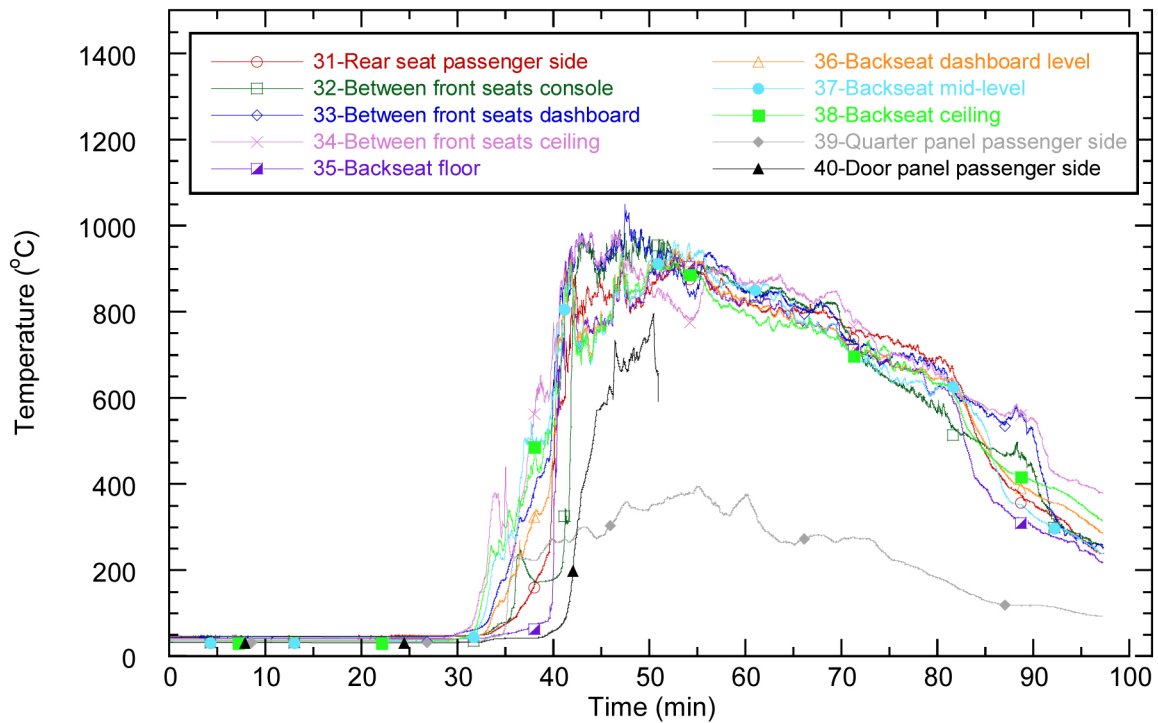


Figure 7. Temperature at measurement locations 31-40.

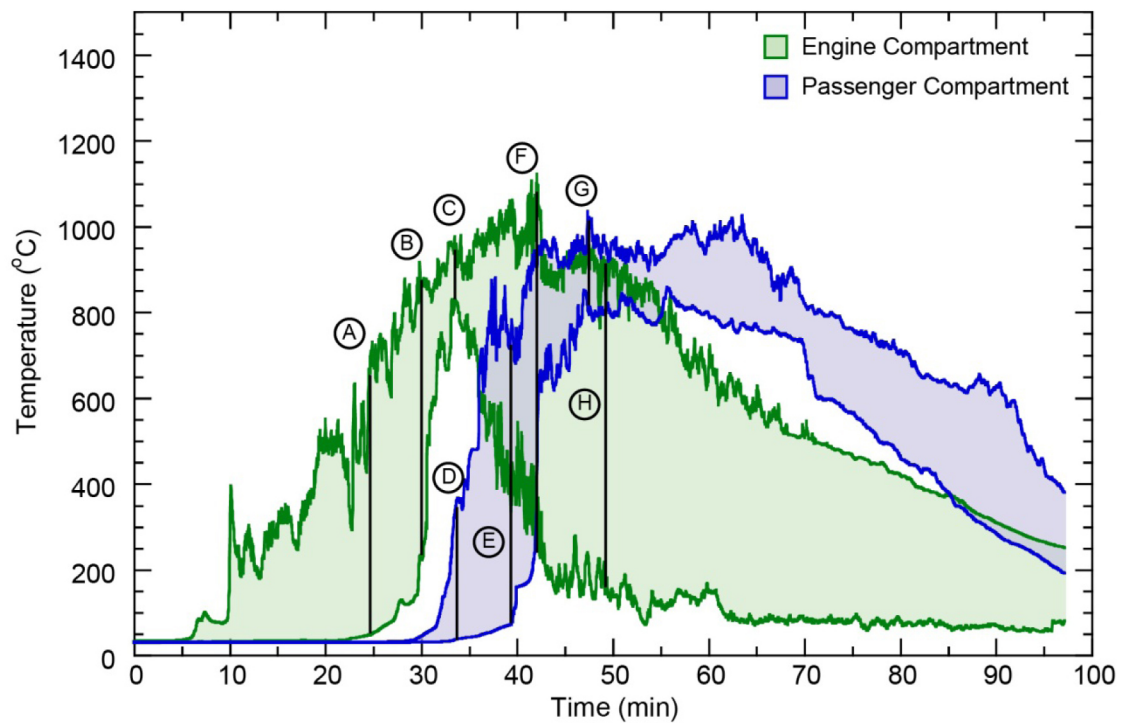


Figure 8. Maximum and minimum temperature in the engine and passenger compartment as a function of time.