

Full-Scale Burn Test of a 1992 Compact Pick-up Truck

Jeff D. Colwell and Michael E. Cundy
Exponent

ABSTRACT

A full-scale burn test of a 1992 compact pick-up truck was conducted to evaluate how temperature distributions changed over time, the manner in which the fire spread, and how burn patterns produced during the fire correlated with important characteristics of the fire such as the area of origin. After the fire was initiated on the lower portion of the dashboard of the test vehicle, it spread locally to nearby dashboard material and, at the same time, developed a strong temperature gradient from the ceiling to the floor. Once the ceiling temperature reached about 600°C, the rate of fire spread increased and, within 1 minute, the passenger compartment was fully involved. Initiation of the engine compartment fire, which occurred about 4 minutes after the passenger compartment was fully involved, was consistent with fire spread through the heating, ventilation, and air conditioning (HVAC) duct that passed through the passenger's side of the bulkhead. Instead of spreading to nearby combustibles on the passenger's side of the engine compartment, the fire spread to the driver's side of the engine compartment, along the bulkhead. This fire movement was likely associated with the wind from the passenger's side towards the driver's side of the vehicle. The fire then spread upwind to the passenger's side of the engine compartment, where the peak temperature occurred in an area of relatively high fuel load. The burn damage to combustible material that remained after the fire was extinguished was consistent with the area of origin being within the passenger compartment. However, melt damage to aluminum components and oxidation patterns on steel surfaces did not correlate with the area of origin.

CITATION: Colwell, J. and Cundy, M., "Full-Scale Burn Test of a 1992 Compact Pick-up Truck," *SAE Int. J. Trans. Safety* 1(2):2013, doi:10.4271/2013-01-0209.

INTRODUCTION

Although examination of physical evidence that remains after a vehicle fire can be an important part of an investigation, there are currently few studies in the literature that correlate post-fire physical evidence to known characteristics of a full-scale vehicle burn test. In the present study, using an approach similar to that used by Colwell [1], we present the results of a full-scale burn test of a compact 1992 pick-up truck and compare the post-fire physical evidence to important features of the fire. 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. Burn damage to combustible material that survived the fire is then described and related to the area of origin. Other patterns that were created during the fire, namely melt damage to aluminum components and oxidation patterns on steel

surfaces, are illustrated and discussed. A summary of the key results from the test is then presented.

EXPERIMENTAL SET-UP

The test vehicle for this study was a fully functional 1992 Ford Ranger. All fluids were 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. Of these thermocouples, 21 were located within the engine compartment, 17 were in the passenger compartment, and 2 were located on exterior body panels. An overview of the thermocouple locations is shown in [Figure 1](#), [Figure 2](#), [Figure 3](#), while [Table 1](#) describes each thermocouple location. [Figure 4](#) shows the engine compartment layout and associated variation in fuel load. The measurement junction of each thermocouple was created with a thermocouple welder that produced a nominal bead diameter of 1 mm. The engine

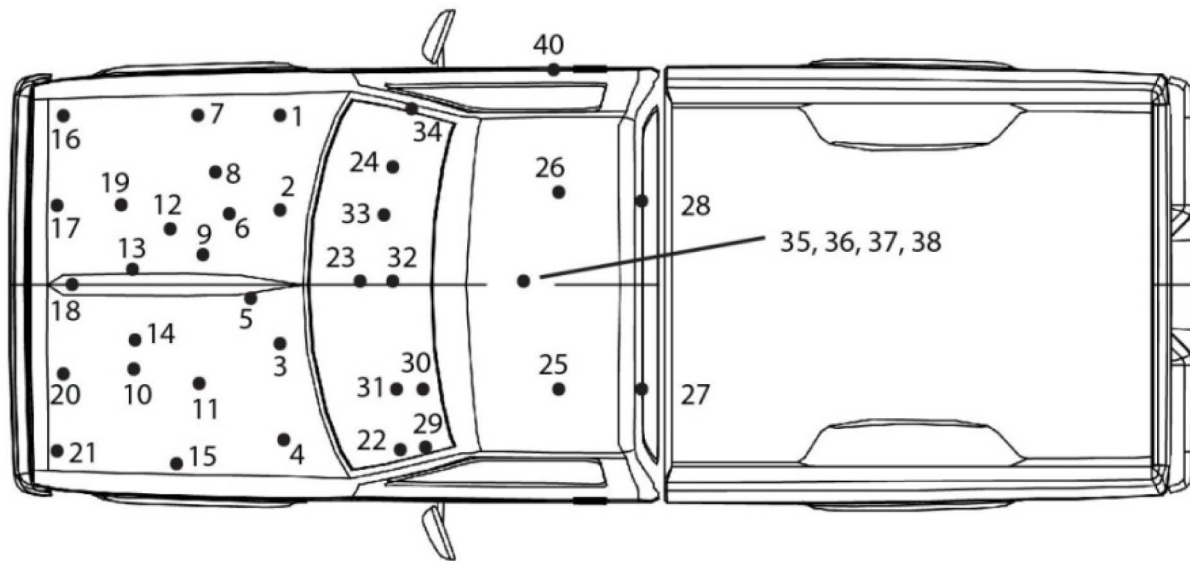


Figure 1. Top view schematic of thermocouple locations.

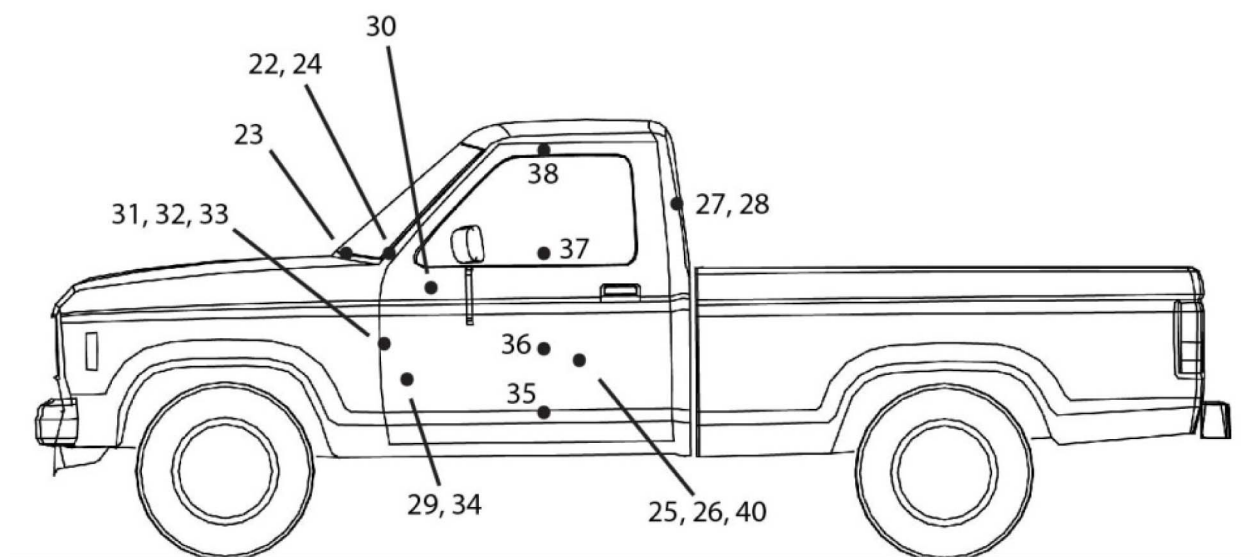


Figure 2. Side view schematic of thermocouple locations.

compartment thermocouples were held in place with steel wires, with the bead not in contact with any objects. All the engine compartment thermocouples were within 13 cm (5 in) of the hood surface with the exception of the air conditioning (AC) drier, power steering reservoir and alternator, channels 6, 10 and 12, respectively, which were between 20-25 cm (8-10 in) below the hood. The passenger compartment thermocouples were located on top of the dashboard, seats, headrests and under and within the dashboard. Additionally, four thermocouples were mounted on a thermocouple tree located between the front seats. With the exception of the thermocouple tree and thermocouple 29, these thermocouples rested on top of, or were secured to, combustible material. As a result, these locations could experience movement during

the fire, particularly once this combustible material was consumed. 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 m from the test vehicle. As shown in Figure 5, the wind speed generally ranged from 2 to 7 m/s (5-15 mph) over the duration of the test. The wind was generally blowing from the passenger's side towards the driver's side as the vehicle was facing 120 degrees (southeast)

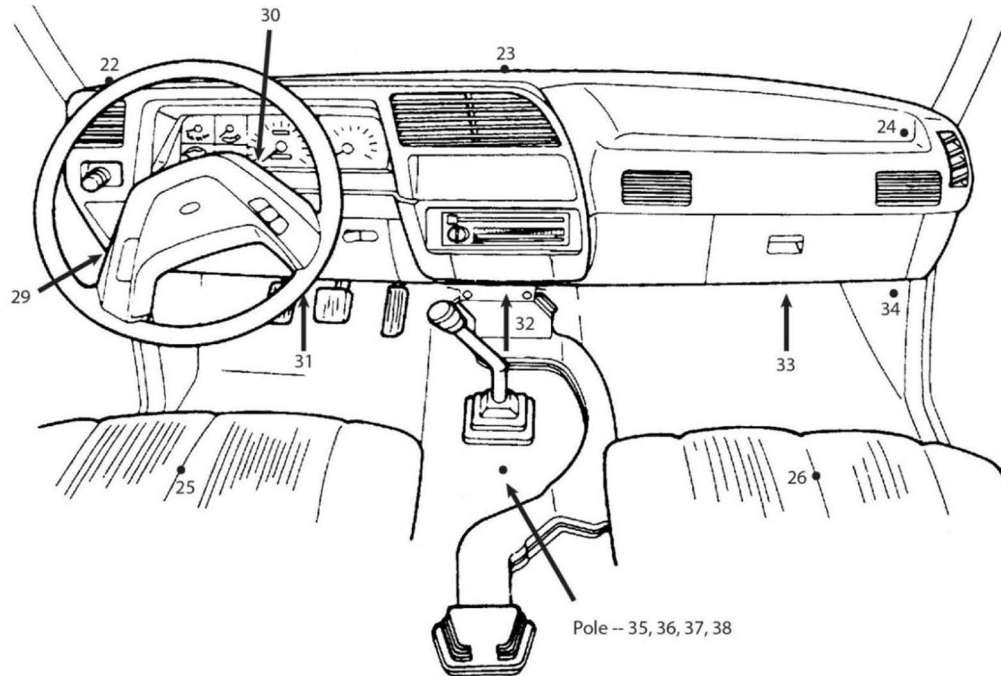


Figure 3. Passenger compartment schematic of selected thermocouple locations.

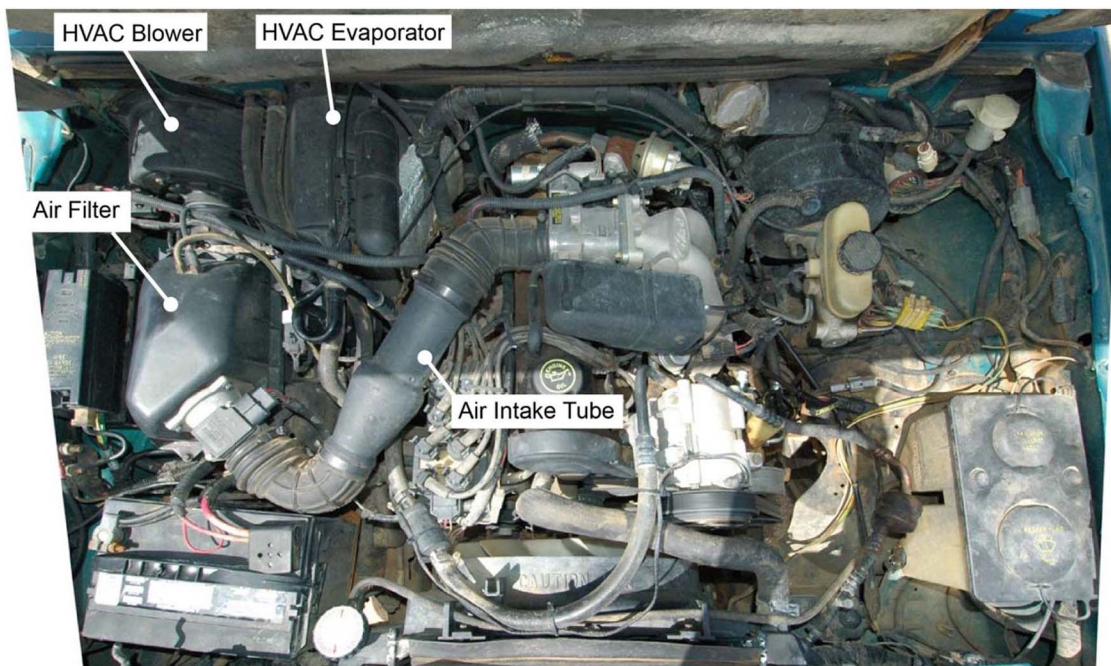


Figure 4. Overview of engine compartment layout and fuel load variation.

during the test, with the wind direction generally coming from about 225 degrees (southwest).

The fire was initiated using a small butane torch near the lower part of the dashboard on the driver's side near thermocouple 29, 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

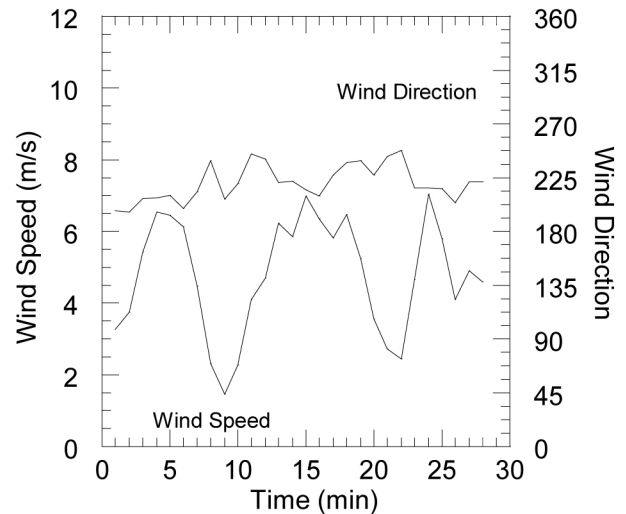
to this location until a test time of 2.5 minutes, and then the driver's side door was closed. The passenger side window was rolled down about 10 cm (4 in) and the rear sliding window was also open about 10 cm (4 in). The fire was extinguished at a test time of 26.7 minutes.

Table 1. Thermocouple locations.

Thermocouple	Description
1	Bulkhead – HVAC blower
2	Bulkhead – HVAC evaporator
3	Windshield wiper motor
4	Bulkhead – vacuum booster
5	Throttle body
6	AC drier
7	Power distribution box
8	Air filter
9	Air intake tube
10	Power steering reservoir
11	Master cylinder
12	Alternator
13	Ignition system
14	AC compressor
15	Coolant reservoir
16	Battery
17	Radiator – passenger side
18	Radiator – center
19	Air intake
20	Radiator – driver side
21	Washer fluid reservoir
22	Dashboard – driver side
23	Dashboard – center
24	Dashboard – passenger side
25	Driver seat
26	Passenger seat
27	Headrest – driver side
28	Headrest – passenger side
29	Dash panel above parking brake
30	Steering column
31	Under dashboard - steering column
32	Under dashboard – center
33	Under dashboard - HVAC duct
34	Under dashboard – passenger side
35	Center of cab – floor
36	Center of cab – seat-level
37	Center of cab – dashboard-level
38	Center of cab – ceiling
39	Quarter panel – passenger side
40	Door panel – passenger side

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 [2] 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.

**Figure 5. Wind speed and direction during the test.**

RESULTS

One of the important features of the temperature data, shown in Figure 6, Figure 7, Figure 8, Figure 9, was that the fire progressed in distinct phases, as shown in the temperature envelopes in Figure 10. These envelopes were constructed using the maximum and minimum temperature at all measurement locations in the engine compartment and the maximum and minimum thermocouple tree data in between the seats in the passenger compartment. The floor location of the thermocouple tree is excluded from this comparison as it was located less than 1 cm above the floor at the onset of the test and may have moved downward and come into contact with the floor pan, or it may have been covered in debris at some point during the test. To more clearly illustrate the features of these phases of the fire and how the fire developed, the temperature data is examined in more detail below at select times, which are denoted by A through I in Figure 10.

Once the fire was initiated on the lower part of the driver's side dashboard, the temperature measured by the nearby thermocouple increased to over 800°C, as shown in Figure 11. At about 4.5 minutes, flames could be seen through the windshield on the driver's side and the temperature measured on the steering column and the driver's side dashboard also began to increase. At the same time, the temperature measured at the ceiling level of the thermocouple tree between the front seats began to increase. At 6.6 minutes, the heat produced from the localized burning of the driver's side dashboard cracked the upper portion of the windshield, as shown in Figure 12.

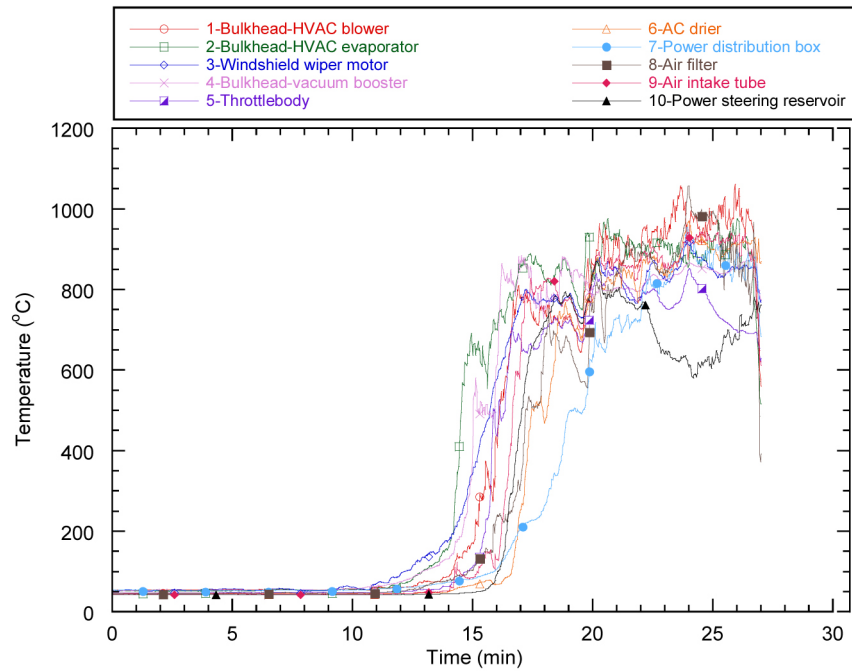


Figure 6. Temperature at measurement locations 1-10.

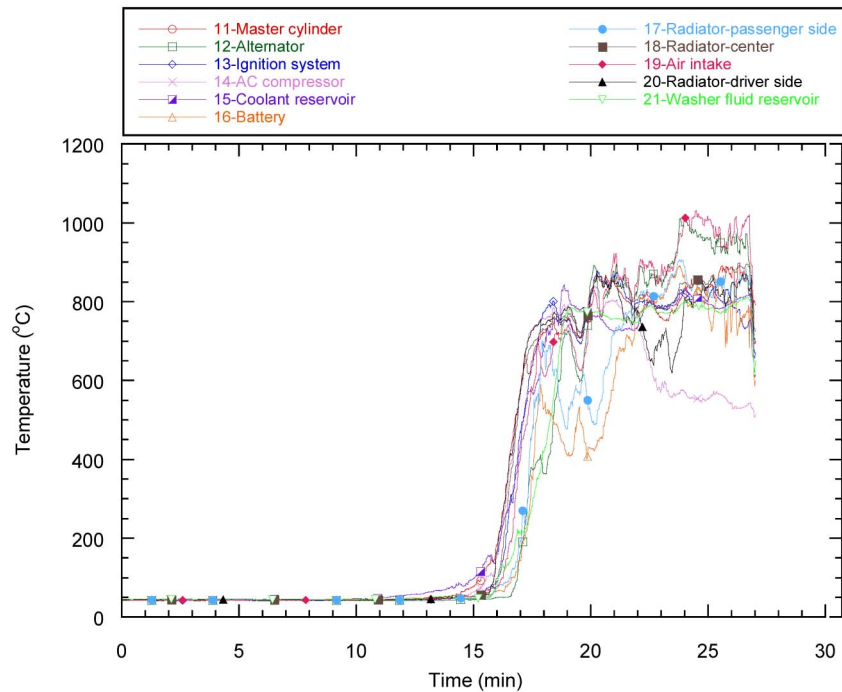


Figure 7. Temperature at measurement at locations 11-21.

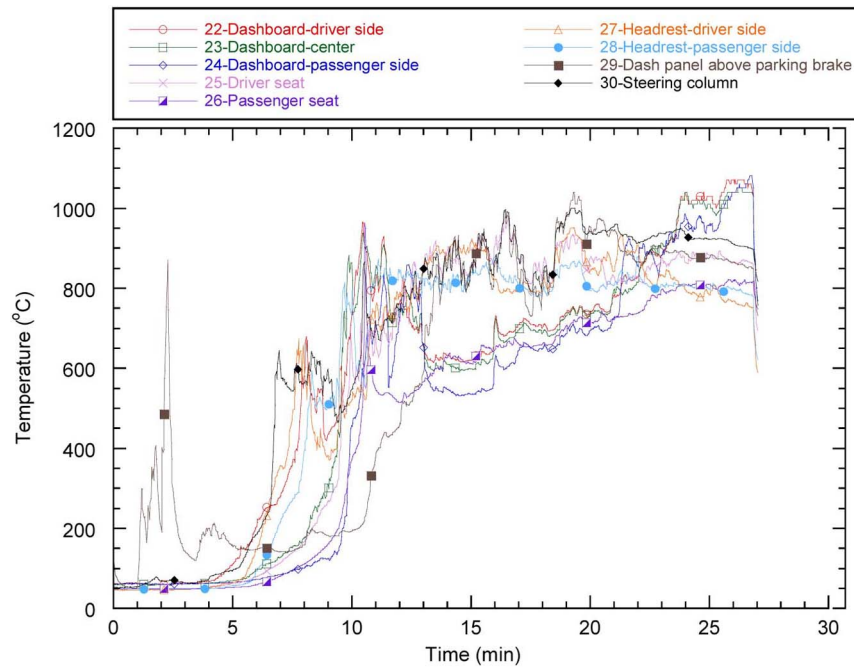


Figure 8. Temperature at measurement locations 22-30.

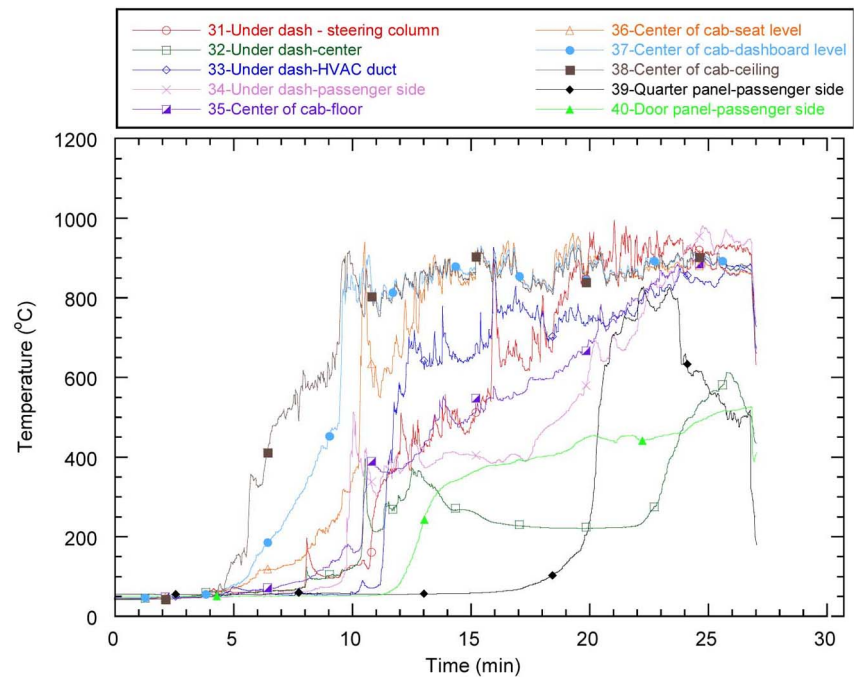


Figure 9. Temperature at measurement locations 31-40.