Test Results

Specific burn tests were conducted on three sites between February and July 1996:

- Lake City, FL (February 1996)—in cured bunchgrass, and matted grass and thatch (NFFL Model 3):

- Valencia, CA (June 1996)—in 2- to 3-foot (0.6- to 0.9-m) tall chamise with a cured grass understory (NFFL Model 4):

- Beaverhead National Forest, MT (July 1996)—in lodgepole pine slash (NFFL Model 12).

Figure 13—The Florida burn was not intense enough and did not burn for long enough to seriously test survivability inside either the shelters or the vehicles.

Florida Burn

At Lake City, FL, two surplus vehicles were selected for testing: the first was a standard wildland engine; the second was a standard pickup truck used for carrying a crew, with a slip-on pump and tank unit in the back.

The first burn was conducted on February 27, 1996, on an open, grass-covered field that had dry, cured bunchgrasses 30 to 36 inches (76 to 91 cm) tall, with a 2- to 4-inch (5 to 10 cm) mat of cured grass and thatch on the ground. The burn was in late afternoon with a 3- to 5-mile per hour wind. It was over in less than 1 minute, and had neither the intensity nor the duration to seriously test the survivability of the shelters or the engines (Figure 13).

Despite the brief duration and low intensity of this burn, some meaningful data were gathered:

- The peak air temperature was 650 °C in front of the engine and 950 °C in front of the pickup truck, as measured by the thermocouple trees.

- In the grass fuel type, air temperatures decreased as the height above ground level (AGL) increased.

- Air temperatures inside the engine cabs cooled more slowly than air temperatures outside after the burnover.

- Maximum heat flux was 70 kW/m^2, decreasing with the height above ground level.

- Fire shelters subject to the burnover showed no visible signs of damage, although the stainless steel prototype shelter had some discoloration.

- Air temperatures inside the shelters were 20 to 40 °C lower at 1 inch (3 cm) AGL than at the thermocouple 12 inches (30 cm) AGL.

- Temperatures less than 3 feet (0.9 m) above the ground surface were 1000 °C, with a heat flux of 8 kW/m^2.

- Personal protective equipment laid out in the fuels suffered varying degrees of damage: the Military Nomex flight suit was badly damaged, as was the FR cotton brush coat. The standard FS Nomex shirt and trousers showed signs of the heat, but were not destroyed. They would have offered some protection from serious burns (Figure 14).

A second burn was planned in a heavier palmetto-galberry fuel type (NFFL Model 7). Heavy rains prevented us from conducting the burn as planned.

In summary, this burn served as a good "shakedown" for the procedures and techniques used in future tests, but it was not long enough or hot enough to develop meaningful data about the differences between the protection offered by a fire shelter and an engine cab.

Figure 14—The change in color of the pants shows the effect of heat. Water bags inside the fire shirt and upper pants served as a heat sink, keeping them from becoming as hot as the pant legs.

Los Angeles County Burns

At Valencia in Los Angeles County, CA, two vehicles were available for the burnover tests: the first was a "Crown" structural fire engine, the other was a pickup patrol truck that had previously been equipped with a slip-on pumper unit. The Crown engine had hose in the hose bed, and a ladder hung on the side as it would normally be configured.

Two burns took place on June 5 and 6, 1996, in dry, cured grasses 12 to 24 inches (30 to 61 cm) tall, with a 2- to 3-foot (0.6- to 0.9-m) chamise brush overstory (NFFL Model 5). Air temperatures were approximately 32 ˚C, with wind speeds of 5 to 10 miles per hour (8 to 16 km per hour) during the burns. Flame lengths averaged 12 to 20 feet (4 to 6 m), with short periods (less than 30 seconds) where lengths were 20 to 30 feet (6 to 9 m).

The June 5th burn took place on slopes averaging 70%. The engines, fire shelters, and PPE were on a road near the top of the slope (Figure 3, page 3). Flames came in direct contact with the engines and shelters, since they were positioned at the road's edge to receive the maximum effect of the flaming front (Figure 15).

This burn occurred in heavier fuels and on a day with higher air temperatures than the Florida burn. It produced a significant amount of meaningful data:

❖ Air temperatures measured in the free air outside the engines peaked at 1000 ˚C between 48 and 60 inches (122 and 152 cm) AGL.

❖ Radiometers measuring heat flux at the 3-, 6-, and 9-foot (0.9-, 2-, and 3-m) levels recorded a maximum heat flux of 70kW/m^2 for periods less than 10 seconds, and long term fluxes of 15 kW/m^2; the levels decreased as the height above the ground increased from 3 to 9 feet (0.9 to 3 m).

❖ Temperatures measured inside the engine cabs ranged from 60 to 85 ˚C.

❖ Outside skin temperatures on the standard fire shelter were 430 ˚C at the Crown engine and 180 ˚C at the patrol engine. Inside the shelter adjacent to the Crown engine, temperatures ranged from 150˚C at 1 inch (3 cm) AGL to 220 ˚C at 12 inches (30 cm) AGL.

❖ Items of personal protective clothing laid out beside the engines and shelters showed serious degradation from the intense heat during the burnover. A difference of less than a foot (30 cm) from the fire made a significant difference in damage to the clothing (Figure 16).

❖ On the stainless steel shelter, outside skin temperatures reached 520 ˚C, with the inside skin temperatures reaching 220 ˚C. Inside temperatures were 160 ˚C at 1 inch (3 cm) AGL and 250 ˚C at 12 inches (30 cm) AGL.

❖ The personal protective equipment laid on the ground showed varying degrees of damage from the combination of direct flame contact and radiant heat.

❖ Neither fire shelter showed any visible sign of heat damage.

❖ The Crown engine showed these signs of damage:

–Windows cracked in the cab.

–The 4-inch (10-cm) cotton-jacketed, rubber-lined hose in the exposed bed on the back of the engine melted in some places and began dripping.

–The mud flap on the rear tire caught fire (Figure 17).

–The exterior ladder hanging outside the engine was badly scorched.

Figure 15—This image (taken from video) shows the intensity of the June 5 burn in Los Angeles County.

Figure 16—These items of personal protective clothing show the effects of the June 5 burn in Los Angeles County. Note the difference made by being just a few feet from the edge of the roadway.

Figure 17—Mudflaps are just one of the flammable items on the engine's exterior.

–The brake line at the rear of the engine burned through, rendering the engine immovable because the air brakes locked.

✦ Windows were cracked on the patrol engine and the paint was scorched. The cab filled with heavy smoke, even though nothing burned inside the cab. Video footage filmed inside the cab showed heavy smoke within 1 minute after fire reached the engine.

✦ The heat lasted longer inside the engine cabs than it did inside the fire shelters.

The table at right shows the levels of six gases in a vehicle and in a fire shelter.

The second burn in Los Angeles County was on June 6th, the next day. Weather conditions were nearly identical, but the slope, aspect, and fuel loading were different. The engines were positioned at the head of a small draw with 35 to 45% slopes (Figure 18). Some chamise brush was cut and piled next to the engines and shelters to increase the fire's intensity and duration. Because of the topographic effect of some adjacent spur ridges, the flames were diverted from the engines and shelters.

Although the engines and shelters had less direct flame contact than expected, important data were obtained from the effects of the radiant heat load:

✦ Air temperatures outside the Crown engine reached a maximum of 700 ˚C at 60 inches (152 cm) AGL, and a maximum of 75 ˚C inside the cab (40 ˚C on the floor inside the cab).

GASES (parts per million)	Engine	Shelter
SO_2	18.7	4.4
HCN	0.0	0.0
Benzene	1.5	0.8
HCl	7.8	1.0
Toluene	13.6	6.3
CO	29.3	5.5

✦ The patrol engine (Figure 19) had outside air temperatures of 440 ˚C, with inside air temperatures of 280 ˚C at the roof. The inside door panel on the driver's side caught fire, leading to the high temperatures inside the cab of the patrol engine (Figures 20 and 21). Floor temperatures were 45 ˚C.

✦ The maximum outside skin temperature of the standard fire shelter adjacent to the Crown engine was 300 ˚C, with inside skin temperatures of 180 ˚C. Air temperatures stayed below 80 ˚C at both the 1- and 12-inch (3- and 30-cm) levels inside the fire shelter.

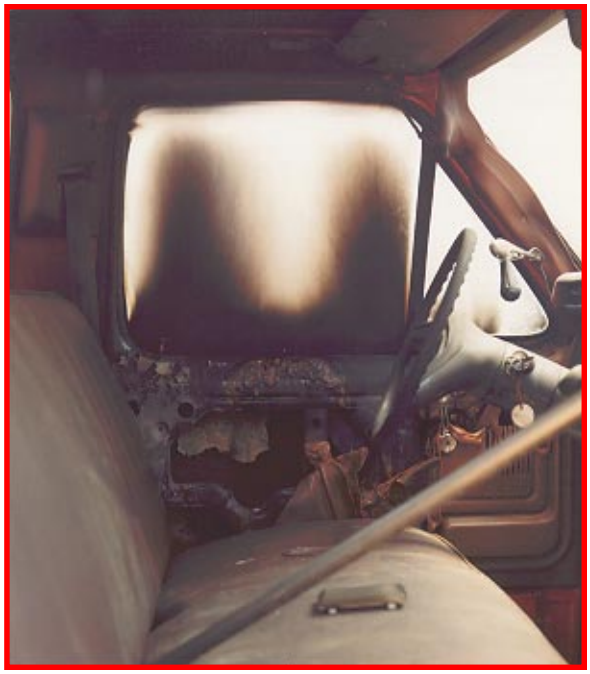
✦ The stainless steel shelter adjacent to the patrol engine had a maximum outside surface temperature of 360 ˚C, while the inside surface reached a maximum of 120 ˚C. The air temperature inside the shelter reached a maximum of 180 ˚C.

✦ Video footage showed that the cab of the patrol engine filled with dark smoke in less than 60 seconds. The driver's side door panel caught fire from radiant heat on the outside of the door;

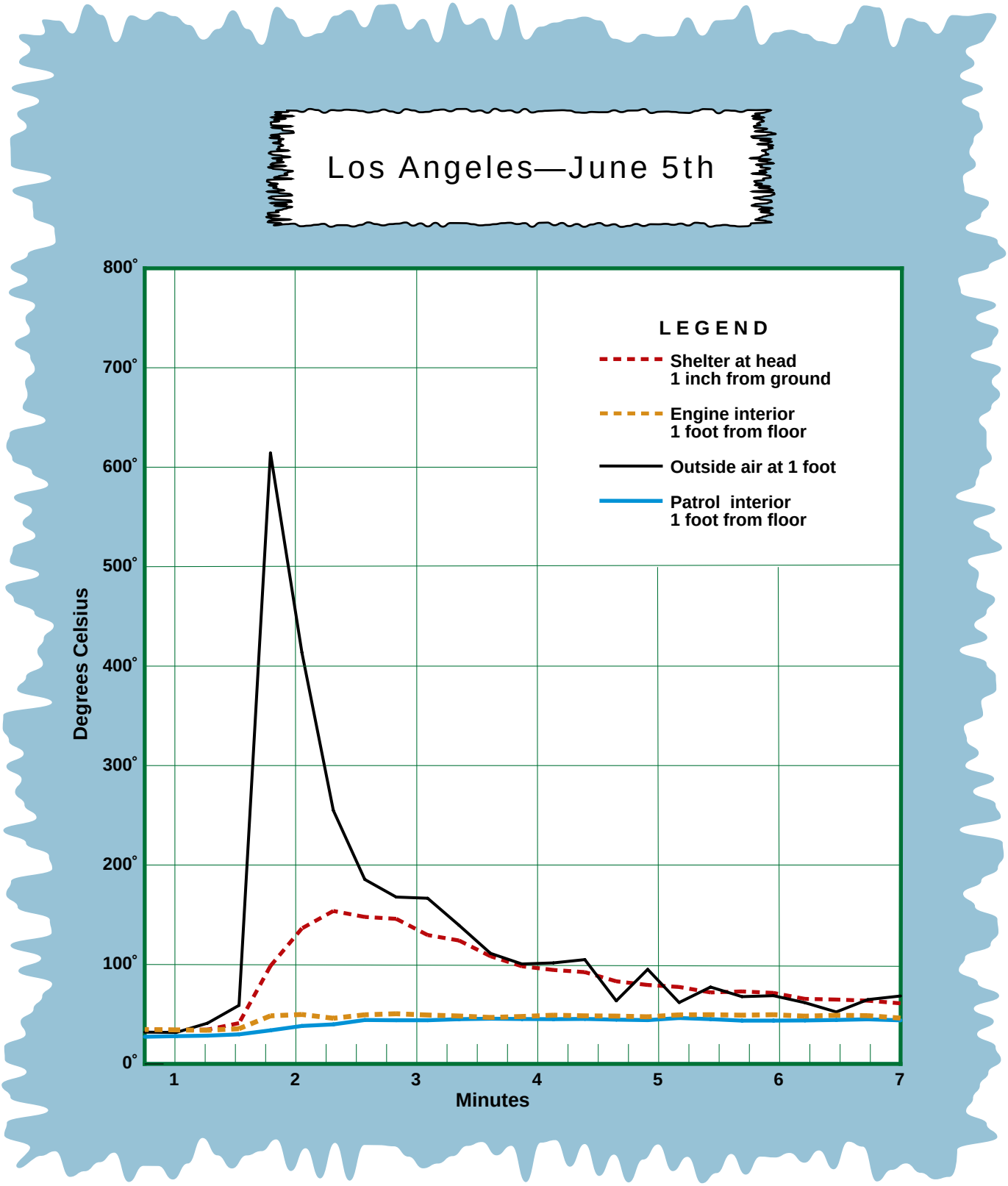
✦ PPE and additional fire shelters—both the standard Forest Service version and the stainless steel prototype—were placed at the head of the small draw away from the engines and other shelters. We intended to subject these items to direct flame contact and the maximum radiant heat load. The effect of the terrain prevented direct flame contact. Temperatures inside the stainless steel shelter reached a maximum of 135 ˚C, while temperatures inside the standard shelter reached just 70 ˚C. The PPE laid out in the open, including FR cotton coveralls from the Northwest Territories of Canada and standard FS Nomex, reached maximum temperatures of 120 ˚C. The clothing showed no visible signs of damage.

Figure 18—The engine, patrol engine, and fire shelters positioned for the second burn in Los Angeles County, June 6th.

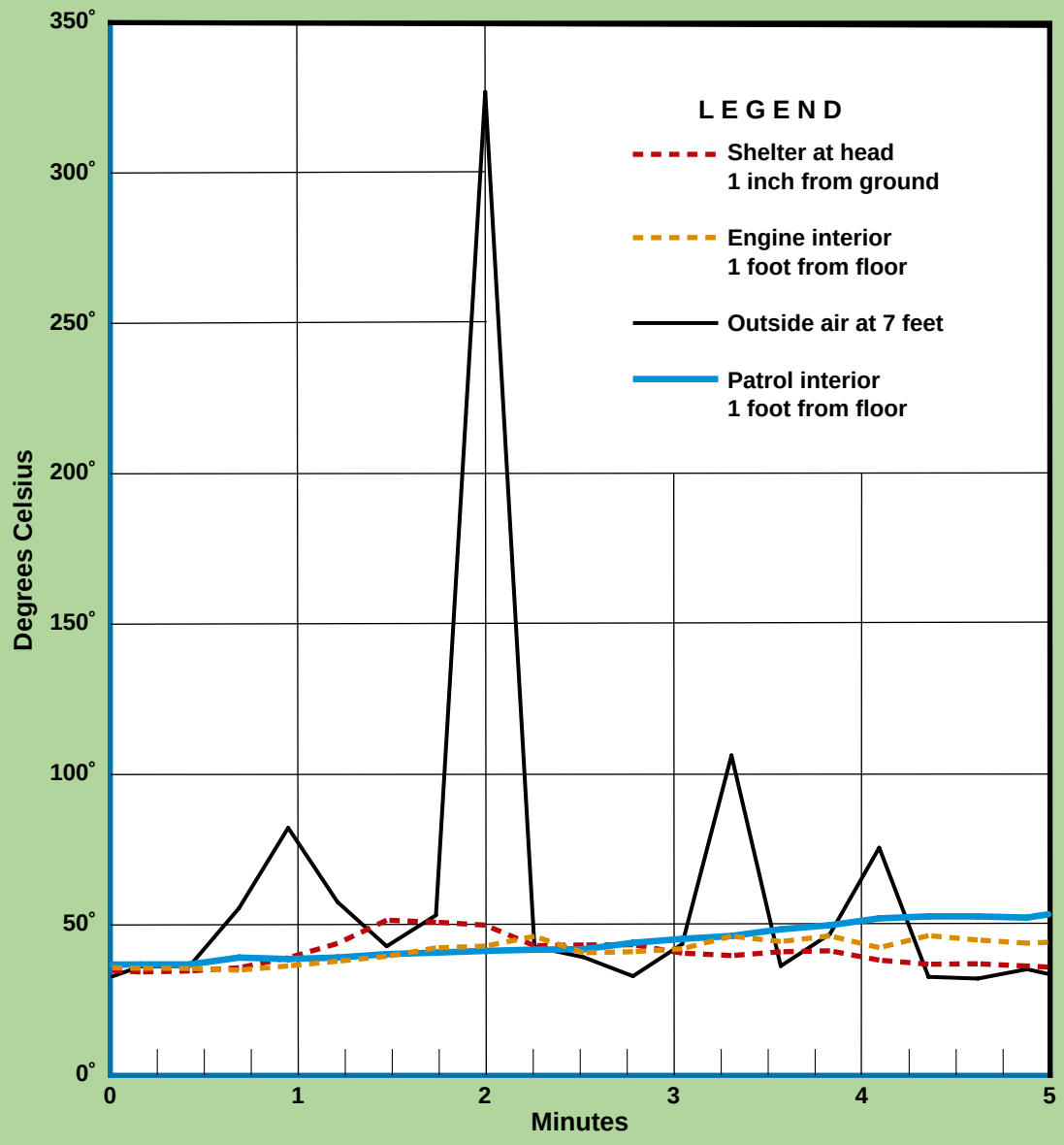
Figure 19—The patrol engine caught fire during the June 6 burn in Los Angeles County.



Figures 20 and 21—Firefighters put out the fire in the cab of the patrol pickup. Material on the inside door panel burned, emitting smoke that would have forced entrapped firefighters to leave the truck.


Los Angeles—June 5th
LEGEND
Shelter at head
1 inch from ground
Engine interior
1 foot from floor
Outside air at 1 foot
Patrol interior
1 foot from floor
Degrees Celsius
800°
700°
600°
500°
400°
300°
200°
100°
0°
1
2
3
4
5
6
7
Minutes

Los Angeles—June 6th



Montana Burn

The Montana Department of Natural Resources and Conservation supplied two engines for the test in southwestern Montana. One was a surplus military 2½-ton truck that had been converted to an engine. It was similar to the engine that was burned over on the Point Fire near Kuna, ID, in 1995, killing two firefighters inside. The other was a crew carrier pickup that had been fitted with a slip-on fire tank and pump.

The test burn was conducted in late July in an area of thinned lodgepole pine slash that had been piled about 5 feet (2 m) high, 8 feet (2 m) wide, and 200 feet (61 m) long. Air temperatures that day were in the mid-70's (about 21 ˚C), with humidities in the low 20's. The engines, fire shelters, and PPE were laid out beside the edge of the slash piles to obtain maximum heat load.

An unforecast wind shift just before ignition prevented direct flame contact on the vehicles and shelters being tested (Figure 22). However, satisfactory results were obtained:

- Maximum air temperature outside the 2½-ton engine was 400 ˚C, while temperatures inside the cab exceeded 700 ˚C. The inside of the engine cab caught fire (Figure 23) and burned, resulting in the higher temperatures.

- The crew cab truck outside air temperatures were less than 200 ˚C. Air temperatures inside the cab exceeded 250 ˚C because the interior caught fire.

- Surface temperatures on the fire shelter at the rear of the 2½-ton engine reached 150 ˚C, although they generally

Figure 22—Wind prevented flames from directly contacting vehicles during the test burn near Dillon, MT.

Figure 23—Even though flames did not directly contact the 2½-ton truck, its cab caught fire.

remained in the range of 100 to 150 ˚C. Inside surface temperatures remained below 100 ˚C, except for a momentary spike to 140 ˚C.

❖ Air temperatures inside the fire shelter at the rear of the 2½-ton engine were only 40 ˚C at 1 inch (3 cm) AGL and 75 ˚C at 12 inches (30 cm) AGL. The shelter had no visible damage.

❖ The stainless steel prototype shelter in front of the crew cab engine had outside surface temperatures of 250 ˚C, and inside surface temperatures of 220 ˚C. The free air temperature inside the stainless steel shelter at 12 inches (30 cm) AGL was 105 ˚C; the thermocouple at 1 inch (3 cm) AGL was faulty and did not record.

❖ The radiometer at the front of the crew cab engine measured a radiant heat flux of 170 kW/m^2, with a prolonged level (longer than 6 minutes) of 130 kW/m^2; the heat flux decreased with the height above the ground.

❖ The radiometer at the front of the 2½-ton engine measured a peak radiant heat flux of 150 kW/m^2 at 9 feet (3 m) AGL.

❖ The cabs of both engines filled with thick smoke. Within a few minutes after the burn was ignited, the interior of both cabs caught fire from the radiant heat.

❖ Protective clothing and equipment was instrumented with thermocouples and laid between the fire shelters and the engines. The items selected (trousers, shirts, flight suits, and coveralls) were placed over a 5-gallon water bag that had been covered with a 100% cotton T-shirt (see *Test Procedures and Methods*).

–Nomex trousers recorded an outside surface temperature of 160 ˚C and an inside temperature of 20 ˚C, with no visible damage to the trousers.

–A Nomex fire shirt recorded an outside temperature of 100 ˚C, and an inside temperature of 70 ˚C, with no visible damage.

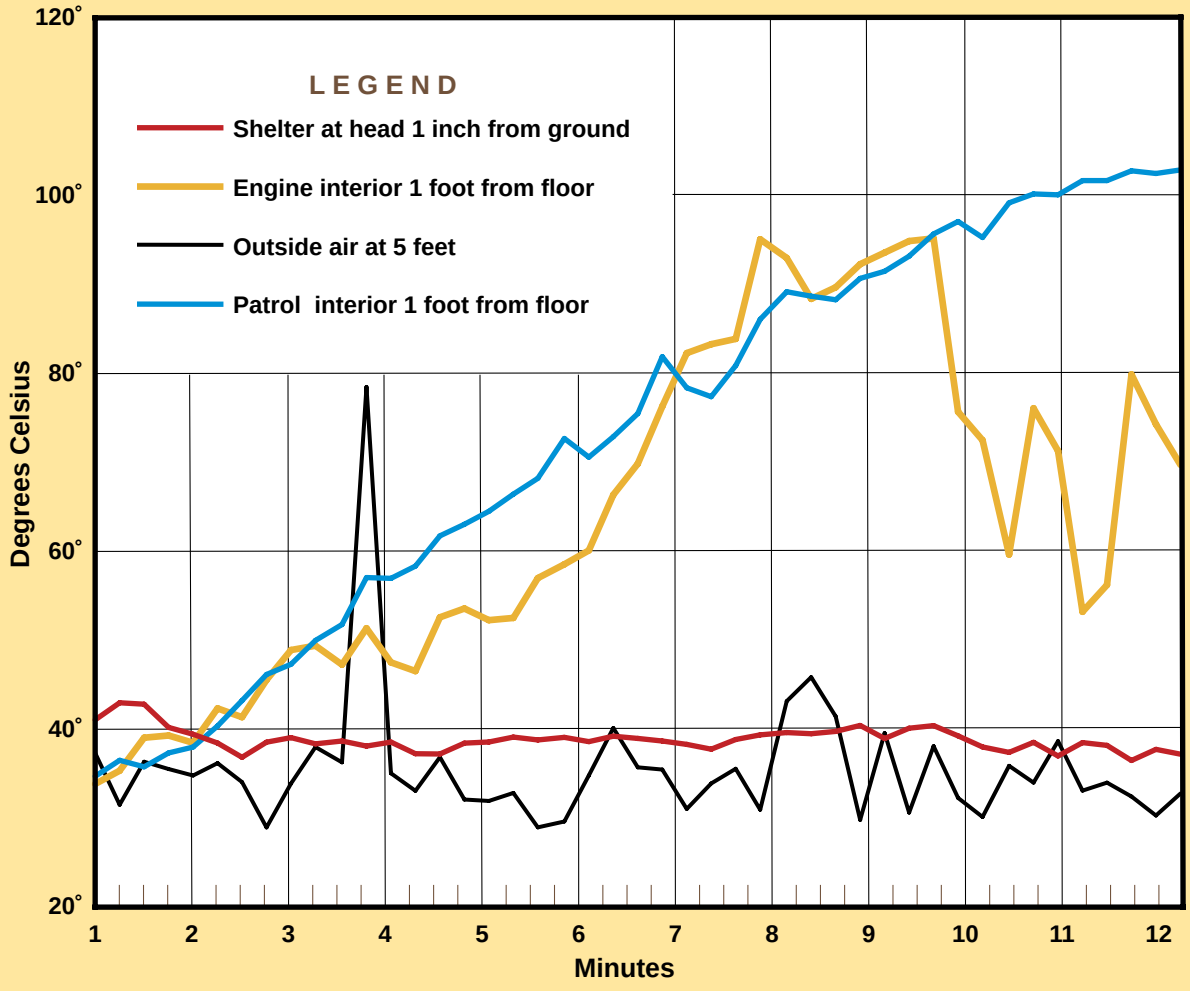
–Although the Nomex had some heat discoloration, it retained its structure and did not break apart or catch fire.

–FR cotton coveralls from the Northwest Territories were not instrumented, but they were laid out immediately adjacent to the Nomex shirt. They were partially consumed by fire ignited by radiant heat.

–A GSA firefighter's hardhat (Model 5100-P) was placed on the ground beside the fire shelter in front of the crew cab engine. It showed significant melting for about 5 inches (13 cm) from its edge, but the rest of the helmet showed no melting or damage (Figure 24).

Figure 24—This hardhat shows the difference a few inches can make at ground level. The hardhat melted where it was closest to the fire, but wasn't damaged just a few inches away from the heat.

Beaverhead



End Part 2