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Surviving Fire Entrapments

Comparing Conditions Inside Vehicles and Fire Shelters

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7E62P87–Vehicle Entrapment

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Introduction

Since early in the days of wildland fire suppression, mechanized equipment has played an increasingly important role. Engines have become especially popular, providing transportation, water (and now foam), and a wide range of equipment for ground firefighters. This dependence on motorized equipment is not unique to the United States. Australia, Spain, Portugal, and France are just a few of the countries where engines are an important part of the fire suppression arsenal.

As engines are more widely used, the risk that fire will burn over the engine increases. Protective clothing and equipment (such as the fire shelter) are well accepted in the fire community. A wide range of opinion has been expressed concerning the protection an engine might afford during a burnover.

In recent years firefighters have been entrapped in their engines during a number of incidents. They have been forced to make instantaneous decisions about their best chances for survival: in an engine, or in a fire shelter.

✥ In 1958 on the Wandilo Fire in Australia, 11 firefighters were trapped in a fast-moving bushfire: three survived and eight died. Of the three survivors, one laid in the wheel rut on the sandy road, and the other two stayed in the engine cab until it caught fire.

✥ In October 1985, three Santa Barbara County firefighters abandoned their engine when the plastic lights and gauges melted and the front and side windows cracked from the heat. They went into fire shelters and survived uninjured.

✥ In 1987 on the Crank Fire in northern California, firefighters took shelter in their engines until the intense heat began melting components inside the cab. They left the engines and used their fire shelters as protective capes when they fled the burn area.

✥ In 1990 on the Wenatchee Heights Fire in central Washington the local fire chief attempted to ride out a burnover in the cab of an engine. When the heat became so intense that it blew out the engine's front windshield, he was forced to leave the engine and run through open flames, suffering third-degree burns over much of his body.

✥ In 1993 during a Santa Ana-condition firestorm in southern California, firefighters attempting to take shelter in their engines were burned because they were unable to get inside the engine quickly enough.

✥ In 1995, a fast-moving grass/sagebrush fire near Boise, ID, trapped two rural volunteer firefighters in the cab of their engine. Neither firefighter had a fire shelter, and both died in the engine.

✥ In 1995, many engines were destroyed by a fast-moving timber fire on Long Island, NY. All firefighters abandoned their engines and survived (Figures 1 and 2).

Figure 1—This engine burned during the 1995 fires on Long Island. Although many engines were destroyed, all firefighters escaped without injuries.

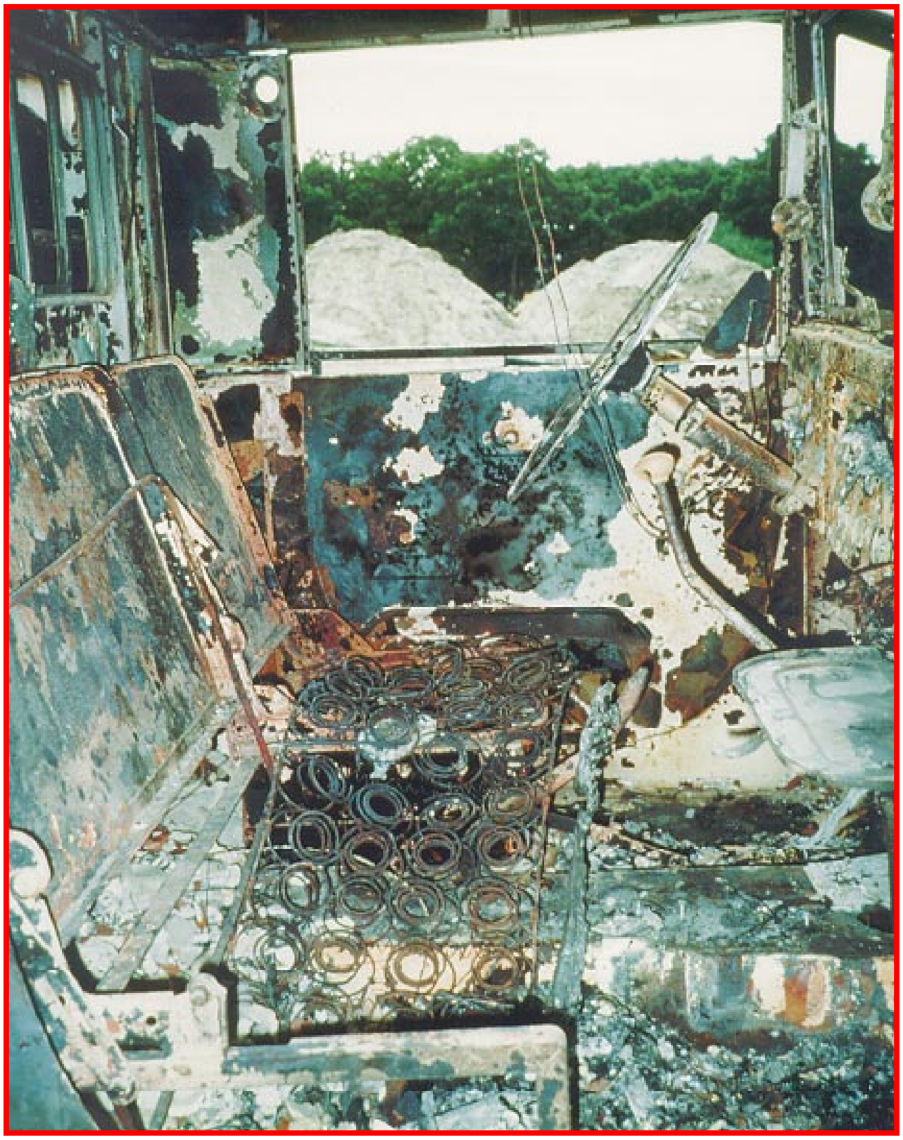

Figure 2—The cab interior of the same engine burned during the 1995 fires on Long Island.

❖ In 1996 on the Calabasas Fire in southern California, firefighters seeking shelter in their engines were at risk when the flame front curled around the vehicle, reaching firefighters who were seeking shelter behind the engine.

In October 1995, the Missoula Technology and Development Center in Missoula, MT, began a 1-year study to compare conditions inside a fire shelter and inside an engine under identical fire conditions; cooperators in this study included the Florida Division of Forestry, Los Angeles County Fire Department, Montana Department of Natural Resources and Conservation, and the Intermountain Fire Sciences Laboratory.

Objectives

The study was designed to quantify the conditions that existed inside the cab of an engine and inside a fire shelter—at the same time—during a wildfire burnover (Figure 3).

The specific factors to be measured included:

✥ Air temperature in the immediate vicinity of the engines and shelters, at levels from 6 to 108 inches (15 to 274 cm) above ground level

✥ Radiant heat flux levels in the immediate vicinity of the engines and in fire shelters, 3, 6, and 9 feet (0.9, 2, and 3 m) above the ground

✥ Air temperatures within the cabs of the engines, measured every 6 inches (15 cm) from the floor to the ceiling

✥ Surface temperatures on the outside and inside surfaces of the standard fire shelters and prototype stainless steel fire shelters (Figure 4)

✥ Air temperatures within the fire shelter, 1 inch (3 cm), and 12 inches (30 cm) above the ground

✥ Gas compounds released by heat and burning in the engines and fire shelters.

Video and still photographs would be taken of the fire conditions affecting the test vehicles and the fire shelters, including video footage taken inside the cab of the engines. These photographs would be used for technology transfer.

There is no intention on the part of MTDC or the WO Fire and Aviation Management in this study to set policy to determine whether firefighters should remain in a vehicle or deploy a fire shelter—rather, the study should provide as much quantifiable data and observations as possible so managers can formulate policies that apply specifically to their agencies.

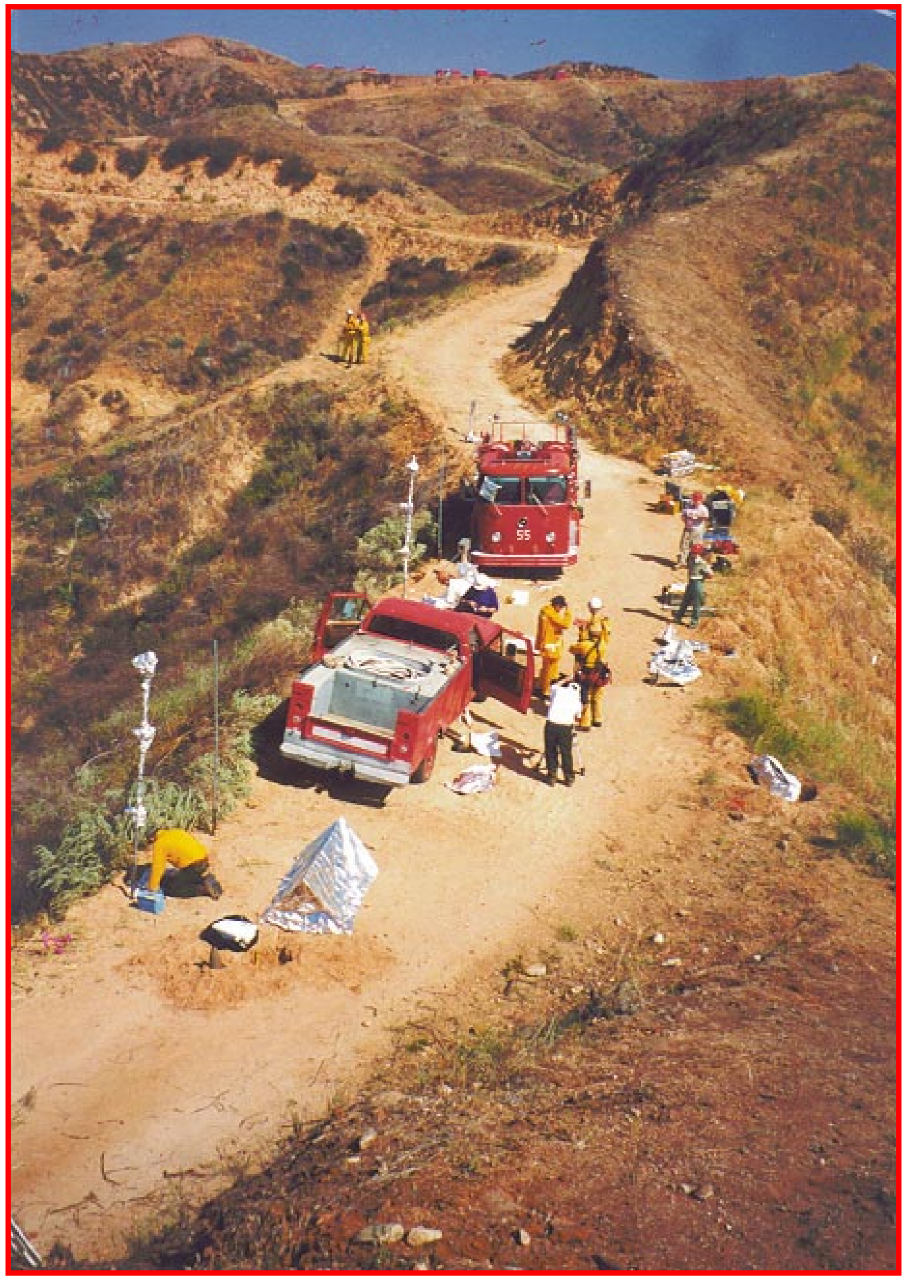

Figure 3—Layout for the June 5 burn in Los Angeles County.

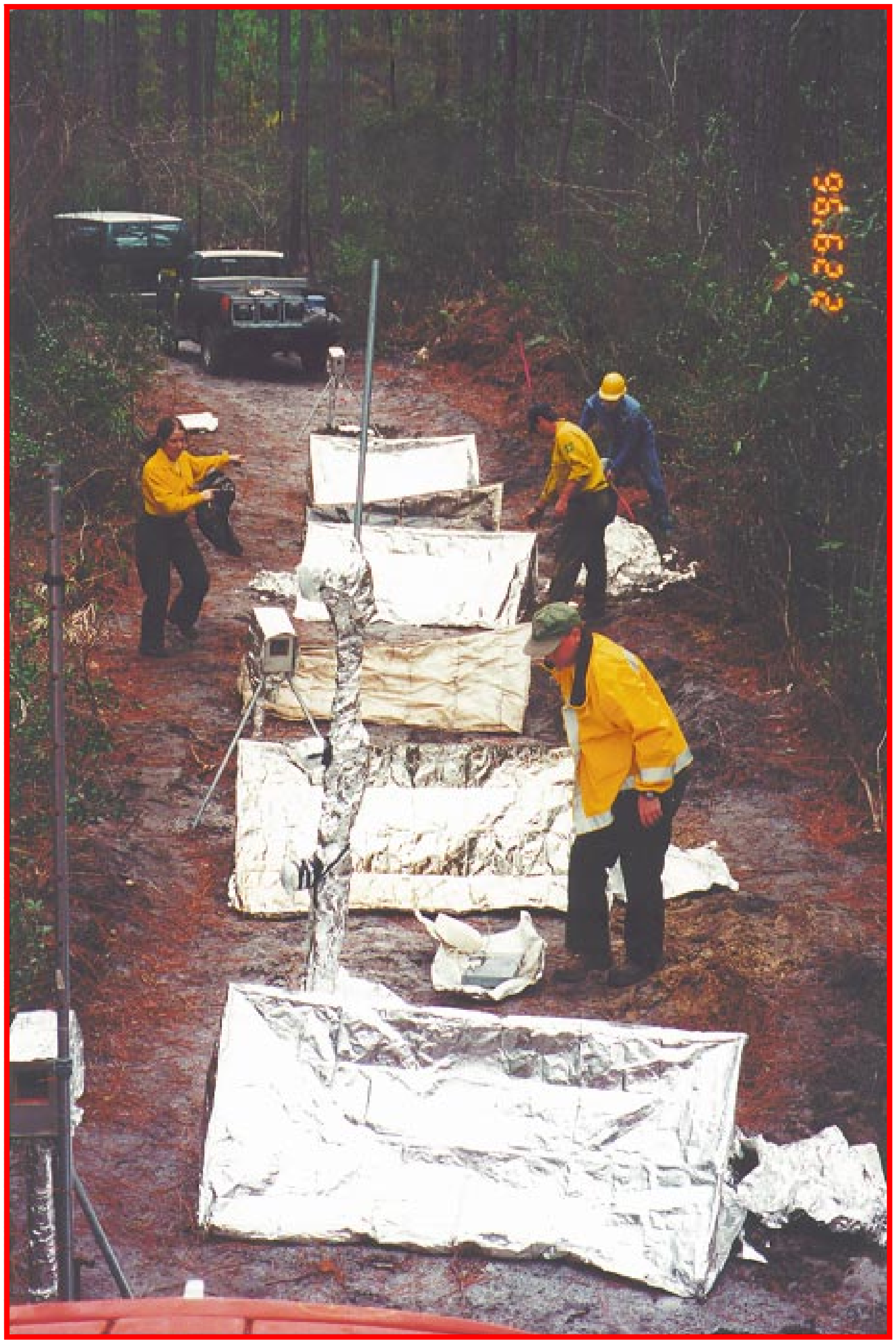

Figure 4—Several types of fire shelters were tested, including the standard Forest Service fire shelter and prototypes from MTDC and a private firm.

Previous Studies of Vehicle Burnovers

Although engines and other vehicles have been used in fire suppression for many years, surprisingly little has been written about firefighters becoming entrapped in engines. Many of the early field studies took place in Australia. Australians continue to study the safety of firefighters entrapped in their vehicles (Figure 5), as well as the safety of the general population as they attempt to flee from rapidly spreading bush fires.

In a 1972 report, *Studies in Human Survival in Bushfires*, Cheney reported that temperatures within a few feet of the ground and within a few feet of trees up to 35 feet (11 m) tall were lower than 120 ˚F (49 ˚C). In vehicle tests, car windows blocked half the radiant heat, but occupants would have still received severe burns to their bare skin. Within 4 minutes after the test fire was ignited, temperatures inside the vehicle reached 390 ˚F (199 ˚C). The roof lining and rubber seals burned, filling the cab with thick, dense smoke. Plastic and rubber material used in the interior lining smoked, causing "severe discomfort; tyres were caught alight by severe radiation heating; and 8 to 10 minutes after peak radiation, the engine compartment caught alight and burned strongly."

In a 1995 personal communication, Cheney recounted his experience on a bush fire during 1965 when the Australian version of the fire shelter was being developed. He believes he took additional risks because he had a fire shelter, that it was very hot and uncomfortable inside the shelter, and that he would have been safer if he had stayed in his vehicle.

In an April 1996 article, *New Fire Tactics for New Car Fires,* Bill Gustin discusses the hydrocarbon-based synthetic materials now used to reduce vehicle weight. He says that these materials produce thick, toxic smoke, "a witches brew of toxic gases." He also discusses the possibility of explosions from tires, batteries, hollow drive shafts, and components of the air-conditioning system. The plastic fuel lines used in newer vehicles carry gasoline at 15 to 90 psi. An electric fuel pump pumps gasoline from the tank to the engine. If a fire causes the fuel line to leak, gasoline will be under pressure, resulting in a sudden, intense fire fed by a spray of atomized gasoline.

Fuel tanks can no longer be vented to the atmosphere because of environmental concerns. Instead, vapors are pumped into a charcoal canister in the engine compartment. Excessive pressure from the heat of a fire could cause the fuel tank to leak along a seam, spilling fuel to the ground, increasing a fire's intensity. Fuel tanks made of polypropylene are lighter than metal tanks, but would melt more quickly.

Figure 5—This engine burned during the 1990 Toolara Fire in Australia. Three firefighters were trapped, one of whom was badly burned when he ran for safety. The other two men stayed in the vehicle, spraying themselves with water until the tires caught fire. Then they too ran for safety.

Cooperators

The Missoula Technology and Development Center depended heavily on the cooperation of wildland fire agencies, locally and across the country, to conduct a study of this complexity and scope.

The availability of engines that could be destroyed when subjecting them to the full effects of direct flame was critically important. In response to requests over the Internet, personal contacts, and inter-agency contacts throughout the wildland fire community, surplus engines were identified at the Florida Division of Forestry, Los Angeles County Fire Department, and the Montana Department of Natural Resources and Conservation. These engines enabled MTDC to fully implement the test plan as designed, with the engines and fire shelters exposed to a flaming front of fire for varying durations in a variety of fuel types.

Figure 6—Cooperators provided vehicles used in the tests, such as this engine and pickup provided by the Florida Division of Forestry.

Once engines were available, suitable sites had to be found where prescribed burns could be ignited under conditions similar to an engine burnover without damaging the site. Several of the agencies that contributed engines to this study also offered areas where burns could be conducted that met all of the criteria: where engines could be easily accessed and observed, where fire could impact both engines and shelters simultaneously, and where the risk of fire escape was minimal. The Florida Division of Forestry (Figure 6) and the Los Angeles County Fire Department offered burn sites that met these criteria. Both agencies had surplus engines available nearby. In Florida, lands of the Lake Butler Forest Unit of the Georgia-Pacific Corporation were selected. In Montana, the Beaverhead National Forest offered a site where we could to test the engines from the Montana Department of Natural Resources and Conservation.

Because the purpose of this study was to quantify the effects of flame and heat on the engines and fire shelters, scientific procedures had to be used when measuring:

- Air temperature outside and inside the engines and the shelters
- Radiant heat levels on the burn site
- Potential off-gassing from the various materials in the engines and shelters.

Dr. Bret Butler of the Forest Service's Intermountain Fire Sciences Laboratory in Missoula provided valuable expertise gathering and processing much of the data discussed throughout this report.

Preparing all the equipment, vehicles, and instrumentation for the test burns was labor intensive. Several smokejumpers from the Forest Service's Aerial Fire Depot in Missoula, MT (detailed to MTDC), helped complete these tests. In addition, the MTDC employees who helped implement the test plan were: Jim Kautz (photography), Lynn Weger (gas chemistry), Loren DeLand and Dave Gasvoda (instrumentation), and Ted Putnam and Bob Hensler (fire shelters and PPE).

Test Procedures and Methods

Because the study's objective was to quantify conditions in an engine compared to a fire shelter, test procedures and methods had to realistically measure the critical factors in a fire entrapment.

A study plan developed by the staff at MTDC was given wide review by cooperators, Forest Service fire specialists and researchers, and other fire specialists in the United States, Canada, and Australia. The final version of the study plan is in Appendix A.

Vehicles were positioned in or adjacent to fuels as they would normally be configured in a typical wildland setting:

✥ In the grass fuel type, they were placed in the middle of the fuels, with no clearing.

✥ In the brush and timber fuel types, engines were placed on roads, immediately adjacent to the fuels, but not in direct contact with them (Figure 7).

Fire shelters, both the Forest Service's standard model and a stainless steel prototype, were erected in front of or behind an engine, using tent framing to keep them erect. Weights along the inside edge of the shelter simulated a firefighter holding the edges to keep them from rising during the burnover. These shelters were adjacent to the fuels, rather than in a preferable deployment site as far from the oncoming fire as possible. This ensured that the data gathered were fully comparable to that obtained from the engines.

Instrumentation on the sites included two poles 9 feet (3 m) tall outfitted with thermocouples every 6 inches (15 cm). Data were recorded on Campbell Scientific data loggers, providing vertical temperature profiles on the burnover site. Radiometers were placed at the front or rear bumpers of the engines and on poles (Figure 8) to measure radiant heat flux. In the passenger side of the cab, 4-foot (1-m) thermocouple "trees" were outfitted with thermocouples every 6 inches (15 cm). The data were recorded on Campbell Scientific data loggers.

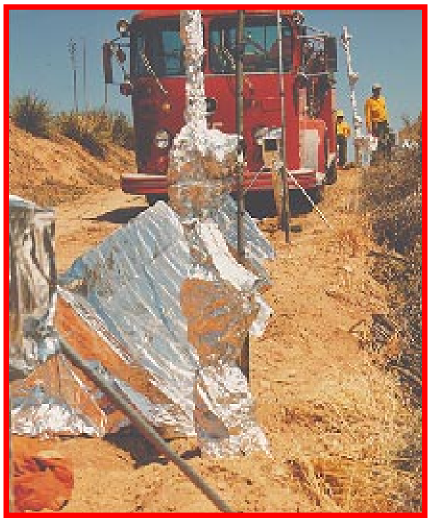

Figure 7—Both vehicles and fire shelters were placed right beside fuels. Firefighters would normally set up their shelters farther from the fuels, but the test compared fire shelters and vehicles under the worst conditions.

Figure 8—Radiometers on these poles measured radiant heat flux.

The fire shelters had thermocouples attached at the foot end, on the shelter's inside and outside skin. Thermocouples were placed at the head end of the shelter, 1 inch (3 cm) and 12 inches (30 cm) above the ground to measure air temperatures in an entrapped firefighter's critical breathing zone.

Both the engines and fire shelters had gas collection devices (Figures 9 and 10) placed inside to measure gases that could be harmful or fatal to an entrapped firefighter. The breakdown of materials inside the engine cab, such as the volatilization of petroleum-based plastics and sound-deadening materials inside the door panels, were a special concern, as was the off-gassing of the fire shelter adhesive that bonds the aluminum foil to the glass cloth. Detailed documentation of the gas collection system used on these burns—and on the gases collected—can be found in Appendix B.

Personal protective clothing (Figure 11), equipment, and other items commonly used by wildland firefighters were laid out near the fire shelters to visually evaluate their protective value during an entrapment. Items included the standard Forest Service Nomex shirt and trousers; leather firefighter gloves; hardhat; military-issue flight suit; and various outer garments such as brush coats, FR coveralls from Canada and Australia, and shirts from various cooperators. Clothing was tested as though it were on a firefighter. Five-gallon water bladders were filled with water and covered with 100% cotton undershirts. The shirts and jackets (or flightsuits) were placed over the undershirt. The bladder filled out the garments and simulated a heat sink, not unlike that of the human body. While some of these items were not instrumented, we felt visual observation of damage would offer valuable lessons for firefighter training. Specialized fireproof video photography equipment (Figure 12) was developed to take closeup shots of the

Figure 10.

fire's effects on the engines and shelters. These boxes were designed to withstand temperatures as high as 2300 ˚F (1260 ˚C) for extended periods (see Appendix C).

Figures 9 and 10—Gas collection devices sampled gases inside vehicle cabs. Instrumentation was buried inside ammunition boxes so that it would survive the fire.

Figure 11—Personal protective clothing was laid out to observe the fire's effects on it.

Figure 12—Video cameras were set up inside specially designed fireproof boxes to observe the fire from several vantage points.