Discussion

This project's primary purpose was to gain quantifiable data on conditions in engine cabs and fire shelters under identical, real-life conditions. However, we made a number of qualitative observations that are relevant to survivability in an entrapment. They include:

❖ In most fuel types (besides grass and light brush), the temperature and radiant heat flux generally increase with the height above the ground. This is consistent with the principle that heat rises. This observation has special relevance considering the height of an engine cab compared to the height of a fire shelter.

❖ Heat from the passage of the fire front appears to be retained in the vehicles longer than in the fire shelter or other items of PPE, indicating that the metal in an engine may act as a "heat sink" (Figure 25).

Figure 25—Even after a fire has passed, a vehicle retains heat, acting as a "heat sink."

❖ When fire comes up a steep sideslope, it appears to go over the top of an engine ***and*** under the chassis, creating an eddy on the back side that draws heat and flame (Figure 26). A firefighter taking shelter behind an engine parked on a steep slope would not be protected from heat or flame. This effect was demonstrated in October 1996 when a engine was burned over during the Calabasas Incident in southern California.

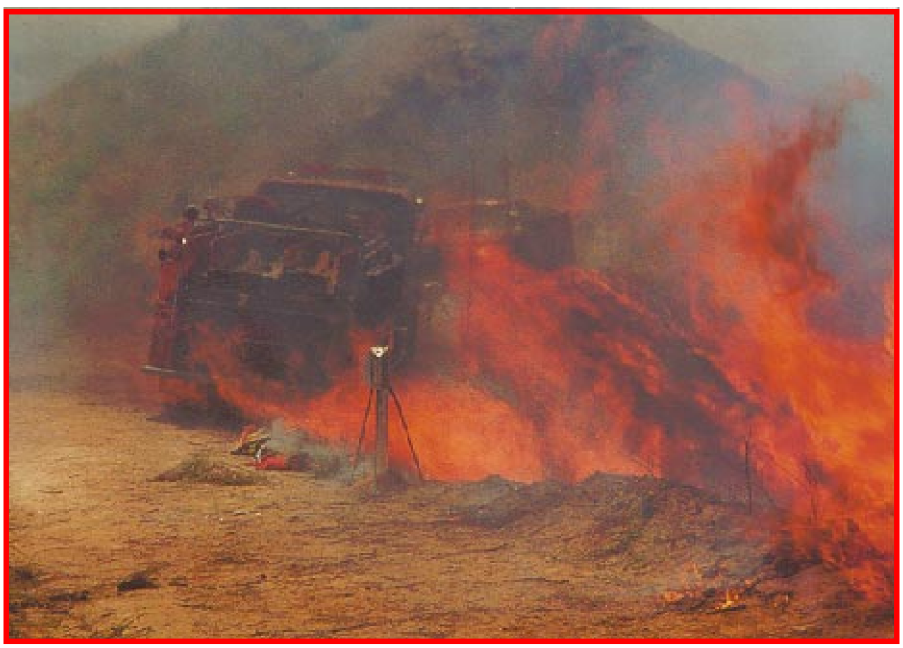


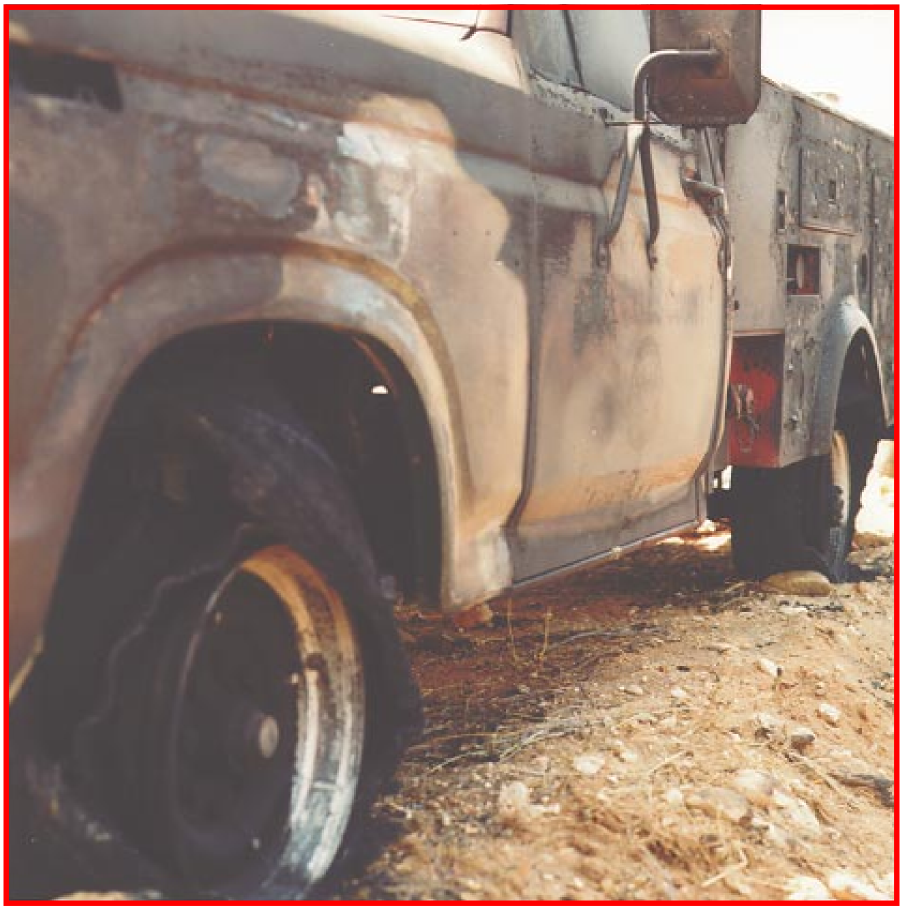
Figure 26—When a fire comes up a steep sideslope, it appears to go over and under the engine, creating an eddy on the back side that draws heat and flame.

❖ Video footage shows that a large volume of smoke seeps into the engine cab, even when the cab's windows are tightly rolled up. This occurred under low-temperature conditions when the cab might appear to be survivable.

❖ When the outside doors of an engine cab are subject to high radiant heat loads, the petroleum-based plastics and sound-deadening materials in the door panels and dashboard volatilize. The smoke generated by this volatilization may cause both short-term and long-term health effects on firefighters without respiratory protection, and will create conditions that force them from the cab into the fire area.

✥ During the moderate-intensity, short-duration exposure of the Los Angeles County tests, exterior components of the engines either caught fire or experienced some melting (Figures 27 and 28). Under higher intensity or longer duration exposures, the engine could catch fire and continue burning when conditions outside would be harmful to a firefighter attempting to leave the engine.

✥ For these tests, both the engines and fire shelters were placed in the area most likely to receive the highest exposure to the flaming front and the radiant heat flux. In a real-world fire entrapment, moving just a few feet back from the oncoming flaming front—especially on a road cut on steep slopes—appears to significantly reduce the effect of temperature and radiant heat flux on both the individual firefighter and an engine.



Figures 27 and 28—Items on an engine's exterior may catch fire during moderate-intensity, short-duration fires.

✥ Because of safety concerns during testing, the gas tanks on all the engines were empty. In an actual fire operation, damage to the fuel tanks during a burnover could increase the danger to firefighters in or near an engine.

✥ Observation of the exposed PPE indicated that under experienced radiant heat loads, the protective characteristics of the clothing and personal protective equipment appear to offer adequate levels of protection (Figure 29) for an entrapped firefighter who has neither a shelter nor an engine for protection.

✥ The temperature difference between the 1-inch (3-cm) and 12-inch (30-cm) levels in the fire shelters reinforces the need to encourage entrapped firefighters to get on the ground and to keep their face and mouth as close to the ground as possible, protecting their respiratory system.

✥ Since the test engines were drained of gasoline or diesel fuel, the engine's motors could not be left running during the burnover to assess the effect of reduced oxygen on engine performance.

Experience during the recent Calabasas entrapment showed that an engine became "oxygen starved" and quit running in a burnover situation. Firefighters hoping to escape a burnover by driving away in an engine should consider this possibility.

✥ Under high heat loads, tempered glass in the cab's windows may break out. This may occur when the difference in temperature inside the cab and the temperature outside is only 4 ˚C. Consideration should be given to using safety glass for greater levels of protection.

Figure 28.

Figure 29—Even though the engine is on fire, the shelters and personal protective clothing are undamaged.

In a real fire entrapment or burnover, the human dimension is a critical factor:

✥ What is the experience and training of the individuals involved? Does their frame of reference (experience) allow them to recognize the situation they are in, and make the appropriate response?

✥ Do the firefighters have knowledge of all the pertinent factors? In the Wenatchee Heights entrapment, Fire Chief Rick West thought he knew the fuel conditions (grass), but was unaware of the woody component from apple orchard trimmings. That fuel resulted in a high-intensity, long-duration flame front that compromised his safety in the cab of the engine. When he was forced to flee the engine, he suffered serious burns over much of his body.

✥ How much time is available for the critical decision? Can you get all the exposed firefighters into an engine cab safely in less than the 20 to 25 seconds needed to deploy a fire shelter?

✥ Have firefighters considered the need for an adequate Safety Zone early on during the fire suppression, or do they consider their engine or fire shelter to be their "Survival Zone?"

References

Anderson, Hal E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station NFES 1574. Boise, ID: National Wildfire Coordinating Group

Bond, A.; Cheney, N. P. 1986. A discussion paper on techniques and equipment for bush fire fighters entrapped by fire. Canberra, Australia: CSIRO National Bush Fire Research Unit.

Cheney, N.P. 1972. Forestry and timber bureau studies human behavior in bushfires...don't panic and live. Canberra, Australia: CSIRO Division of Forestry. NAT/DEV: September 1972.

Cullom, Keith D. 1986. The breaking point: twice in one season. Boston MA: National Fire Protection Association. Fire Command. March 1986: 22-27.

Douglas, D. R. 1969. Safety as a factor in the design of fire-fighting vehicles. In: South Australian Emergency Fire Services E.F.S. Manual: 30, 32, 34, 47.

Gustin, Bill 1996. New fire tactics for new-car fires. Fire Engineering. April 1996: 43-54.

Harris, J. P. 1997. Calabasas Incident entrapment analysis. Los Angeles, CA: County of Los Angeles Fire Dept.

Knight, Ian 1988. What intensity of fire can a fire fighter survive in a reflective shelter? Boston, MA: Fire Technology. November 1988: 312-331.

Mangan, Dick. 1993. New standards for wildland firefighting protective clothing and equipment. Tech Tip 9351-2340-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.

Mangan, Dick. 1995. Safety zones versus survival zones (Recommendations B.5 and B.8). In: Interagency Management Review Team on South Canyon Fire: Final Report.

Mangan, Dick. 1994. Lessons learned: the use of personal protective equipment on wildfire entrapments in 1993. Tech Tip 9451-2335-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.

Mangan, Richard J. 1996. Wildfire safety: equipment, training and attitudes. In: Seminar on Forests, Fire and Global Change. Sushenskoye, Russian Federation.

McArthur, A. G.; Douglas D. R.; Mitchell, L. R. 1966. The Wandilo Fire, 5 April 1958: fire behavior and associated meteorological and fuel conditions. Leaflet No. 98,O.D.C. 431.6. Canberra, Australia: Department of National Development, Forestry and Timber Bureau, Forest Research Institute.

National Fire Protection Association Committee on Fire Gas Research. 1952. Fire gas research report: report of research by Arthur D. Little, Inc. Quarterly. January 1952. Boston MA: National Fire Protection Association.

Putnam, Ted 1995. Your fire shelter: 1995 edition. Tech. Rep. 9551-2819-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.

Putnam, Ted 1996. Your fire shelter—beyond the basics: 1996 edition. Tech. Rep. 9651-2829-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.

Queensland Forest Service. 1992. Swampy Fire no. 7-S.F. 1004: Toolara State Forest -22 September 1991. Queensland, Australia: Queensland Forest Service.

Smith, J. E. 1994. Fire storm: after action report. Arroyo Grande, CA.

About the Author

Dick Mangan has been Fire and Aviation Program Leader at MTDC since 1989. His major responsibilities include developing equipment for wildland firefighters, primarily personal protective equipment and equipment for smokejumpers. Dick serves on the National Wildfire Coordinating Group Fire Equipment and Safety and Health Working Teams, and is chair of the National Fire Protection Association's technical committee for wildland fire personal protective equipment. He is red-card qualified as an Operations Section Chief I and Planning Section Chief II, and serves as Operations Section Chief on a national Type 1 fire overhead team. Dick has a bachelor of science degree in forestry from Humboldt State University and more than 20 years experience on Ranger Districts and National Forests in Oregon and Washington. His last assignment before coming to MTDC was as Fire Staff Officer for the Ochoco National Forest in Prineville, OR.

Library Card

Mangan, Richard. 1997. Surviving fire entrapments: comparing conditions inside vehicles and fire shelters. Tech. Rep. 9751-2817-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 37 electronic p.

Describes tests in California, Florida, and Montana during which vehicles, fire shelters, and firefighters' personal protective equipment were purposely placed in the path of test fires. Temper-atures inside the vehicles, fire shelters, and surrounding air were measured at levels of from 1 inch to 9 feet above the ground. Radiant heat flux was measured in the immediate vicinity of the engines and in the fire shelters. The levels of six gases (sulfur dioxide, hydrogen cyanide, benzene, hydrochloric acid, toluene, and carbon monoxide) were measured in-side the vehicles and inside fire shelters. The tests showed that temperatures are lower within 12 inches of the ground (where a firefighter would be if lying in a fire shelter) than several feet off the ground (where a firefighter would be sitting in an engine cab). During several tests, plastic materials inside the vehicle caught fire, filling the interior with black smoke. Color photographs show the tests and their outcome.

Keywords: fire engines, fire fighting, fire shelters, protective clothing, safety devices, toxic gases.

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