The Development and Implementation of an Improved Fire Shelter for Wildland Firefighters

L. Anderson
U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center, Missoula, MT, USA

Abstract
The fire shelter is an element of personal protective equipment used by wildland fire fighters in the United States. The shelter is carried in a pouch on the belt or pack by each individual fire fighter as a last resort to protect against heat injury during a wildfire entrapment. The fire shelter was completely redesigned at the Forest Service's Missoula Technology and Development Center (MTDC) between 2000 and 2002. Distribution of the new shelter design began in June 2003.

The original fire shelter design, used for over 30 years, was made of a laminate of fiberglass cloth and aluminum foil in the shape of a pup tent. It saved more than 300 lives and prevented a similar number of serious burn injuries. The original shelter offered protection by reflecting radiant heat. However, direct flame contact could rapidly damage the shelter. Fatalities have occurred when flame contact was severe.

The new fire shelter was designed to offer fire fighters better protection from flames and convective heat while maintaining or improving the protection from radiant heat offered by the original shelter. Considerations of weight, bulk, strength, durability, ease of use, and potential toxicity were also critical in the selection of the new shelter.

This paper reviews the process used by MTDC to assess the performance of new fire shelter designs and materials. It includes a description of the parameters used to evaluate the shelters and an examination of the performance of the selected shelter. The report includes a description of the design features of the new fire shelter and a review of some of the steps involved in providing the new shelter to fire fighters in the field.

Introduction

This summer, firefighters in the United States will begin to carry a wildland fire shelter newly redesigned by the United States Forest Service's Missoula Technology and Development Center (MTDC) in Missoula, Montana, U.S.A. This "new generation" shelter will provide improved protection from radiant heat and flames.

Wildland firefighters in the United States have carried fire shelters since the shelters were developed during the 1960s. More than 1,100 firefighters have deployed their fire shelters. The shelter is credited with saving more than 300 lives and preventing hundreds of burn injuries. The original shelter (which this paper will call the standard fire shelter) was designed to reflect radiant heat. Direct flame contact can damage the standard shelter. When flame contact has been severe, firefighters have died inside the shelters.

In January 2000, MTDC was asked to develop an improved fire shelter. The goals of the project were to maintain the level of protection from radiant heat provided by the standard shelter while improving protection from direct flame. Other considerations included material strength, durability, flammability, weight, bulk, toxicity, and cost.

Development Process

The first step in the development process was to devise tests to evaluate the performance of the prototype shelter materials and designs. Field testing had provided some valuable information on fire shelter performance, but the expense and difficulty associated with field testing, and the variability of field test conditions, led us to conclude that repeatable lab-based tests would provide more reliable information on fire shelter performance. To help develop these tests, MTDC gathered information on the fire environment during field tests in the Northwest Territories in Canada and in the State of Montana in the United States.

With assistance from the Departments of Human Ecology and Mechanical Engineering at the University of Alberta in Canada, and from private laboratories in the United States, small-scale laboratory tests were designed to allow materials to be screened for strength, flammability, thermal performance, and toxicity. Full-scale tests were developed to measure the strength, durability, flammability, thermal performance, and toxicity of the overall shelter designs.

Interest from private industry in the development of a new fire shelter was high. Most of the private companies submitted materials rather than designs. Although these companies had expertise in fire protection, they had little background in the requirements of a fire shelter. So MTDC developed a fire shelter design that would allow us to test promising materials in full scale. One company, Storm King Mountain Technologies (SKMT), submitted fully designed shelters for testing. The SKMT shelters were tested in the form in which they were received. In all, over 60 materials and combinations of materials were considered and 17 different materials were selected for testing as full-scale prototypes.

The Federal Fire and Aviation Leadership Council, made up of fire managers representing the U.S. Departments of Agriculture and the Interior, and State agencies with responsibilities for wildland fire management, selected the final fire shelter design in June 2002.

International Effort

The development of the new generation fire shelter benefited tremendously from international involvement. Critical information on fire shelter performance and the fire environment was gathered during the International Crown Fire Modeling experiments in Canada's Northwest Territories in 1997-1999. These tests involved scientists from numerous countries and presented an environment for testing and research that was unique, in both the physical and academic senses. During these tests we learned about the limitations of the standard shelter design and gathered data on the fire environment that permitted development of reliable lab-based tests. Further international ties were established when MTDC contracted with the University of Alberta's Departments of Human Ecology and Mechanical Engineering for the development of small and full-scale performance tests.

The New Design

The shape of the new generation shelter differs from that of the standard fire shelter (figure 1). The shelter is now shaped like a half cylinder with rounded ends. The new shape has a number of advantages. The rounded design reduces the surface-area-to-volume ratio, decreasing the amount of material needed to provide enough volume inside the shelter. The new materials improve protection from flames, but they weigh twice as much as the old materials. If the new materials had not been used efficiently, the new generation shelter could have weighed more than twice as much as the standard shelter.

Figure 1—The new generation shelter (right) is longer, rounder, and lower than the standard shelter.

The new shelter is narrower and longer than the standard shelter. Overall, the shelter offers significantly more protection than the standard shelter, but it may feel smaller to users. The new shelter was designed and tested using subjects up to 6 feet 4 inches tall. Military studies show that less than 1 percent of the military population is taller than 6 foot 4 inches. Because some firefighters are taller than 6 feet 4 inches, MTDC is designing a version of the new shelter to fit them.

The new design's reduced surface-area-to-volume ratio improves protection because the shelter has less surface area to absorb radiant heat. The rounded ends also solve a problem noted during field testing of the standard fire shelter. Video taken during test fires showed that the flat ends of the standard shelter could reflect heat onto adjacent fuels, igniting them before the flame front arrived. Flames from adjacent fuels could damage the shelter, reducing its protection just before it was most needed. The rounded ends of the new shelter design scatter radiant heat to the atmosphere, rather than focusing heat on fuels next to the shelter.

The new generation shelter is made of two layers of material (figure 2). It weighs 4.2 pounds, compared to about 3.4 pounds for the standard shelter. The outer layer is woven silica laminated to aluminum foil. The inner layer is fiberglass laminated to aluminum foil. The outer layer of foil reflects radiant heat and the woven silica slows heat transfer to the inside of the shelter. The inner layer of foil prevents heat from being reradiated inside the shelter, and it helps keep gases

out of the shelter. When the two layers of material are sewn together, the air gap between them provides additional insulation.

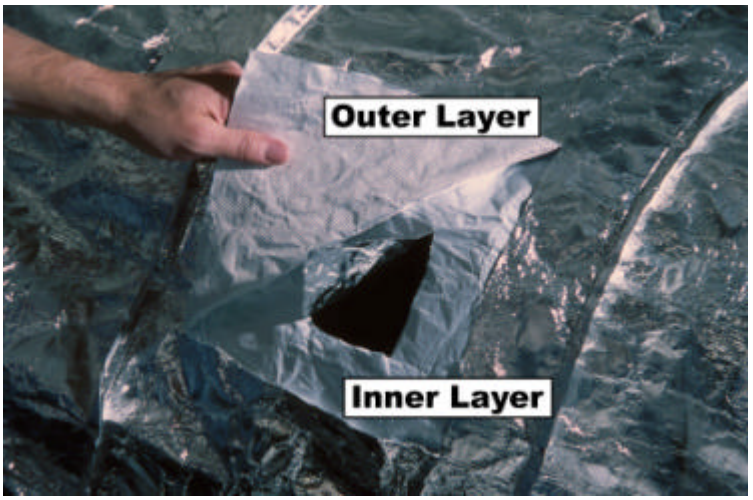

Figure 2—The new generation shelter has two layers of material. The outer layer is woven silica laminated to aluminum foil. The inner layer is fiberglass laminated to aluminum foil.

Seams across the top of the shelter support its main shell. The seams also help keep the outer foil layer in place. When the shelter is heated to 260 °C (500 °F), the adhesive that bonds the foil to the silica breaks down, allowing the layers to separate. In turbulent conditions, the foil can tear and peel away from the silica layer. Seams protect the foil layer because the foil stops peeling when it reaches a seam.

Ease of Deployment

The new shelter has “shake handles” to speed deployment. If the user grasps the handles and shakes, the shelter will unfold quickly. As with the standard shelter, the new generation shelter does not have a “head end.” It can be deployed in either direction.

The shelter includes holddown straps that a firefighter uses to keep the shelter on the ground during turbulent winds associated with the fire front. The straps on the standard shelter crossed the opening of the shelter. Sometimes these straps snagged when a firefighter was deploying the shelter. The holddown straps on the new generation shelter are alongside the opening, where firefighters can slip their hands through them when deploying.

Performance in Radiant Heat and Flames

Radiant and convective testing is critical when assessing a shelter's ability to limit heat transfer. The greatest threats a firefighter faces during an entrapment are burns to the body and inhalation of hot gases, which can cause asphyxiation. We assessed the inhalation threat by measuring the temperature at various locations inside the fire shelter. We assessed the potential for burns with temperature and heat flux measurements inside the shelter.

Scientific estimates of the maximum survivable air temperature vary, but dry air temperatures as low as 149 °C (300 °F) are considered survivable only for very short periods (Society of Fire Protection Engineers 1995).

The new generation shelter provides improved protection from both radiant heat and direct flame. In radiant heat tests using full-scale designs, temperatures inside the new generation shelter rose 22 percent less than temperatures inside the standard shelter after 300 seconds. The temperature rose an average of 76 °C (169 °F) in the new generation shelter compared to 97 °C (207 °F) in the standard shelter (figure 3). In direct-flame tests, temperatures inside the new generation shelter rose 81 percent less than temperatures inside the standard shelter after 40 seconds. The temperature rose an average of 56.5 °C (134 °F) inside the new generation shelter, compared to 300 °C (572 °F) inside the standard shelter (figure 4).

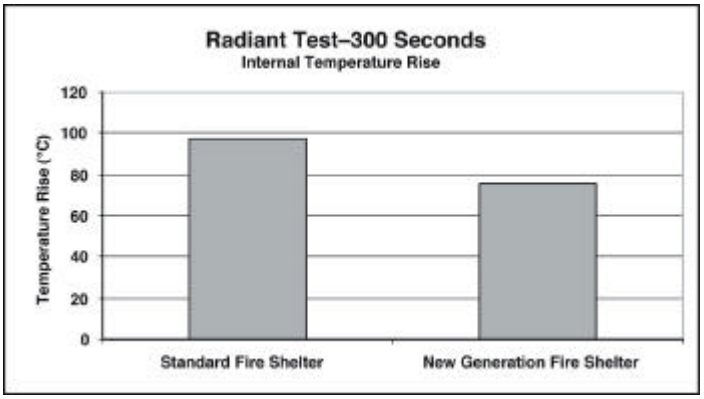

Figure 3—Temperatures inside the new generation fire shelter rose 22 percent less than temperatures inside the standard shelter during radiant heat tests of full-scale designs.

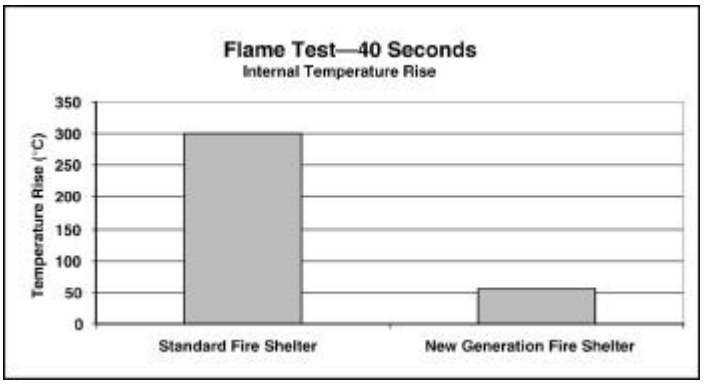

Figure 4—Temperatures inside the new generation fire shelter rose 81 percent less than temperatures inside the standard shelter during flame tests of full-scale designs.

One way to understand heat flux is to picture it as a measure of the rate at which heat strikes a surface. A heat flux of 5 kilowatts (kw) per square meter (m^2) would lead to second-degree burns in about 40 seconds on bare skin (Society of Fire Protection Engineers 1995).

In radiant heat tests, the average peak heat flux was reduced 59 percent, from 3.7 kw/m^2 for the standard shelter to just 1.5 kw/m^2 for the new generation shelter (figure 5). In direct flame tests, the average peak heat flux for the new generation shelter was 97 percent lower, just 1.3 kw/m^2, compared to 44.1 kw/m^2 for the standard shelter (figure 6).

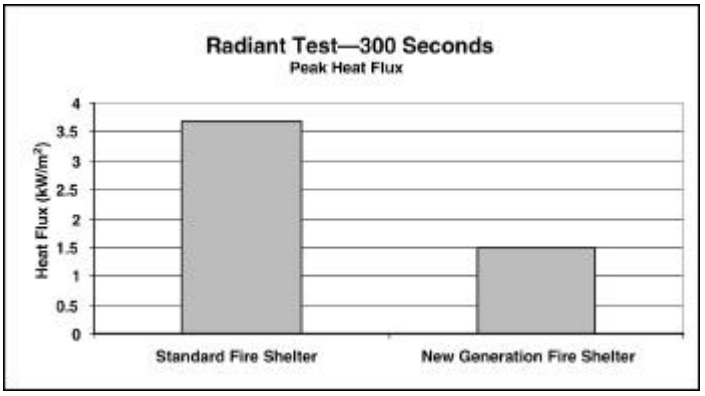

Figure 5—The average peak heat flux was 59 percent lower for the new generation fire shelter than for the standard shelter in radiant heat tests of full-scale designs.

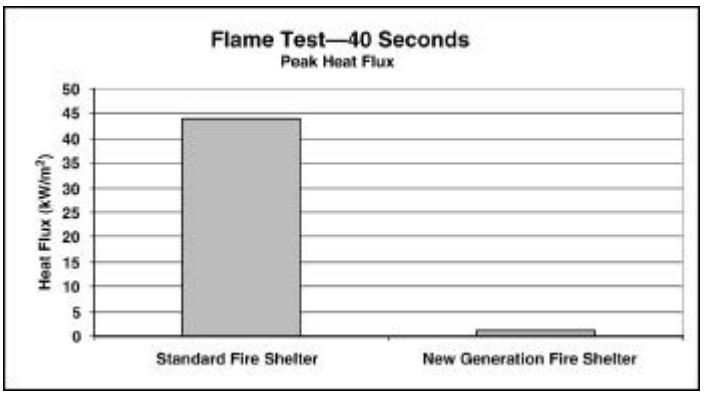

Figure 6—The peak heat flux for the new generation shelter was 97 percent less than for the standard shelter during direct flame tests of full-scale designs.

Outfitting Wildland Firefighters with the New Generation Fire Shelter

As of this writing, the new generation fire shelter has not yet been deployed in a wildland fire entrapment. The new shelter is just reaching the field. Firefighters involved in initial attack activities have been given the highest priority for receiving the shelters. MTDC has developed additional products to help smooth the transition from the standard fire shelter to the new generation shelter.

Training

Because the new generation shelter is deployed somewhat differently than the standard shelter, firefighters are advised not to carry the new generation fire shelter until they have been properly trained. MTDC has developed a new training video (also available as a DVD), a new training pamphlet, and a new practice fire shelter. The video, DVD, and the pamphlet (all titled "The New Generation Fire Shelter") can be purchased from:

National Interagency Fire Center
Attn: Great Basin Cache Supply Office
3833 South Development Ave.
Boise, ID 83705
Fax: 208–387–5573 or 5548

Specifications and drawings for the new generation practice shelter are available from MTDC:

USDA Forest Service
Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808-9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: wo_mtdc_pubs@fs.fed.us

Carrying the New Generation Fire Shelter

The two layers of material in the new generation shelter have increased the shelter's bulk. In the past, the folded fire shelter fit inside a hard plastic liner that measured 22.9 by 14.6 by 8.3 centimeters (9 by $5^{3}/_{4}$ by $3^{1}/_{4}$ inches). The liner for the new shelter is an extra 3.2 centimeters ($1^{1}/_{4}$ inches) deep. The new liner is too large for many of the field pack sleeves that were designed for the standard shelter.

The new shelter will come with a case that can be worn on a belt or on a chest harness. MTDC has also designed a new fireline pack that will accommodate the new generation fire shelter. Other fireline packs can be retrofitted, if necessary, to accommodate the new generation shelter. MTDC recently published a "Tech Tip" that describes a simple way to retrofit a common field pack design. This Tech Tip, "New Generation Fire Shelter Developed for Wildland Firefighters" (0351–2313–MTDC) is available from MTDC (406–329–3978).
http://www.fs.fed.us/t-d/pubs/htmlpubs/htm03512313/index.htm

Transition Period

The new generation shelter is available through the General Services Administration Wildland Fire Equipment Catalog. The cost of the complete unit with case and hard liner is $256.75 (U.S. dollars). The new generation shelter should be available soon from private distributors.

We realize that some of our State and local partners will be phasing the new shelter in slowly because of its increased cost. The standard fire shelter still meets all agency requirements and will remain in the system for about 5 years. The standard shelter has saved many lives and provides good protection so long as flame contact is minimized. All training materials for the

standard shelter will be available until the standard shelter has been declared obsolete and removed from service.

Conclusions

This paper concludes with a caution. The new generation fire shelter provides distinctly improved protection from radiant heat and direct flame, but it has limitations. No shelter can protect against all conditions and guarantee a firefighter's safety. It is critical that firefighters understand that carrying the new generation fire shelter is not an excuse to take risks on the fireline. A firefighter's highest priority is still to stay out of situations that can lead to entrapment.

References

Society of Fire Protection Engineers. 1995. Handbook of Fire Protection Engineering. 2nd ed. Quincy, MA: National Fire Protection Association.