

ANALYSIS OF ESCAPE EFFORTS AND PERSONAL PROTECTIVE EQUIPMENT
ON THE SOUTH CANYON FIRE

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Overview

On July 6, 1994, at about 1615, 14 firefighters were trapped and perished on the South Canyon Fire. Less than 24 hours later, I was on the site as a member of the MTDC investigation team gathering data to piece together what happened. Our focus was the firefighters' personal protective equipment (PPE) -- primarily the clothing and fire shelters -- and how it performed.

From an analysis of the PPE, along with other the physical evidence recovered from the site and autopsy reports, we would write a "thermal analysis" for each firefighter who perished. This analysis determines as accurately as possible the cause of death, escape efforts before entrapment, and whether the equipment the firefighters carried helped or hindered their efforts. The information generated is used to update escape and fire shelter training documents so firefighters can minimize future risks.

A key to reconstructing entrapment events is the analysis of the PPE. We studied the effects of heat on the fire shelters as well as how the shelters were used. We also studied the passage of heat through outer clothing layers to the skin and how the clothing was used.

Not only does this information help us reach some educated conclusions about how and why people died, but it also helps policymakers decide whether current PPE is providing adequate levels of protection or whether national standards for protection need to be revised.

The Fire and Escape, July 6

Starting about 1130 16 smokejumpers began building fireline downhill. By 1245 nine Prineville Hotshots started down behind them. They cleared out the oak brush and dug fireline from the main ridge down the flank and over to the lunch spot. It was tough going and tiring but otherwise uneventful. After lunch, about 1430, some of the jumpers and Prineville were told to improve and hold the flank. The rest of the jumpers were to punch the line from the lunch spot toward the south to cut off the fire creeping downhill. The jumper line scout, Longanecker, went ahead to size up the fire and the route of the fireline to the south.

About this time there were flare ups in the pinyon juniper, indicating increasing instability. The jumpers were vacillating between starting down toward the line scout or heading up to the survival zone at helispot H1. Next, a 100- to 200-foot-long crown fire in the pinyon juniper put out a lot of radiant heat and sent up a large column of smoke. Runs like this in pinyon juniper indicate increasing instability, so the jumpers stopped to reevaluate going downhill any farther. The line scout called in a bucket drop on the spots, which cooled them down. This is about 15 minutes before the blowup begins or is perhaps the beginning of the blowup. The timing is about right for the rotor down wash to have caused burning materials to start rolling down the hill. Whether dislodged by the helicopter or natural processes, the most likely precipitating cause of the blowup was burning fuel that rolled all the way to the bottom. A log was reported to have rolled down the hill about this time. Shortly after the copter leaves and the line scout says its safe to come down the rest of the jumpers start downhill again, toward the south.

About 5 minutes later when the fire started up the ridge to the west and up the bottom of the drainage one of the jumpers, Petrelli, located on the ridge to the south of the lunch spot, sees it and calls in a warning. Mackey, the jumper in charge, quickly sizes up the situation and gives the nine jumpers in this location the order to head for H1. Blanco, the incident commander, gives all of his people the order to head for H1 and the escape effort has began for all firefighters. Mackey at this point heads downhill to check on the line scout and the three jumpers and nine Prineville crew on the flanking fireline to the west.

On this west flank fireline, north of the lunch spot, Hipke, Roth, and Thrash see a column of smoke and note that it is increasing in volume. To them, this fire is likely to come up and across the ridge the lunch spot is on, then move toward their position. At this time they are 1,450 feet away from the main ridge between H1 and H2 (the heliport 1/2 mile north of H1). They quickly make the decision to move out. When they turn to tell Prineville they are leaving, the Prineville firefighters are already on their way. Kelso, the Prineville squad boss, also saw the column or relayed Petrelli's message to Sheppard, the Prineville Hotshot superintendent on the ridge near H1, and was told to get out. As the firefighters move out the fire continues up the main drainage parallel to their escape route.

It is not clear why Mackey started out along the west flank fireline. Hipke said he was not aware of any warnings given. Thrash was leading, followed by Roth who had a radio, then Hipke. If Roth had talked to Mackey, Hipke would have been aware of it. So it is likely Mackey didn't call Roth, otherwise there was no need to check on them. To catch up to Prineville, Mackey had to run most of the way, and he had to leave the lunch spot within 1-1/2 minutes after the jumpers and Prineville started out in order to catch up with them where he did.

Note: Reference distances cited below are the number of feet from the center of the ridgetop at the top of the west flank fireline:

Somewhere near the felled tree (830 feet) Hipke said the crew saw that the fire in the west drainage had moved up beyond the ridge the lunch spot was on, burning on both sides of the canyon. This was the first time they felt threatened. Before seeing fire in the west drainage, they moved at a moderate hiking pace. Hipke said they immediately picked up the pace to a fast hike. When asked why they didn't run or drop their equipment, he said he felt the threat was there but not yet life threatening. This was because there was little wind and the fire was predominately terrain driven. The fast hiking pace was keeping them ahead of the observable flames without exhausting anyone.

When Hipke crested a spur ridge (730 feet), he looked back and saw all the Prineville crew coming in a tight group with no stragglers. He saw Mackey at the end of the line, and they made eye contact. Hipke did not observe the fire at this moment. Haugh, a BLM district firefighter, and Erickson, a smokejumper, were at the "tree" (200 feet), and Erickson had radioed Mackey to warn him the fire was getting close and to run. Mackey made a reference to the fire in the drainage and Erickson said no, that a spot was beneath them behind the ridge.

By the time the last people are at the 600 foot point, a picture taken from the ridgetop 250 feet south of H2 shows the fire is burning uphill toward H1 south of the spur ridge and about 800 to 900 feet from the ridgetop. This is likely the same run that prevented firefighters on the main ridge from reaching H1. It is likely that this fire stayed beyond the spur ridge because Hipke couldn't see flames when he looked back from below the spur ridge. When they reached the bottom of what would become the fatality site (280 feet), the vegetation changed from predominantly oak to a more open mix with grass and pinyon juniper. Thrash, the smokejumper in the lead, stepped to one side, followed by Roth, and said he was going to deploy his shelter. Hipke didn't know why and walked past them. Thrash may have stopped to deploy if he heard the Erickson and Mackey radio talk and realized the slope had turned from 20% to 55% grade and felt it would be hard to outrun the fire up to the ridgetop.

As Hipke went past Thrash and Roth he heard Erickson and Haugh yelling for them run. Hipke looked back (at 240 feet) and saw Roth, Thrash then Prineville all coming up the line about 30 feet lower. He was not aware of any flames but could hear the fire. After turning back uphill Haugh and Erickson were gone. Hipke started into a power hike and never looked back. At some point Blecha followed and within 30 or 40 seconds the rest of the crew was overrun by a blast of hot gases.

Discussion

It is significant to note that these fatalities follow a pattern that started in 1990 with the Dude Fire. People are escaping uphill, carrying all their equipment and being caught before they can deploy fire shelters. Analysis of times to escape shows most of these firefighters likely would have lived if they had dropped tools and packs and run only with shelters.

An interview was conducted with Eric Hipke who was the sole survivor of the firefighters who attempted escape along the west flank fireline. It documents the firefighters efforts getting to the fatality site. They traveled pretty much in a tight group with the first and last person about 30 seconds apart. When they reached the site, Thrash stopped and said he was going to deploy his shelter. Hipke kept going and when he last looked back Roth was in the lead about 30 feet back with everyone else coming behind him. Roth and Thrash moved about 60 feet farther up the hill to where they deployed. What happened after that is speculation based on available evidence.

Assuming Blecha moved up the slope as fast as Hipke, he would have delayed 9 to 30 seconds before continuing up the fireline to end up where he did. It is 9 seconds if he was near the end of the Prineville column and 30 seconds if he was behind Thrash. Any delay longer than 30 seconds and he could not have made it as far as he did. This shows there wasn't much decision time for anyone.

When the hot gases caught people at the site, Mackey, Bickett, and Kelso, who were the three leaders, were together. They may have stopped briefly to talk and at least the Prineville crew would wait for an order to deploy. Roth and Thrash had to start deploying by then to have had time to finish full deployment. Hagen was near them and may have started to get out her shelter. The decision to deploy may have come from Bickett/Kelso because they and Hagen are the only ones who appear to have gotten their shelters out of the cases. The shelters of these three are uphill, suggesting they were blown uphill by the initial blast of hot gases. Everyone else was caught with their shelters still in their packs, showing they were overrun unbelievably quickly.

On the Dude Fire people were caught standing up trying to deploy their fire shelters and the fatality scene was best described as "chaotic." This entrapment scene could best be described as "flattened" and "frozen-in-motion." People were likely knocked to the ground by a blast of superheated gases that froze them where they were. Because this had to happen without recognizable warning, it needs to be explored. Flame fronts are typically very visual and usually noisy, so was not likely the initial event. **What would make more sense would be if hot gases similar to what caught Erickson, Hipke, and Blecha caught these people.** In fact, it was likely the same "gas wave" that hit everyone.

Before arrival at the site, the fire was seen behind the victims with a spur ridge between them. This fire was burning uphill toward H1 rather than along the fireline. If the main fire was still running toward H1, the leaders may have been trying to estimate rates of spread toward them to decide whether to keep walking uphill or deploy shelters. Also, it probably appeared that the head of the fire beyond the spur ridge was already up to H1 and likely to cut off their escape further up the fireline. Meanwhile the fire may have started uphill toward them coming up the draw that starts in the bottom of the drainage and runs straight toward the site. After coming part of the way up it may have paused. Sometimes hot gases containing unburned, vaporized fuels move uphill ahead of the flames. This gas movement would not be highly visible and would be detected more as noise below in the oak brush or as an odor. This could explain why Hipke didn't see any flames when he last looked back, about 40 seconds before this site was overrun.

Just before the hot gas arrived it may have ignited and literally exploded and hit as a shock wave. It would take such an effect to knock people to the ground, unconscious, and freeze them there. This could account for seven people who didn't have time to even get their shelters out, why Johnson still had his hand on the chain saw handle, and why three people who got their shelters partially out, had them blown straight uphill. Only the three jumpers were different.

The evidence suggests that Mackey was the only one at the site who changed locations. His shelter and packsack are up with Brinkley, Bickett, and Kelso. He may have already been kneeling on the ground when the shock wave hit and was able to get back up. He started downhill in the heat with his knife falling off near Johnson, and he was found lower down near Holtby. The other two jumpers, who Hipke said had already mentioned deploying when he was there, likely started to deploy when everyone stopped. This may be when Blecha left. Once deployed and hit with hot gas, the shelters would delaminate in a few seconds. Whereas shelter performance would be excellent for radiant heat, good for moving flame fronts, it would be poor for hot gases. And in turbulence, the hot gases would enter the shelters and quickly increase the temperature.

As the hot gases passed on uphill toward the other escaping firefighters the flame front came through. It followed the draw that comes out of the canyon bottom toward the entrapment site, makes a right turn under the site, and then heads toward H1. The three shelters that were opened lengthwise were all blown uphill before the flame front arrived. Then the shelter upper surfaces were blown toward the right. Some large shelter pieces from this site were found at the top of H1 with retardant on them. Also, the heat damage to people, shelters, and ground articles shows the flames passed left to right. For Blecha and Hipke near the top of the fireline there is no dominant left-right effect so the hot gases came straight up hill at their location.

The flame front moved straight up hill, turned to the right, and followed the draw up toward H1. This change in direction allowed Haugh, Erickson, and Hipke enough time to escape. The hot gases caught Blecha 120 feet from the top where he perished. They did not catch Hipke until he was on the flat part of the ridgetop. The hot gases contacted Hipke long enough to burn him. But he was able to get up and make it over the ridge top because the hot gases either rose straight up or were shifted toward H1 by in-drafting air. When Haugh looked back he observed a wall of flames cresting the ridge below H1. A low intensity fire came up the fireline after Haugh, Erickson, and Hipke started down into the east drainage.

Something similar happened to the two helitack crewmen, Tyler and Browning. As they ran up the ridge away from the other firefighters who escaped down the south drainage they likely made the decision to go for the rock outcropping to the northwest. The rock would be visible above the oak brush and a main game trail headed in that direction. Evidence shows they did not encounter much smoke. As they got near the draw, the fire was likely coming behind them moving east to west. They may have entered the draw to get to the rocks or to get away from the flames and heat from the east. They both started to deploy their shelters then dropped them. Likely hot air came first, as it did for Blecha and Hipke, causing them to drop the shelters and for Browning, who was above Tyler, to move downhill. But like the main site these two also appear to have been knocked over backward. It is as if they heard something coming, turned east to face it and then were knocked over. Like the others they did not move once the heat hit them. After they died, additional heat came up the draw, and the rocks began to roll into the draw when the soil became unstable.

Recommendations:

- I. Although these recommendations resulted from the Dude and California Fires in 1990, they are still relevant for the South Canyon Fire:
 1. Firefighters must carry fire shelters where they can be easily reached and removed without taking off packs. Shelters should never be carried inside a pack. Shelter removal should be practiced with all gear on the same way it will be carried on the fireline, and while running or walking fast.

2. Once an entrapment becomes likely, protecting airways should dominate all decisions while attempting to escape or deploy shelters.
3. First attempt escape where success is likely.
4. When escape is questionable, the first priority is to take the shelter out of the carrying case and remove the polyvinyl bag by pulling the red ring. Firefighters should carry the folded shelter in their hands ready for quick use. While trying to escape it can be partially opened to use as a heat shield against radiant heat but not for hot gases or a flame front, which would leave airways unprotected. When extra speed is essential for escape, tools, saws, packs, etc., should be dropped to travel as light as possible.
5. It is critical, whether trying to escape or when finding and improving deployment sites, to leave enough time to get under the shelter before hot gases or the flame front arrives. It is more important to be on the ground before the hot gases and flame front arrive than to be in the shelter. If this happens, the firefighter should finish deployment on the ground as rapidly as possible but without exposing airways. When only partially deployed, the top priority is to protect the head and airways with the shelter. We now recommend that everyone practice at least one ground deployment.
6. Before a flame front arrives, the air is often very turbulent. This results in longer deployment times and the necessity to hold the shelter very tightly, so it is not blown away or damaged.
7. Movement of people after they deploy, but before thermal and smoke hazards dissipate, is contributing to the number of fatalities and seriousness of injuries. Once deployed, the firefighter should stay under the shelter. No matter how bad it is under the shelter, the heat can be 10-20 times worse outside the shelter.
8. If entrapped without a shelter, the firefighter should be face down with arms curled around the head, remaining that way, no matter how bad the back is being burnt. This is the best chance to survive. It is always hotter off the ground than at ground level, so the the firefighter should keep the nose and body pressed to the ground and remain that way.
9. When under the fire shelter, if the inner layer of glass cloth starts to separate from the aluminum foil, the glass cloth may cause burns, but it will cool off rapidly. If this occurs, it is critical to remain under the shelter and keep movement to a minimum since the foil can now be torn easily. Even if the foil breaks open and flames enter, it is still worse outside the shelter. When conditions are so extreme that the fire shelter starts to fail, severe injury and death are very likely if the firefighter leaves the shelter. Survival is possible only by staying under the shelter.

Additional recommendations resulting from the South Canyon Fire include:

10. Fireline fatalities since 1990 have a common cause: Firefighters, carrying all their tools and wearing packs, trying to escape fires while moving rapidly uphill. Most of these firefighters might have lived had they run with only their shelters. You are 15% to 20% faster without tools and packs. Most of these firefighters died before they could open their shelters.

11. It is no longer acceptable to take packs under fire shelters. Packs should be kept well away from shelters. If time permits, water should be taken into shelter to drink.

*DROP PACK when speed is critical for escape; in a close call or entrapment it is likely to burn up anyway.

*It takes four times longer to get into a shelter in turbulence wearing a pack than without it.

*Pack contents can compromise safety and shelter effectiveness.

12. Fusee's are the most dangerous item firefighters carry. Fusees will self-ignite at 375^oF. We have seen many routine, non-entrapment instances where equipment is exposed to temperatures in the 300-320^oF range -- very close to the fusee self-ignition temperature. We recommend carrying fusees in covered outer pockets of pack to prevent direct exposure to radiant heat.

13. South Canyon Fire evidence suggests the fatality victims may have been overtaken first by a blast of super-heated air. When last seen, there were no flames near them and within 30 seconds they were overcome. Since most of the victims didn't get their shelters out of their packs, it came on extremely fast and with little warning. When in the vicinity of flames be aware that hot gases are not always visible and your only warning may be an increasing hot wind, vegetation turbulence, or airborne sparks. Unlike flameovers, there may not be breathable air near the ground, and it becomes more critical to be in the fire shelter and keeping the edges sealed to the ground.

II. There is a clear and compelling need to start training crew supervisors, IC teams, smokejumpers, and hot shots in how to lead, communicate, and make decisions under highly stressful conditions. At South Canyon it is obvious that leadership and decisionmaking became more rudimentary as exterior conditions deteriorated. Perceptual awareness and communications collapsed inward with fatal consequences. This is a natural, almost automatic, process unless active mental actions are initiated to counter those induced by stress, fear, and panic. Unless these counter behaviors are prelearned and over learned they will not be available when they are needed the most.

This area of leadership and decision failure has been well explored in the area of aircraft "Cockpit Resource Management." Resultant strategies now taught to pilots and crew are credited with dramatically reducing aircraft fatalities. Such a course tailored to wildland firefighters is highly recommended.

III. There have been 23 lives lost since 1990 that might have been saved if firefighters had dropped their tools and packs for greater speed escaping. South Canyon and other entrapments in recent years leave no doubt that the majority of firefighters are not well trained in escape procedures and fire shelter use. After the Dude Fire many agencies and Forest Service regions implemented Standards for Survival courses and made the courses mandatory. Nevertheless, there is no national agency or interagency policy as to minimum requirements or course content. These courses were a start in the right direction, but none have met reasonable minimum standards. To catch shelter training up to the most current state of knowledge, the following are recommended:

Mandatory Fire Shelter Training Every 3-4 Years for all Wildland Fire Personnel

1. All fire personnel should receive their own copy of Your Fire Shelter and read it.
2. All fire personnel should watch the Your Fire Shelter video.
3. All fire personnel should practice deploying a fire shelter until they can get under it in 20 seconds for Type I crews and 30 seconds for Type II crews and 40 seconds for everyone else.
4. All fire personnel should practice while walking fast in full gear dropping tools, getting fire shelters out, dropping packs, and starting to open a shelter without stopping.
5. Practice one deployment while lying on the ground.
6. Practice one deployment in turbulent winds or in front of large fans when possible.
7. Discuss characteristics of Safety, Survival, Injury, and Dead Zones. If available, view slides of each type of zone to show differences.
8. Review materials currently given in Standards for Survival.
9. Discuss material in the publication Your Fire Shelter - Beyond the Basics. This is required reading for all crew superintendents and should be made available to all fire personnel.

Mandatory Refresher Training Every Year for Those Who Took Mandatory Course

1. At time of step test, must practice deploying a fire shelter under time requirements as suggested above.
2. Reread Your Fire Shelter pamphlet. Receive a new copy if needed.
3. Instructed on any lessons learned from past fire season.
4. One or more practices retrieving fire shelter and dropping pack while walking.